Egypt Telecommunications Master Plan II

Volume 2

Broadband Access Technology & Architecture

Prepared by

Infocom Technology Inc.

Prepared for USAID Mission to Egypt, Egypt Ministry of Communications and Information technology and Telecom Egypt (MCIT/TE)

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EXECUTIVE SUMMARY

This is the second volume of Egypt Telecommunications Master Plan II. This volume is addressing the detailed technical issues and architecture of Egypt Broadband Access Strategy. It provides detailed framework and functional requirements for the architecture. Volume I provides the strategy and policy recommendations. This volume provides the details of such strategy covering VDSL and FTTP, Wi-Fi, CATV, last mile access, and 3G mobile communications. Volume 3 provides summary of the Master Plan II recommendations and addresses voice over IP (VoIP) technology.

Both VDSL and FTTP represent the next frontier in Broadband Access offering higher speeds than available today using ADSL, Cable Modem or Wi-Fi to end users. The technology and standards for both technologies are still evolving. VDSL, however, may be a little ahead of FTTP, especially in terms of product availability, applications and suitability to the Egyptian market. FTTP has a place in the Egyptian telecom infrastructure as well, though our view at this point is that it makes more sense to use it as a backbone technology, for example to interconnect ISP routers, as opposed to an access technology given the limited metro fiber deployment that exists in Egypt today.

We proposed a market trial with each technology, though we suggest to start first with the VDSL one. However, since the two technologies address different applications, network segments and end-users, it may be possible to hold both at the same time, assuming that enough resources within MCIT, TE and the other entities are available to manage them properly.

The purpose of the *Wi-Fi study* has been to assess the application of wideband wireless access technology to MCIT/TE's objectives for providing increased broadband access to the Internet for consumers and business and governmental enterprises. In this report, we discuss the still-emerging worldwide market for Wi-Fi, as well as the on-going evolution of Wi-Fi technology, services, and business models.

Based on this study and discussions held with key broadband players in Egypt in September 2003, we provide recommendations as to how Egypt can benefit from the Wi-Fi technology in the next three years, ad provide discussions of trials of the Wi-Fi technology.

In general, we believe that Egypt should include *CATV* as a major component of its national broadband strategy. This will uniquely position Egypt to offer a more diverse and capable broadband infrastructure. We also recommend a controlled pilot of CATV services in Egypt to further analyze Egypt specific issues. We have provided a preliminary outline, along with various issues and parameters involved in conducting such a pilot, at the end of Chapter 3. The pilot program needs to be structured along five dimensions. These dimensions are Regulatory, Community, Services, Technical, and Financial/ Business Model. Each dimension is structured to address specific issues.

Regarding *the last mile access*, The novel idea of leasing space inside of existing sewers, electrical conduits, drinking water pipes, and natural gas pipes by telecommunications companies has a rather interesting appeal in that owners of these pipes get to generate a new revenue stream and telecommunication companies could install their optical fiber cables at an attractive cost. Egypt is continuing to upgrade its sewers, gas pipes, and waterlines in the coming years. It appears that a viable partnership could be arranged among TE, pipe owners, service providers, and vendors, where each party has something to gain by cost sharing.

This report provides a detailed account of usual impediments to last mile construction, an overview and benefits of various technologies that could be used to lay last mile fiber in existing pipes, track record of such technologies around the world, and general cost as compared to open-cut laying of fiber cables in the last mile using American construction data.

It is highly recommended that the Egyptian government proceeds with the feasibility study of how the various technologies described in this report would apply to solving the last mile in Egypt by using existing pipes for its population with the technologies outlined in this report and implements a pilot project for this technology.

In the report we address the status of cellular service in Egypt and the potential for introducing *3G mobile communications* technology is discussed. It is clear, that given the popular demand for 2G cellular service, and the increased access to the Internet across all segments of society, a move to 3G is a viable option. The success of any 3G deployment will depend largely on pricing, what the market is willing to bear, and the cost to enter the market. Currently voice service is the most popular if not the only service that cellular technology is used for. Internet access remains much more cost effective using the wireline infrastructure.

OVERVIEW

This volume discusses in details the technical aspects and the architecture for Egypt broadband access strategy. It provides detailed framework for the technology architecture whereas Volume I presents the broadband access strategy and policy recommendations. The technical areas covered in this volume include VDSL and FTTP, Wi-Fi, CATV, last mile access, and 3G mobile communications. This volume complements the other volume (volume I) in providing the complete the broadband access strategy and the technology architecture. While volume 3 presents summary of the Master Plan recommendations and addresses voice over IP technology. Below, we provide an outline of the Egypt proposed Telecommunications Master Plan Phase II Documents and its contents.

Volume 1
Egypt Broadband Strategy

- Broadband Status Globally
- Strategy and Recommendations
- Next Steps

Volume 2
Broadband Access Technology

- VDSL and FTTP
- Wi-Fi
- CATV
- Last Mile Access
- 3G Mobile Communications

Volume 3
Recommendations &Voice over IP

- IP Centrex
- VoIP over DSL, VoIP over Cable
- VoIP over International Network
- VoIP in TE's Core Network
- Recommendations

Egypt Telecommunications Master Plan Phase II Documents Outline

1 VDSL and FTTP

SUMMARY

As Egypt invests in Broadband technology starting with ADSL and Wi-Fi, it is a good time to start considering other forward-looking technologies such as VDSL and FTTP that are still, for the most part, in design and trial phases around the world. By participating in the on-going discussions about these newer technologies within standards organizations, industry forum and international conferences, Egyptian Telecom leaders will be able to hear first hand where the industry is going, the lessons learned and to eventually be one of the early adopters of these new technologies instead of playing catch-up as has been the case so far.

The purpose of this chapter is to present an overview of these technologies, discuss where service providers seem to be heading and propose a course of action for the Egyptian Telecom infrastructure starting with market trials.

Both VDSL and FTTP, as all new technologies, come with a number of architectural /implementation options, partly due to the relative immaturity of standards and market adoption. We attempted in this chapter to provide a balanced assessment of which options would make most sense given the specific conditions of the Egyptian Telecommunication Infrastructure and the Egyptian market needs.

As mentioned earlier, both technologies are still evolving, though VDSL may be a little more ahead of FTTP. Hence we recommend that this report be updated in one to two years from now, to reflect the most recent advances in standards, products and trial learning.

1.1 VERY HIGH SPEED DSL (VDSL)

1.1.1 Introduction

DSL is the most common broadband access method in the world today. Currently Asymmetric DSL (or ADSL) is the most popular commercial access for residential users. Symmetric DSL (SDSL) has gained some momentum with business customers. The typical DSL architecture (Figure 1.1) consists of DSL Modem on the customer side that modulates the data onto the local loop. A DSL Access Multiplexer (DSLAM) terminates all the loops, demodulates the DSL signal, and multiplexes all the data streams to be carried by the data network, which tends to be ATM based at the link layer.

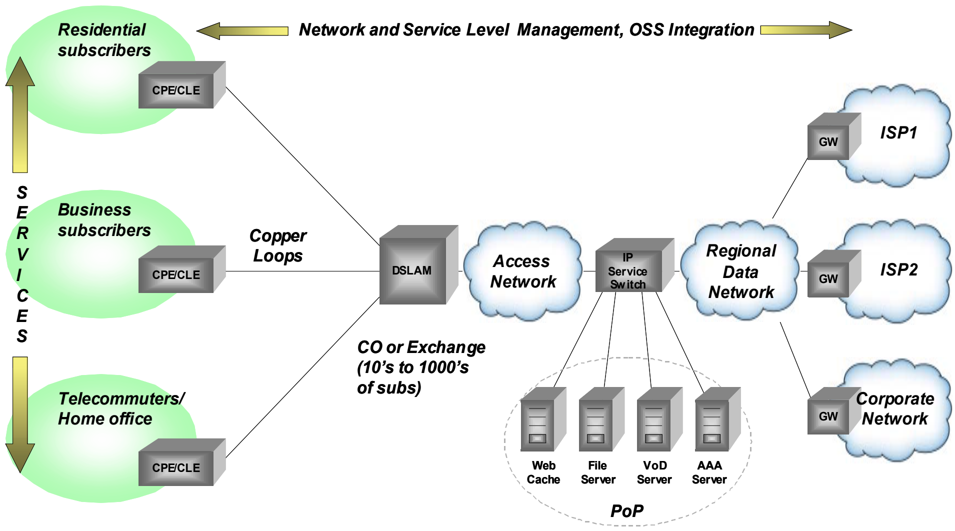

Figure 1.1: Generic DSL Architecture

In the future we expect DSL to evolve to higher speeds and longer reach as evidenced by the development of ADSL2+ and Very High Speed DSL (VDSL). We also expect to see more integration of system capabilities, including the inclusion of Wi-Fi Access Point, Router and Firewall functionalities in the DSL CPE. On the DSLAM side, IP services and IP Multicast will eventually be integrated with the DSL functions. See Table A-1 in Appendix A for a comparison of the different DSL technologies.

DSL deployment continues to face some challenges, including loop qualification issues such as:

- Loop length
- Impairments
- Existence of Digital Loop Carriers (DLC)
- Cross-Talk with other circuits in the same bundle
- Higher price relative to dial-up access to the Internet
- Lack of financial motivation for deployment in rural markets

In the rest of this Chapter we will focus on VDSL, as the next natural step for evolving the broadband loop.

1.1.2 VDSL Drivers

VDSL has not been fully standardized [1], yet it is being pursued as the ultimate version of DSL that will allow the combination of voice, high-speed data and video. In theory, it can accomplish very high speeds, up to 52 Mbps (downstream). That speed (52 Mbps) is only possible on very short loops (~1000 ft). At the other end of the spectrum, the maximum line speed is 13 Mbps for longer loops (4500 ft). However, the actual speed that the end user will experience will depend on the length of the loop and conditions such as the number and quality of bridge taps. In any case, because of the higher speeds, new applications especially video are now possible on copper loops.

VDSL is a technology that is pursued by telephone companies which own loop plants and are either not allowed to get into the cable business or are not interested because of the high costs associated with building a new cable infrastructure (right-of-way, trenching, etc). In some cases, it is just not possible to build a cable plant, for example in dense urban areas due to all the obstructions, right-of-way issues and major traffic and business disruptions that could result from all the digging. Furthermore, VDSL could be used as a high speed indoor or campus distribution technology that makes use of existing wiring instead of having to install new fiber cables.

1.1.3 Services

In addition to all the applications that can be carried over ADSL, the high bandwidth offered by VDSL opens the door for many new applications in the Egyptian market, especially in the consumer and educational markets. It cannot compete though with other media, especially cable TV and satellite, nor in regular video channels broadcasting since its bandwidth, even at 52 Mbps, is still too limited to offer a significant number of video channels. However, it has a good niche application where specialized programming needs to be sent to a limited number of destinations (e.g. schools, end-points of a corporate VPN) or when it is sent at the request of a customer. So VDSL applications include:

- **High Speed Internet Access Service,** same service as normally offered over ADSL or SDSL except for the higher bandwidth which allows Internet-based multi-media applications
- **Video on Demand (VoD) Service** in which consumers can request, from a menu, a specific movie. In a basic service, there is a limited list of movies that play back at fixed times. In a more advanced service, the movie will play back at any time as specified by the customer.
- **Multicast Video Service** for businesses that desire to broadcast a video program to its locations or to a set of clients
- **Voice Services** which include:

  - Regular **Voice TDM service** as offered today by TE. The major difference is that the loop is now the responsibility of the VDSL service provider.
  - **VoIP service** which requires the use of a PC or special VoIP phones. The head-end provider will own a VoIP gateway to convert the voice IP packets back to TDM and then forward them to TE so they can be handled the normal way.
- **VPN Service** in which the user connects to a corporate data center using the PC and a secure mechanism (e.g. IPSec) to encrypt the data. The service provider does not get involved in setting up the VPN or in providing any of the security software. Those functions are the responsibility of the user and the corporate customer. The only functions required from the service provider is to provide connectivity to the corporate data center via the ISP and to troubleshoot the connection end-to-end in case there is a problem.
- **Interactive Gaming**, which requires high bandwidth and performance. The VDSL provider would undertake the role of hosting the multi-player gaming software and other organizational responsibilities, including managing communities of interest, chat rooms, regional/local competitions, marketing, etc.
- **Video Teleconferencing** for businesses**.** Applications include remote training of technicians, corporate executive broadcasts, etc. **Shared Access Applications,** e.g. multi-tenant buildings, hospitals, hotels, Wi-Fi hot-spots, campus, etc.

1.1.4 Architecture

The reference VDSL architecture consists of customer premise equipment (CPE), also known as the ***VDSL Gateway***, which terminates several types of consumer devices including an 10/100BaseT Ethernet port for a PC or an Ethernet hub, a port for a TV set, and one or more Ethernet port for VoIP phones (derived voice).

A regular TDM phone can continue to connect to the copper loop via a splitter. In this case, the gateway connects also to the splitter, which is typically located in the telephone-wiring box inside the residence or office building. In some products, the splitter is built into the gateway itself. The VDSL line connects to an RJ-21 port on the gateway. See Figure 1.2.

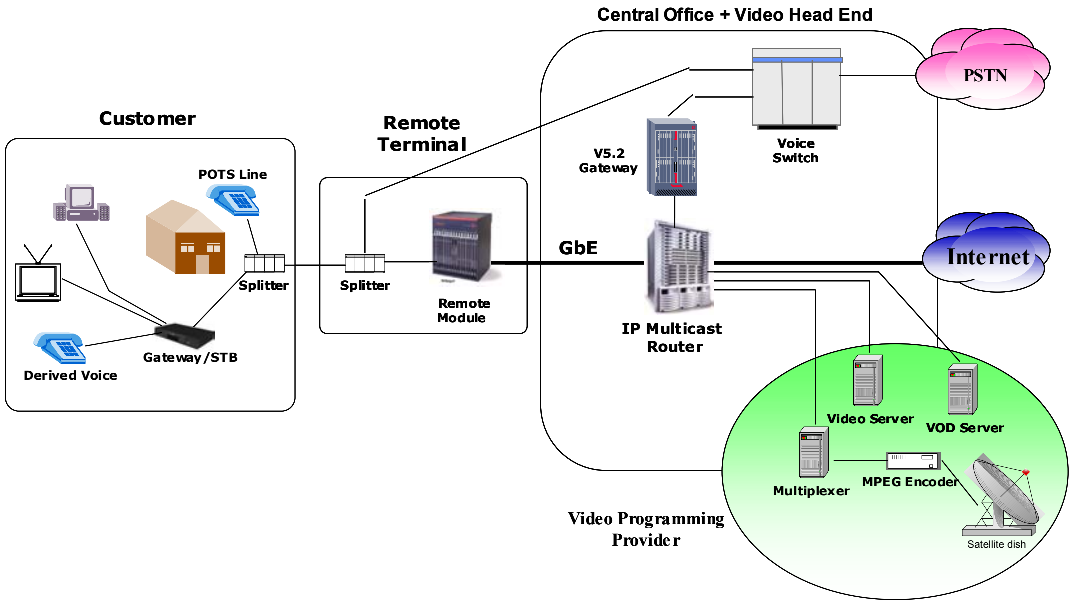

Figure 1.2: VDSL Architecture

Given the distance limitation of VDSL (3000-4500 ft from the CO), the VDSL equipment that terminates the loops cannot be located in the CO if a reasonable number of customer locations are to be served. It has to be deployed closer to the end points. Hence somewhere within the loop plant, typically at a "Remote Terminal" location within the VDSL distance limitation, another splitter filters out (extracts) the TDM voice from the signal. The voice signal is then carried to the standard voice switch located in the central office (CO) via a standard loop backhaul technology. The rest of the VDSL signal is then forwarded to a VDSL demultiplexer also located at the Remote Terminal location, which demodulates the VDSL signal back to Ethernet, and multiplexes it with traffic from other VDSL loops. The multiplexed signal is carried using a GigEthernet connection (over fiber) back to the CO.

In the CO, the GigEthernet lines are terminated on a Gigabit router, which then forwards the IP packets to the right destinations:

- The VoIP traffic is routed to a VoIP gateway, which converts the IP voice, back to TDM, and perform the V5.2 (GR303 in N. America) signaling towards the circuit voice switch.
- The Internet traffic as well as any VPN data from the PC is handed over to an ISP
- The video sessions are routed to the video head-end which includes all the equipment needed to receive and decode the video programming via satellite or other feeds, a voice server for video-on-demand (VOD) applications and other multiplexing equipment

The Gigabit routers in the CO have also a multicast capability to send a video program to multiple destinations at the same time.

1.1.5 Performance

Figure 1.3 illustrates the rate vs. reach for VDSL vs. ADSL and a newer version called ADSL+. The current speeds for VDSL are 13-52 Mbps for downstream/1.6-2.3 Mbps upstream. The maximum distance for effective VDSL operation is around 9000 ft.

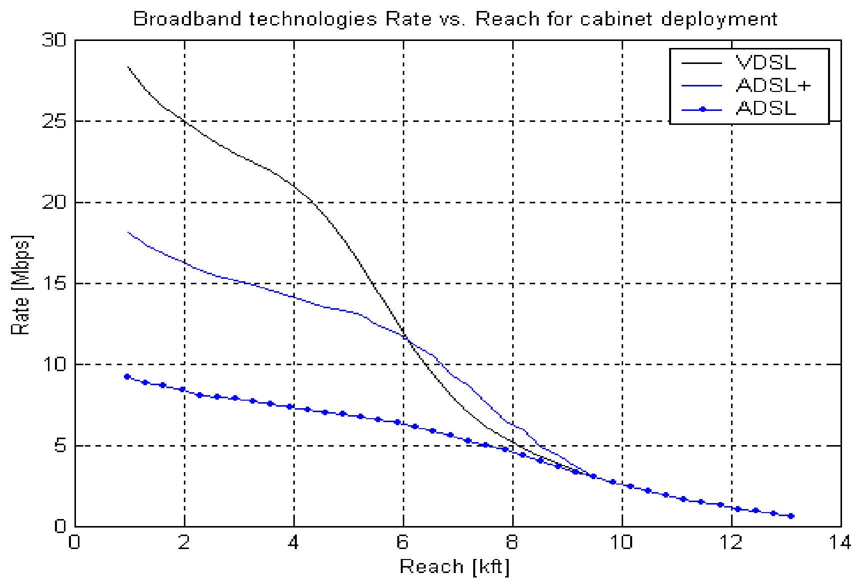

Figure 1.3: Reach vs. Rate

1.1.6 Standards

The VDSL standards are still being finalized. One of the main open issues is the line coding. There are two competing VDSL line coding standards, QAM[1] and DMT[2]. Both line codes provide the same performance in theory. Each scheme is supported by an industry organization with its own economic and political interests. QAM is supported by the VDSL coalition (www.vdslcoalition.net) that includes equipment vendors such as Lucent Technologies, Cisco, Philips, Nokia and Infineon. DMT is supported by the VDSL Alliance (www.vdslalliance.com), which includes Texas Instruments, Alcatel, Broadcom, NEC and LSI Logic.

Overall, there are three main sets of VDSL standards options to be decided:

- Line Coding: QAM vs. DMT
- Band-plan: 997 vs. 998
- Framing: Cell vs. Packet

[1] Quadrature Amplitude Modulation
[2] Discrete Multi-tone

Line Coding:

Even though QAM and DMT have the same performance, they differ in other aspects. For example, QAM's advantages include:

- 20+ years field experience with voice-band/cable modems
- 8 years experience with VDSL
- Chipset density, power and performance
- Lower cost from less complex design
- Availability and deployment in large volume

On the other hand, DMT has the following advantages:

- Can theoretically cope better with RF ingress/egress
- Is perceived as backward compatible with ADSL

The main standards organizations take slightly different approaches regarding the issue with Line Coding. For example, ETSI and ITU allow for both DMT and QAM line coding. ITU allows for both QAM and DMT going forward whereas ANSI (T1E1.4) currently views DMT as the primary line coding and plans to maintain both DMT and QAM going forward.

Band-Plan:

Table 1.1 provides a view on what some select countries/regions plan to do regarding the frequency band-plan.

Table 1.1: Band-Plan in Example Regions/Countries

Region/Country	Standard Now	2004 and beyond
US	T1E1 - 998	T1E1/EFM - 998
Europe	ETSI/ITU - 997/998	ETSI/ITU/EFM - 997/998
CALA	ITU - 998	ITU/EFM - 998
Japan	ITU - 998	ITU/EFM - 998
Taiwan	ITU - 998	ITU/EFM - 998
Korea	ITU - 998	ITU/EFM - 998
China	China Spec	China Spec

Framing:

Currently ADSL is fully cell-based technology as well as the supporting ATM networks. The migration to packet (i.e. Ethernet) is driven by the packet-based user applications and the wide availability of low-cost GigE bandwidth. Asia has leapfrogged to full packet-based solutions while Europe is still deciding given its ATM legacy.

In addition to ITU, ETSI and ANSI there are other standards groups involved in VDSL:

- **IEEE EFM** (Ethernet in First Mile) is a working group within the IEEE whose task is to define an Ethernet over Copper standard (802.3ah) [1], in which one of the options is to use VDSL for short reach EFM. It defines a full duplex service at 10 Mbps to 750 m on a single copper pair and 30-50 Mbps to 500 m.
- **CTSI** is defining a standard for the Chinese market [2]

1.1.7 Product Requirements

This section provides a preliminary list of features to look for in a typical VDSL remote terminal. This list could become the basis if an RFP by an Egyptian operator is issued at a later date for product acquisition. The capabilities include:

- **Interfaces/Processing:**
  - Native Ethernet switch with VDSL based user ports
  - Full transparency for L3 protocols
  - Ethernet/QAM/998/4B
  - DMT, 997
  - IP multicasting (IGMP/PIM)
  - IGMP snooping (L2 multicasting)
  - L2-QoS (802.1p)
  - IP-QoS/DiffServ
  - VLAN support
  - Sub-tending capability (up to 5 units)
  - Integrated POTS/ISDN splitter
  - 1000BaseT copper or 1 x 1000BaseLX optical (>10 km) for uplink
  - 1000BaseT daisy-chain extension port
  - Rate adaptive function
  - Full rate non-blocking switching fabric capacity
  - Built-in POTS/ISDN splitter
  - Integrated Wi-Fi (802.11b and 802.11g) Access point

- **Ethernet**
  - 802.1d Spanning Tree Algorithm
  - 802.1p Priority Queuing
  - 802.1q VLAN tagging
  - 802.3ab 1000BaseT
  - 802.3ad Link Aggregation
  - 802.3u 100BaseT
  - 802.3x Flow Control
  - MAC address filtering
  - Broadcast storm control
  - Port monitoring

- **Management**
  - CLI (Command Line Interface)
  - SNMP
  - Remote SW upgrade
  - RS-232 port for local management
  - 10/100BaseT port for local management
  - Polling
  - Alarms traps
  - Performance monitoring
  - Support Telnet session
  - Provide SNMP MIBS for northbound interface
  - Network Topology display on a map with a Directory tree and the ability to Add/Delete new nodes and to do node search AC/DC power
- **Environmental Conditions**
  - Hardened enclosure
  - Operating temperature 0 to 50 degree C
  - Relative humidity 5% to 90%

- **Performance with payload**
  - Short Reach:
    - Symmetric: 40 Mbps
    - Asymmetric: 70 Mbps in downstream/40 Mbps in upstream
  - Long Reach:

    - High Power: Symmetric: 4 Mbps to 4000m
    - EFM: Symmetric - 2 to 10 Mbps to 2700m
  - High Speed of 26 Mbps/5 Mbps or 10 Mbps/10 Mbps connections over 1km

1.1.8 VDSL Status Globally

There are over 2 million VDSL circuits deployed globally to date. In 90% of the circuits, Ethernet over VDSL is the technology of choice, operating in a symmetric mode at speeds ranging between 10-15 Mbps. In the US, ATM over VDSL is the most widely deployed technology option, running asymmetrically at 19 Mbps/3 Mbps.

Outside the US, most of the deployment is in S. Korea and China (see Appendix A):

- S. Korea started deployment of symmetric 13 Mbps VDSL in 2002 and announced the deployment of 25 Mbps asymmetric. 50 Mbps asymmetric VDSL was announced in 2003. About ~1M lines of VDSL have been deployed to date by Korea Telecom and Hanaro.
- China has many installations in small operator locations, with about ~100K lines deployed so far and expected to grow to 500K lines in 2004.

Other countries, e.g. Japan, Norway, Sweden, Netherlands, and Belgium have completed their trials and announced plans for public deployments in 2004. Many other countries e.g. UK, Canada, and Mexico are still in the middle of trials.

1.1.9 Trial Proposal

Since VDSL is still a new technology and the standards are not finalized yet, it is appropriate for MCIT to encourage the undertaking of a market/technology trial to accomplish the following objectives:

- Understand what it takes to configure all the equipment that is required to provide the architecture
- Verify the technical issues of supporting VDSL on local loops in Egypt
- Test the performance of the various applications
- Test the market from an acceptance and willingness to pay
- Verify interoperability issues between the different products/equipment vendors
- Understand which applications seem to be the most popular
- Evaluate equipment from multiple vendors

There is a lot to learn during such a trial. Technically it is a complex one, especially if it involves services beyond Internet access.

1.1.9.1 Recommendations

- We recommend that the trial involve three types of participants: **residential, businesses and educational**.

- We recommend that the **residential** part of the trial take place in Cairo, in an upscale residential area (e.g. Zamalek, Maadi, Heliopolis or Mohandeseen) where there would be willingness to test a new service/technology and where the income level is high enough given all the cost of the CPE equipment that is needed. This area should, of course, be one where the loop distances are relatively small, i.e. 2000-3000 ft.
- The number of residential trial participants should be between 50-100. A number larger than that will add to the cost and management complexity. A smaller number will not provide enough usage and feedback to accomplish the trial objectives.
- The **business** part of the trial could take place anywhere, as long as the loop distance limitations are not exceeded. One possibility is to solicit participation from companies located in the **Intelligent Village**. Not only those companies tend to have more high-tech orientation than others, but also the setup could eventually be used as a showcase to other companies and institutions.
- The **educational** part of the trial could be with either a university or a couple of model high schools.
- The trial should be offered to the participants at a nominal cost, just to insure that they'll use it and will be providing feedback. The rest of the trial cost could be borne by the respective parties or centrally funded by MCIT.
- The following applications should be tested during the trial:
  - High-speed Internet access
  - Video-on-Demand
  - Interactive Gaming
  - VoIP
  - Video Multicast
- Trial participants:
  - Residential customers as discussed above. The primary services for those customers would be High-Speed Internet Access, Video-on-Demand (movies, shows) and Interactive Gaming.
  - A small number (3 or 4) of business customers to trial some of the business services namely VoIP and Video-on-Demand (e.g. training course material from the trial equipment suppliers).
  - One or two high schools to trial High Speed Internet Access, Video-on-Demand (e.g. any pre-recorded university level courses, or publicly available educational programs such as on nature, space, or history)
- We recommend that a trial team be formed from several organizations, each one with a distinct role. The team should have a composition made up of the following entities and functions:
  - **MCIT** – write trial plan, coordinate with all the entities, project manage, provide directions and most importantly collect feedback from the trial participants and author a trial report.
  - **TE** – provide the loops, and connections to the V5.2 gateway

  - **VDSL Service Provider** – provide video head-end, CPE, V5.2 gateway, Gigabit router and connectivity to TE and the ISP
  - **Content Provider** to provide the applications such as streaming video, streaming audio, video-on-demand, and interactive gaming. More than one content provider may be needed.
  - **NTRA** – as a monitor and to facilitate some of the regulatory issues on an exceptional basis
- The trial is an opportunity to test equipment from several vendors. Although that approach may create more technical issues to be resolved, but it provides a good environment for compiling a list of requirements to select the ultimate vendor(s) for the real service.
- The proposed trial schedule is as follows:
  - Preparation, negotiations, trial plan – 1 month
  - Setup trial configuration, acquire & install equipment – 2 months
  - Setup applications and end-to-end test – 2 month
  - Select trial participants, setup feedback process – 1 month
  - Trial – 6-9 months
  - Trial conclusion, final report – 1 month

1.1.9.2 Technical Considerations

- Use the packet based (Ethernet) version of VDSL since Egypt has a limited based of ADSL (ATM based) deployment.
- The services should be introduced in the trial in a phased approach. The team should start first with residential users with the simplest service (Internet Access) followed by the more complex ones (Interactive Gaming). Later on, the trial should be expanded to Business customers and finally the schools. The reason for the phasing is to avoid adding too many technical issues, organizational and management to be resolved in one shot. As mentioned before, this technology in its fullest potential is a complex one and therefore should be carefully managed.
- The trial should start with low speed connections, e.g. 13 Mbps or lower to reduce the complexity. Later, when all the technical issues are resolved, then the speed could be increased on some of the very short loops gradually to the maximum of 52 Mbps.

1.1.10 Related Technologies

In addition to the recent advances in VDSL, another flavor of DSL – ADSL2+ has evolved recently though it did not attract the same level of attention. ADSL2+ can readily fulfill the customer demand for several video channels, gaming, etc. It can also be used on longer loop lengths and/or higher bit-rates (16/24 Mbps down, 1 Mbps up). It fills the bandwidth gap between ADSL and VDSL and is compatible with existing ADSL networks, equipment (CPE) and chip-sets.

1.1.11 Regulatory Considerations for Egypt

VDSL is similar to ADSL in most ways from a regulatory aspect. Hence many of the issues related to ADSL apply to VDSL as well. For example, the issue of offering voice services, both TDM and VoIP needs to be settled. In the "Broadband Strategy" document [2], we recommended that DSL operators be allowed to bundle voice services with Internet access over DSL lines. This bundling would not affect TE's revenues as the DSL provider can/should to buy voice service from TE at standard tariff rates.

Because of its higher bandwidth, VDSL triggers new regulatory questions, especially in reference to video services, namely the transmission of video broadcast channels on VDSL lines.

1.1.12 Summary

VDSL is a promising technology for the high end of broadband services on copper loops. It is worth trying it in Egypt and if successful, then the recommendation is to proceed with gradual deployment on a selective basis. Because of the cost associated with the equipment and the limited reach of the loops, deployment should be considered only in locations where there is interest and affordability for buying the new services.

1.2 FIBER TO THE PREMISE (FTTP)

1.2.1 Introduction

Several fiber access architectures have been considered over the years to bring fiber as close as possible to the customers. The architectures varied in terms of the technology used and how close the fiber reached the customer's location - hence the terms FTTH (Fiber-to-the-Home), FTTC (Fiber-to-the-Curb), FTTB (Fiber-to-the-Building), etc. Fiber-to-the-Premise or FTTP is a generic terminology that covers all the options. Many market trials were conducted all over the world with various levels of success.

The biggest hurdles so far in deploying FTTP have been in the economics of deploying the fiber as close as possible to the customer, including the cost of the CPE. With advances in technology, cost reductions, more available fiber capacity in the metro areas and the development of broadband applications, recent interest in FTTP has emerged, especially in the US. The FCC is also considering easing some of the regulations on the Incumbent Local Exchange Carriers (ILEC) to encourage them to invest in such an infrastructure. One of those relief measures is exempting the ILECs from unbundling their fiber infrastructures and selling the unbundled elements to their competitors. It is hoped that such a relief will encourage the ILECs to invest the massive capital needed for a wide deployment of FTTP.

Another motivation for this new interest in FTTP is the declining wireline revenues of the ILECs while costs remain flat. To address that issue, the ILECs (and most Service Providers for that matter) feel that bundling of services is needed. Since they offer voice and high-speed data today, what are really missing are video applications, which require broadband access beyond DSL speeds. The bundling is needed also to counter the strategy of Cable Operators who are planning to add voice on top of the existing cable offerings, which include video and data.

Early this year, the three largest telecom providers in the US (Verizon, SBC and BellSouth) adopted a set of common technical requirements for FTTP. An RFP was issued in June 2003 and suppliers banded together to respond, since no one had all the pieces. The plan is to test some of the selected equipment in lab trials by the end of this year and to start some deployment in 1Q2004 with the goal of having an infrastructure that can pass 1M homes by the end of 2004 and 5M by the end of 2006.

1.2.2 Architecture

Two major architectures are being considered as strong candidates for FTTP deployment: Passive Optic Networks (PON) and Optical Ethernet.

1.2.2.1 Passive Optic Networks

In the PON architecture (see Figure 1.4), a wavelength originating on an Optical Line Terminal (OLT) in the Central Office (CO) is split by a passive splitter into multiple beams each carried on a separate pair of fiber. The fibers then terminate at customer locations. The splitter, being a passive device, can be located in the outside plant and does not require any power, maintenance or management. The wavelength is shared between the end-users. Several flavors of PON have been developed, the most established one being ATM PON (APON). Others include Ethernet PON (E-PON), WDM PON (W-PON) and Gigabit PON (G-PON). In the following, we provide a brief description of each.

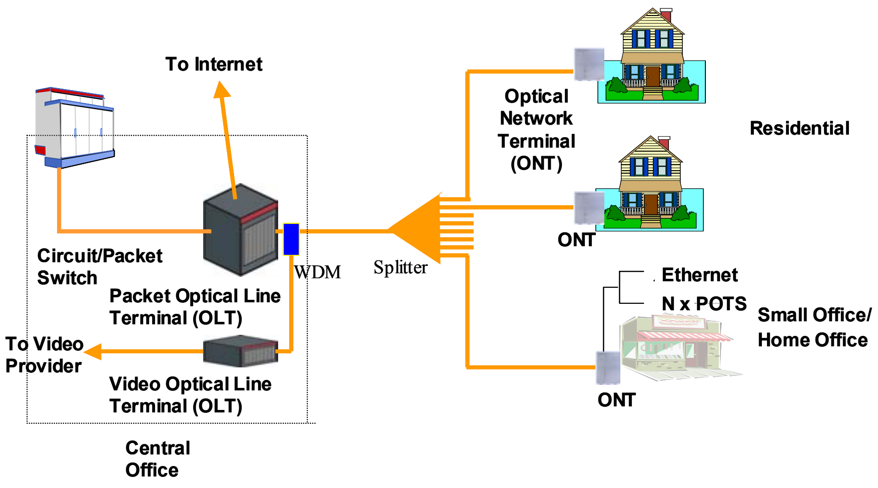

Figure 1.4: PON Architecture

A-PON (ITU-G. 983):

In this architecture, each subscriber sends traffic at 155 Mbps downstream/622 Mbps upstream using the ATM protocol. The uplink from the splitter is shared between all the subscribers and connects to an ATM switch in the CO. The main disadvantage of this architecture is the high cost of the ATM components. There is some contention for the bandwidth between the users, but not as much as in the E-PON case (see below).

E-PON:

E-PON is an option in the IEEE 802.3ae EFM standard which has not been ratified yet. Each subscriber is connected to the network via a 1 Gbps line. At the splitter, all the traffic is statistically multiplexed and carried over 1G connection back to an Ethernet switch at the CO. E-PON's main advantage is lower cost since it is based on Ethernet components which are much less expensive than other types. The main disadvantage is the contention for the bandwidth between the subscribers given the nature of Ethernet.

W-PON:

In this case, each subscriber is assigned one wavelength to carry the traffic to the CO. Traffic speeds over the wavelength vary from 100 Mbps to 1 Gbps. At the splitter, all the wavelengths are multiplexed over a Dense Wave Division Multiplexing (DWDM) link to the CO, where the wavelengths are filtered and switched to the proper destination using the carrier's optical infrastructure. The main advantage here is the dedicated bandwidth that each user gets and the protocol independence of this architecture. However the architecture suffers from the high cost of the WDM equipment.

G-PON (ITU-984)

The bandwidth from each end point is 28-56 Mbps downstream/4.1-68 Mbps upstream. The lines are multiplexed by the splitter to a 1.2 or 2.4 Gbps connection downstream/155 Mbps-2488 Mbps connection upstream. The user protocols are supported natively. G-PON suffers from high cost. However, because of its high bandwidth all the video applications can be supported in-band.

A-PON was the first standardized architecture and was tried by several service providers. It is now considered obsolete. Many carriers are now considering seriously using E-PON because of its cost advantage over the other options, despite some of its drawbacks especially with QoS. However, the expectation is that those issues will be resolved with the advent of new standards.

1.2.2.2 Optical Ethernet

In the Optical Ethernet architecture (see Figure 1.5), the Ethernet traffic from the customer is carried in its native mode over the optical network. Typical Ethernet line speeds are 10 Mbps, 100 Mbps, 1Gbps and 10 Gbps. However, the customer may buy only a fraction of the line speed, e.g. 50 Mbps, and can increase that throughput as traffic grows.

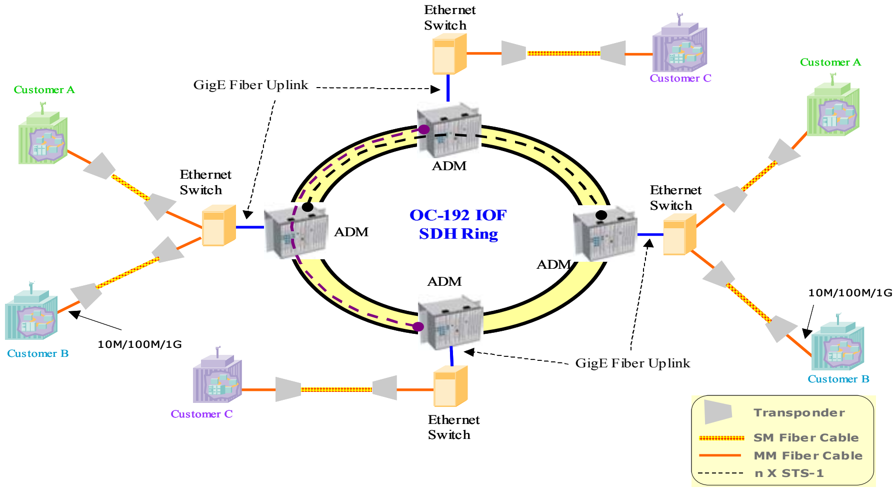

Figure 1.5: Optical Ethernet

There are several technology solutions for the Optical Ethernet, each one with its own capabilities and cost implications. The solutions are:

Ethernet over SDH (EoS)

In this architecture, the Ethernet traffic is encapsulated in SDH frames before it is carried over the transport network. Because of the SDH framing, this approach is most suitable for the low Ethernet speeds, i.e. 10 Mbps, 100 Mbps and up to 1 Gbps. At 10 Gbps, it is much more efficient to use other technologies such as Ethernet over DWDM.

The Ethernet line from the customer equipment is terminated on a SDH Add/Drop Multiplexer (ADM) with an Ethernet interface. This Next Gen ADM could be on a customer location (e.g. bank, factory), in a large office building (equipment room) or on a campus (industrial park, university….). The 10 Mbps and 100 Mbps Ethernet lines terminate on Ethernet electrical ports and the 1 Gbps lines terminate on Ethernet fiber ports.

The ADM could also be located in the service provider CO. In this case, the 1 Gbps Ethernet line from the customer location will need to be extended to the CO using fiber. But because of the electrical distance limitations, the 10 M and 100 M lines cannot not be served from that ADM. Once the Ethernet traffic is received at the ADM, it is then carried using Virtual Concatenated Channels (VCC) over the SDH network. Each VCC carries one SDH AU, which is approximately 150 Mbps. Depending on the Ethernet line speed, one or more VCC will be needed. For example, a 100 M Ethernet line requires one VCC. A 1 G Ethernet line needs a VCG made up of several VCCs. At the other end of the SDH network, the traffic from the VCG that belongs to a particular Ethernet line is reconstructed again into one Ethernet flow towards the customer location. See Figure 1.6.

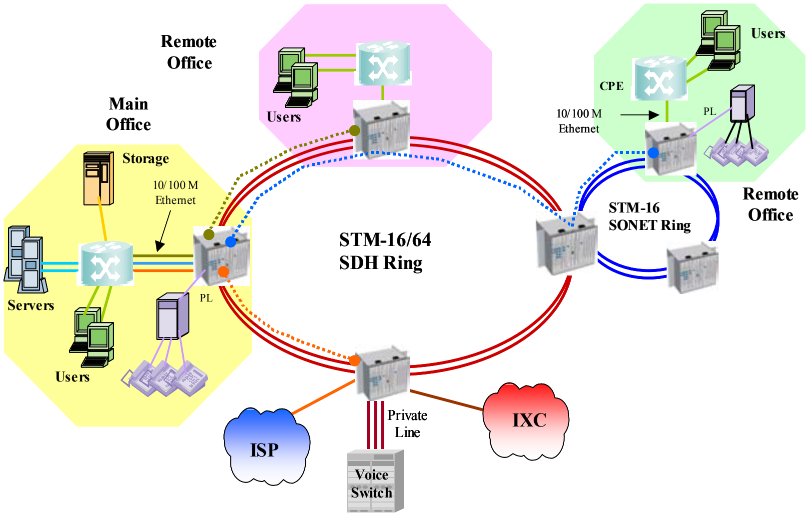

Figure 1.6: Ethernet over SDH Architecture

There are several standards that apply to the EoS architecture, namely:

- **Virtual Concatenation** (ITU - G.707) of SDH tributaries creates variable bandwidth pipes & overcomes SDH granularity
- **Generic Framing Procedure**, GFP, (ITU - G.7041) encapsulates and frames the IEEE 802.3 PHY to the octet synchronous SDH payload
- **Link Capacity Adjustment Scheme**, LCAS, (ITU - G.7042) enables load-sharing, protection and in-service transport pipe re-sizing

This architecture has several advantages:

1. Traffic will be protected as any other SDH traffic. Hence, highly reliable Ethernet applications can be easily offered. Switchover to a backup path typically takes place in less than 50ms.
2. Because of the ability to multiplex the lower speeds into STM-16 or STM-64, the network efficiency is much higher than other alternatives if there is substantial amount of low- speed Ethernet lines.
3. Because of the SDH nature of the technology, Ethernet traffic can be multiplexed with regular TDM private lines over the same rings, hence adding to the efficiency that can be accomplished.
4. Network operators are very familiar with SDH and have significant experience in managing SDH networks. Introducing Ethernet service on top of SDH is a small incremental effort and requires a small investment in knowledge and training

The main disadvantage of EoS is the additional equipment (i.e. SDH equipment) involved in carrying the Ethernet traffic. But if that equipment is already in place, that becomes a non-issue. So the key factors involved in making a technology selection are:

1. Is there already an SDH network in place?
2. Is there TDM private line traffic that also needs to be served?
3. What is the granularity of the Ethernet traffic?
4. Do the Ethernet applications need high reliability?

Ethernet over WDM

In this architecture, each Ethernet traffic stream is carried directly over a wavelength (2.5G, or 10G). The source of the Ethernet traffic at the customer location is connected to a transponder whose function is to interface to the fiber leading to the service provider central office (CO). It also serves as the Network Interface Unit (NIU) for troubleshooting purposes.

From the customer location, a single mode fiber carries the Ethernet traffic directly to the CO. If the customer location has many sources of Ethernet traffic, then each can be carried over its own wavelength. All the wavelengths are then multiplexed by the transponder and carried over one pair of single-mode fiber to the CO.

In the CO, another transponder demultiplexes the wavelengths and interconnects with a DWDM system, which regenerates the signal and multiplexes all the wavelengths on the proper fiber route to be carried over the rest of the DWDM network to its ultimate destination. See Figure 1.7.

Because of the cost of the wavelengths and the DWDM systems involved, this architecture is typically limited to Ethernet speeds of 1 Gbps and 10 Gbps. Hence it is only useful for interconnecting ISP's Gigabit Routers already located in COs or for serving large business locations where all the LAN traffic gets multiplexed first to 1Gbps using an Ethernet switch or an IP router. It can also be used to interconnect Storage Area Networks located in Data Centers. Between the Data Centers, the Fiber Channel protocol is used to carry the storage traffic using 1 Gbps connections over fiber.

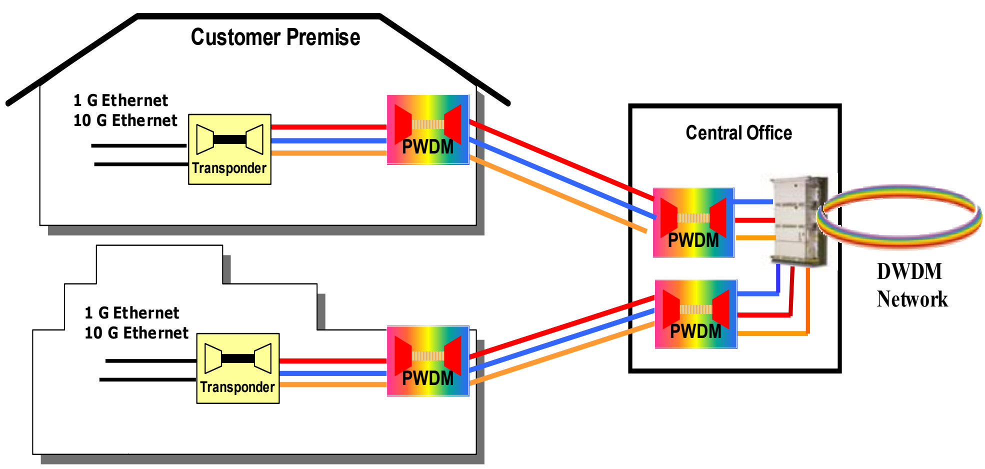

Figure 1.7: Ethernet over DWDM

This architecture has been deployed in N. America, Europe, and Japan. Because of its nature, only Ethernet point-to-point private line service can be offered on these networks.

Ethernet over Fiber

In this architecture the Ethernet traffic from the customer location is carried directly over fiber with the use of a Transponder. A pair of fiber is fully dedicated to the customer all the way to the other destination. So in effect this solution is a simplified version of Figure 1.9 above, but without the DWDM network. It involves fewer network elements, and is easy to setup and troubleshoot. However, it lacks reliability since there is no mechanism to switch to a back-up path in case of failures. It is restricted to the higher bandwidths (1G, 10G) since a pair of fiber is fully dedicated to the client.

This approach was used by some of the service providers in the US early on, as a way to test the market. They quickly realized that it was not a viable solution in the long term because of its limited scalability. Even though it is still being used with some customers who do not need high reliability, it will eventually be replaced by one of the other architectures.

Ethernet over Resilient Packet Ring (EoRPR)

Ethernet over Resilient Packet Ring (RPR) is a new MAC (Media Access Protocol) that is being standardized by the IEEE 802.17 working group. It was designed primarily to carry data services in a Metropolitan Area Network. RPR implements a new protection scheme that can deliver performance equivalent to SDH, i.e. under 50ms recovery from link and node failures while at the same time it can deliver the same or better economics than packet networks.

RPR is designed to work over ring-based networks; hence it is more suitable for metro networks where fiber availability may be limited and where fiber topology may look more as rings than mesh. Traffic is carried over two unidirectional counter-rotating rings. Its bandwidth management features guarantees the fair allocation of resources between all users.

RPR accomplishes the SDH recovery performance by doing “wraps” at the nodes surrounding the cut or by packet ‘steering’ i.e. redirecting traffic away from the fault. In either case, traffic still reaches its destination by going around the ring in the opposite direction. See Figure 1.8.

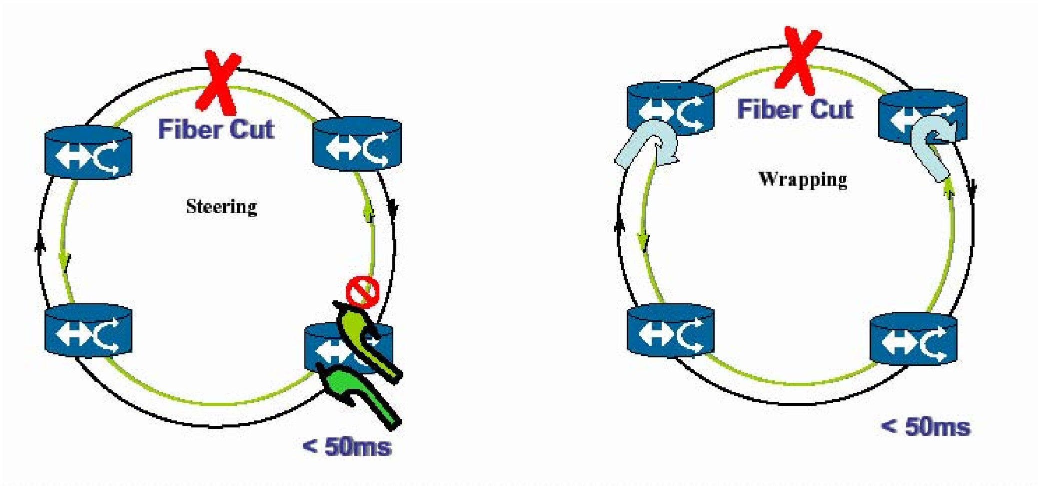

Figure 1.8: RPR Failure Recovery Mechanism

RPR also supports the ability to multicast traffic. If a multicast packet is received at a node, it is copied and allowed to continue on the ring to the next node until eventually stripped from the ring by the source node. This mechanism is more efficient than sending multiple packets from the source node to all the destination nodes.

RPR can operate directly over fiber or over SDH framing. For example, an STM-16 SDH ring can carry 3 traditional protected STM-4 circuits as well as an STM-4 RPR ring. Hence RPR over SDH can make use of some of the new advances in Ethernet over SDH such as VCC and LCAS (see section a above) and still deliver more bandwidth efficiency in dealing with packet traffic than SDH can do on its own. This however comes at the expense of additional functionality in the SDH ADM. Hence, RPR should be considered only if significant packet traffic relative to TDM is expected to be carried in the metro network or if the SDH ADM can support the RPR feature. In the latter case, the same RPR can support traditional SDH rings and an RPR ring over the same physical fiber ring. Such a hybrid configuration delivers the best of both worlds: efficient support of TDM traffic and Ethernet traffic on the same physical ring using the same set of ADMs.

When RPR operates directly over fiber, then it is strictly limited to packet traffic and no TDM traffic (e.g. voice) can be carried over the same pair of fiber. This could be a significant limitation for that option unless there is a very large volume of packet traffic, enough to fill up the entire fiber pair from the outset.

In addition to the IEEE, RPR is strongly supported by an industry group, the Resilient Packet Ring Alliance (http://www.rpralliance.com/) whose aim is to promote the deployment and commercial success of the technology. The standard is still in draft form and is expected to be ratified sometime in 2004. Some vendors are already selling “pre-standard” equipment.

1.2.3 Services

Several services, both point-to-point as well as point-to-multipoint, can be offered on this architecture such as Ethernet Private Lines (EPL), Fractional EPL, and Transparent LAN service. See [4] for more detailed technical description of the Ethernet services that can be offered. Keep in mind that the Ethernet Forum provides a structure for defining Ethernet services as opposed to the services themselves. It is up to each service provider to decide, based on such construct, the specific services to offer, the performance level, etc.

The factors driving demand for Ethernet are similar to those of other metropolitan data services: increasing corporate use of the Internet, multimedia, and other high-bandwidth applications; a need to connect LANs within metropolitan areas; and the need to connect data centers, carrier hotels, and central offices within metropolitan areas. Centralization of servers in the metro is a leading driver. And some companies are doing new applications over Ethernet that were not done before, such as transmitting X rays electronically rather than relying on an overnight courier.

Metro Ethernet's number 1 advantage over other technologies is price. Because Ethernet is used so widely in LANs, Ethernet equipment for both the carrier network and the customer premises is far less expensive than SDH, ATM, and Frame Relay equipment due to economies of scale. This allows carriers to price the service below other traditional data services.

1.2.3.1 Ethernet Private Line (EPL)

The **EPL** service is a point- to-point dedicated connection between two customer locations. The Ethernet port and SDH bandwidth is dedicated to the customer. For example, a customer may buy a 10 M Ethernet private line to interconnect two LANs at two company locations. Within the network, that bandwidth is configured as a Point-to-Point Ethernet Virtual Connection (EVC). See Figure 1.9.

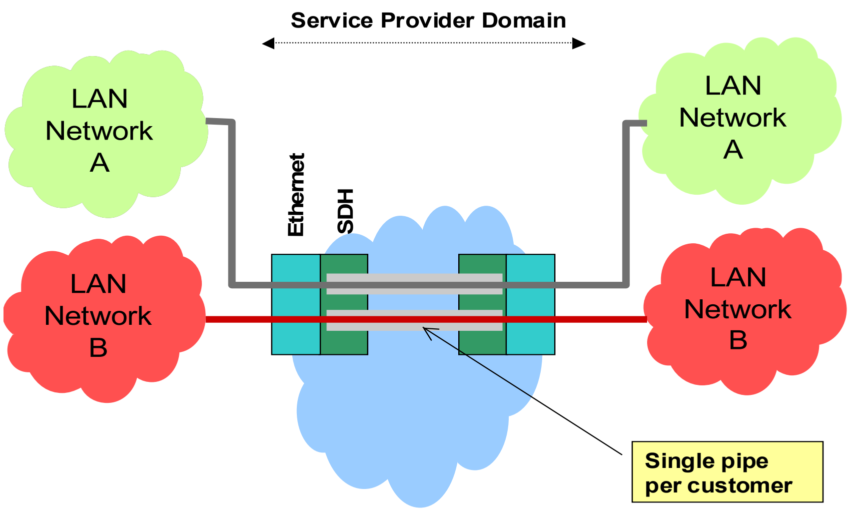

Figure 1.9: Ethernet Private Line Service

A variation on this point-to-point service is called Fractional EPL (FEPL) in which the customer buys a fraction of a typical Ethernet speed, e.g. 6 Mbps, or 15 Mbps. The network equipment limits the speed at which it can process the traffic from the customer to the throughput that has been provisioned for that customer.

1.2.3.2 Ethernet Virtual Private Line (EVPL)

The EVPL service extends the concept of EPL by statistically multiplexing the Ethernet traffic in the network. This is based on the notion that, because of the statistical nature of the Ethernet flows, network utilization can be increased substantially if the traffic from multiple customer lines is multiplexed within the network using Ethernet switches. With that, less network bandwidth is consumed in serving a certain number of Ethernet lines. The implication is some of the cost savings could be passed on to the end customer. See Figure 1.10.

Since traffic from multiple customers is multiplexed on the same transport facilities within the network, a "VLAN tag" is used in the Ethernet frames from each customer line to keep track of the origin of each Ethernet frame. The VLAN tag could be inserted by the customer equipment (e.g. Ethernet switch) or by the first network element that terminates the Ethernet line. Each customer gets a unique VLAN tag to distinguish its traffic from other customers.

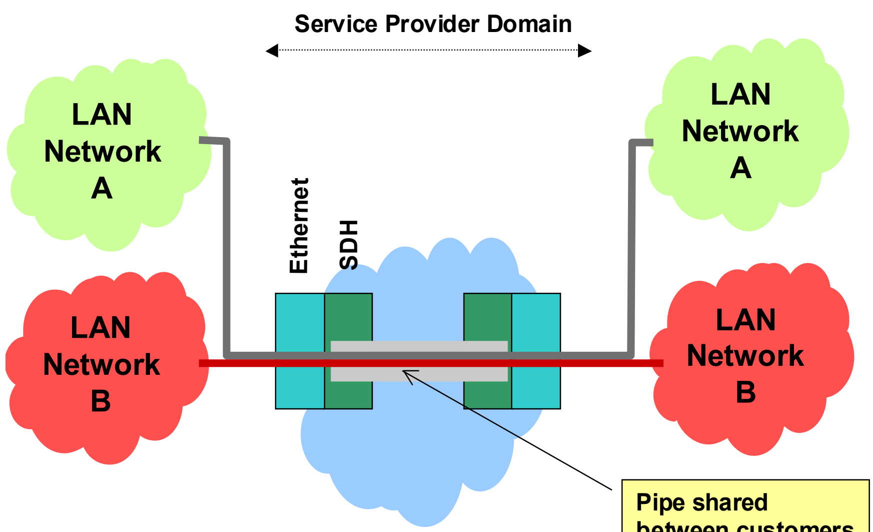

Figure 1.10: Ethernet Virtual Private Line Service

Since statistical multiplexing is used in the network, the customer port is configured with additional parameters. For example, the Committed Information Rate (CIR) defines the amount of bandwidth that the service provider can guarantee to the customer at any time. For example a customer can buy a CIR of 30 Mbps on a 100 M line. The CPE can still burst all the way to 100 M as usual, but the network only guarantees 30 M. During the off-peak hours, all the traffic the CPE sends will be delivered. But during busy times or congestion, only the 30 Mbps will be delivered. This concept is very similar to the CIR in Frame Relay and ATM networks.

1.2.3.3 Ethernet LAN Service (ELS)

The ELS provides multipoint connectivity, i.e. it connects two or more end-points with each other. Data sent from one end-point is transmitted to one or more of the other end-points. Each site is connected to a multipoint Ethernet Virtual Connection in the network. As new sites get added to the network, they are connected to the same multipoint EVC, thus simplifying provisioning and service activation. From the user point of view, the WAN looks like a LAN.

Different levels of performance can be provided, all the way from Best Effort to guaranteed performance using a Committed Information Rate (CIR), Committed Burst Size (CBS), assured delay and jitter, etc. On the same line connecting a site to the network, more than one service can be offered. For example, a customer might have a 100 M line to carry Internet traffic using Ethernet Virtual Private Line (EPL) service as well as LAN traffic to other business locations using Ethernet LAN service. See Figure 1.11 for an illustration of the ELS architecture.

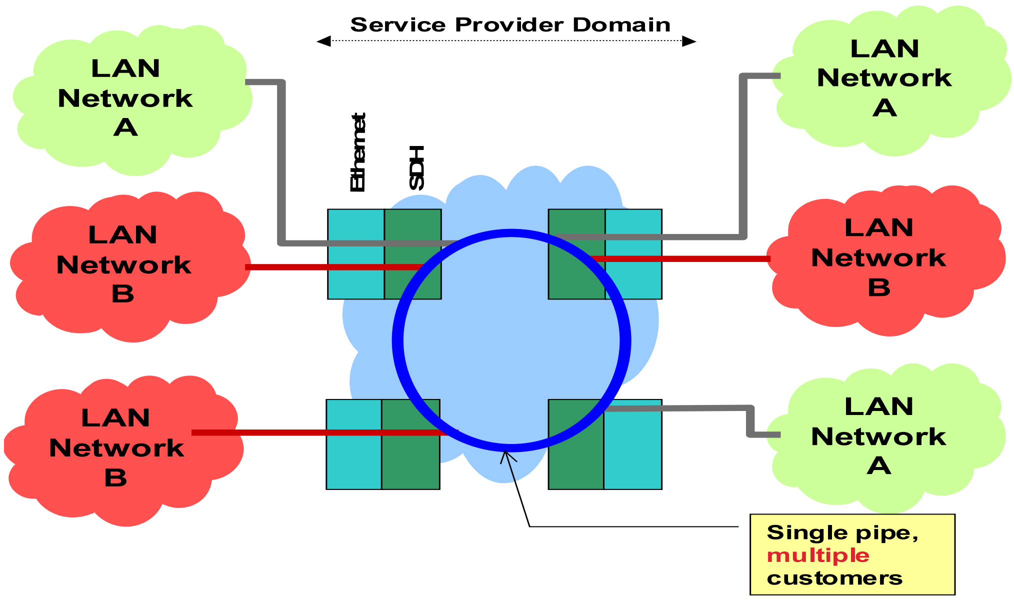

Figure 1.11: Ethernet LAN Service

1.2.4 Fiber Deployment

By definition, FTTP implies that fiber is deployed all the way from the CO to the end user (residential or business customer). The extent and the physical topology of the deployment vary depending on the technology option. As stated earlier, PON requires less fiber than FTTP to cover a certain geography and set of end points.

1.2.4.1 Fiber Deployment Alternatives

It is safe to say that most carriers today do not have significant fiber deployment in the metro areas to reach a substantial percent of residences and businesses. A great deal of activity is going into analysis and planning of deployment of fiber routes. The vast majority of fiber deployment will be in traditional underground conduits, though it is expected that in some cases, especially in dense or historical urban areas, alternatives solutions might be considered. Some of the alternatives include:

Fiber cables in utility pipes

Since most cities have already extensive network of utility pipelines laid-out, several companies have developed technology to install fiber cable inside natural gas, water and sewerage pipes. Small-scale trials and deployment have taken place in the US, and Europe. The first step in the process is video inspection and mapping of the pipelines where fiber cables are to be deployed. Obstructions are removed and/or repairs are performed before cable deployment starts.

Next is to install the cable inside the pipes using robotic technology. There are several techniques for attaching the cable to the inside of the pipe to reduce mechanical stress on the cable. In one technique, the cable conduit is attached to steel rings that are inserted in the pipe and expanded against its inside wall. The fiber cable is then pulled inside the conduit to its terminating point which is can be a patch panel in a manhole. In another technique, the conduit is attached directly to the inside wall of the pipe using steel fasteners and then the cable is pulled inside the conduit.

In the case of gas pipes, the gas service doesn't need to be interrupted. The conduit and cables are installed through "hot-taps" in an isolated section of the pipeline using gas-tight packing seals. **Sempra Fiber Links and Gastec are two pioneers of this technology.** The main advantage of this approach is obviously the economics of using existing pipes instead of new ducts with all its associated problems. However, there are some key issues that need to be considered:

1. Not all pipes will qualify for such an installation because of age, obstructions, size, location, etc. Careful mapping of the pipeline network is needed to identify top candidates.
2. Because of the dual use of the pipes, any maintenance activities have to be coordinated between the Telecom Carrier who owns the fiber cable and the Gas Utility Company.
3. No significant track record exists yet for this technology given its novelty. A small trial in Egypt is appropriate at this point in time to assess its viability given the specific characteristics of the gas pipeline system in Egypt.
4. **Because of the existence of flammable gas in the pipes, the procedure should only be performed by highly qualified technicians. Otherwise, a major accident could occur in a dense urban area, as is the case with downtown Cairo or Alexandria**.

Overhead fiber cables along electrical power transmission towers

This approach is more economical and faster than underground conduits. It is usually pursued as a joint venture with power utility companies, which own the transmission infrastructure. The advantages include the speed of deployment, lower cost o installation and of maintenance.

The main drawback of this method is the lower reliability due to the exposure of cables to the natural elements including storms and extreme weather conditions. Furthermore any maintenance activity has to be coordinated between the Telecom operator and the Ministry of Electricity.

Free space optics

Unlike the two previous alternatives, **Free Space Optics** is a laser-based technology – much like fiber optics – but in which the laser beam travels through the air instead of through a fiber cable. The beam carries data at speeds close to those of regular fiber optic cables. Commercial products that exist today allow for speeds up to STM-16 on one laser beam from a transmitter to a receiver. The power of the laser beam is low enough that - if interrupted by a human being - it does not cause any harm whatsoever. The beam needs a line of sight without any full or partial barriers.

This technology is ideal in situations where natural (e.g. river) or man-made barriers preclude the possibility of laying fiber cables. The system is easy to set up and take down, usually in a few hours. Hence it can be used in temporary situation such as in broadcasting major events on TV or during disasters that wipe out major sections of a fiber cable. Several companies produce products in this space including **Airfiber, MRV Communications and LightPointe.**

The main advantages of the technology are the ability to quickly setup the link, and to overcome certain types of obstacles. Its main drawbacks are the system cost (which is expected to go down a bit once the technology matures) and its limited range. Because of the dust and water particles in the air, the laser beam has an effective limited distance of about 3 km at STM-16 speed in dry weather. During a rainy weather condition, the distance is further reduced. In some locations where heavy rain is common, the span of the link should not exceed 1 km to insure a low-error connection all the time.

Because of its nature, this technology is only used to provide a last mile connectivity to a major location where the extra high bandwidth is needed, e.g. a very large government building, a military base or a major TV & Radio Broadcast installation. It can also be used to close SDH rings in the access or metro backbone networks, which may otherwise be costly or difficult to do because of major obstacles.

1.2.4.2 Recommendations

Since fiber deployment in Egypt is fairly limited beyond the Inter-Office Facilities (IOF), a significant analysis needs to be undertaken to develop a long-term plan for fiber deployment. However, one can make some high level suggestions in the mean time:

- Fiber deployment could be a near term viable option for new communities. Even though it may take time to develop the broadband services that will eventually make use of the fiber, however it is a lot more cost efficient to deploy the fiber during the major construction phases than after all the construction work is completed. At a minimum, the fiber conduits should be laid out and the fiber cables could be pulled through the conduits at a later date.
- A consideration should be given to pulling fiber cables through gas pipes. This alternative might be a viable one for dense commercial areas such as downtown Cairo or Alexandria.

  Further analysis is needed to assess the physical layout and characteristics of the gas pipes to assess if one or more fiber cables can indeed be deployed all the way to a typical apartment building or office building.

- Deploying fiber cables inside a building may not be as complicated as the last mile, yet it is still challenging enough and possibly too expensive to prove in. Alternatives include:
    - Use of Wi-Fi inside the building from a customer's office/apartment to the wiring closet where the fiber terminate on the Access Point.
    - Use of VDSL from the customer location in a building to a DSLAM located in the wiring closet of the building.

1.2.5 FTTP Status Globally

Within the FTTP category, there is a substantial difference between PON and Optical Ethernet in terms of services, product availability, maturity of standards and deployment. One major difference is that Optical Ethernet tries to make use of existing transport technology and infrastructure whereas PON is based on entirely new concepts, protocols and products that have not been deployed in any quantity except in trials.

Optical Ethernet has been offered by most major carriers in N. America and by some carriers in Europe. Ethernet LAN (ELAN) services accounted for over 63% of metro Ethernet revenue in 2002 and will account for 60% in 2007. Migration to ELAN is primarily from T1 and T3 private lines. Some of the installations are for new bandwidth (e.g., connecting locations of a school district or hospital system that did not previously have its own network). Small amount of migration took place from Frame Relay, although QoS concerns are causing many Frame Relay customers to be hesitant about moving to metro Ethernet despite the jump in bandwidth.

In N. America, SBC has filed several Ethernet tariffs while Verizon deployed Ethernet LAN services (ELS) over dark fiber in ~24 metro areas in 2003. AT&T deployed Metro Ethernet, ELS and Managed Internet Ethernet Access to about 70 metro areas. BellSouth offers Native Mode LAN Interconnection (NMLI) @ 10/100 Mbps & 1 Gbps and expanded service to its full territory in the southeastern part of the US.

Asia Pacific is seen as the most promising region for near-term native Ethernet deployments due to significant broadband access deployments in S. Korea & Japan, and promising growth in China, H-K, Malaysia, and Singapore. Recent metro Ethernet switch contracts were awarded by NTT, Korea Telecom and Japan Telecom.

In Europe, Deutsch Telecom built a new Ethernet network in 2003 using Ethernet-over-SDH. France Telecom is evolving its DSL backbone from ATM to MPLS Ethernet while Telefonica is building a native Ethernet network

The expected service revenue stream from Optical Ethernet services in the US is illustrated in Figure 1.12. See also Appendix A for additional information.

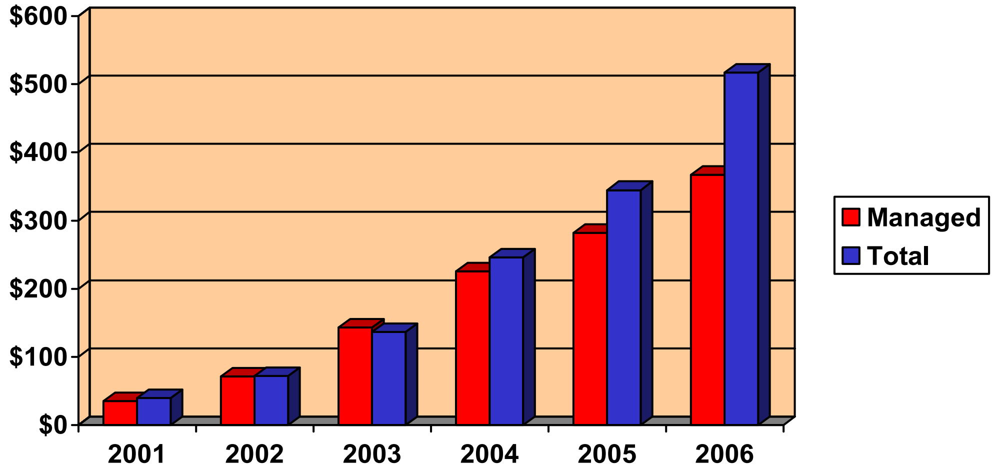

Figure 1.12: Optical Ethernet Services Forecast in $M-US
(IDC-2003)

1.2.6 Trial Proposal

Given the future potential for FTTP, we recommend that MCIT sponsor a long-term trial to address the various aspects of the technology. The trial should be divided into two main phases:

- Phase I: Optical Ethernet
- Phase II: PON

1.2.6.1 Optical Ethernet Trial

The Optical Ethernet technology is more ready for trial/deployment at this point than the PON technology. Of the various architectures that we discussed earlier, the Ethernet over SDH (EoS) might be the most realistic one for Egypt since it builds on the existing SDH network infrastructure and knowledge. It also provides the flexibility to support Ethernet and TDM circuits at the same time. Furthermore it is the most suitable for the lower speed Ethernet lines (10 M and 100 M) that are expected in the Egyptian market. See Figure 1.13 for the Optical Ethernet Trial Architecture

<u>*Recommendations:*</u>

Three different services should be included:

- o Ethernet Private Line service (EPL) to interconnect ISP core routers with each other instead of using private lines.
- o Internet Access using Ethernet Virtual Private Line (EVPL). The setup would provide connectivity at 10 M &100 M from several business customers to an ISP.
- o LAN Interconnect between business locations at 10M & 100 M speeds using Ethernet LAN Service (ELS).

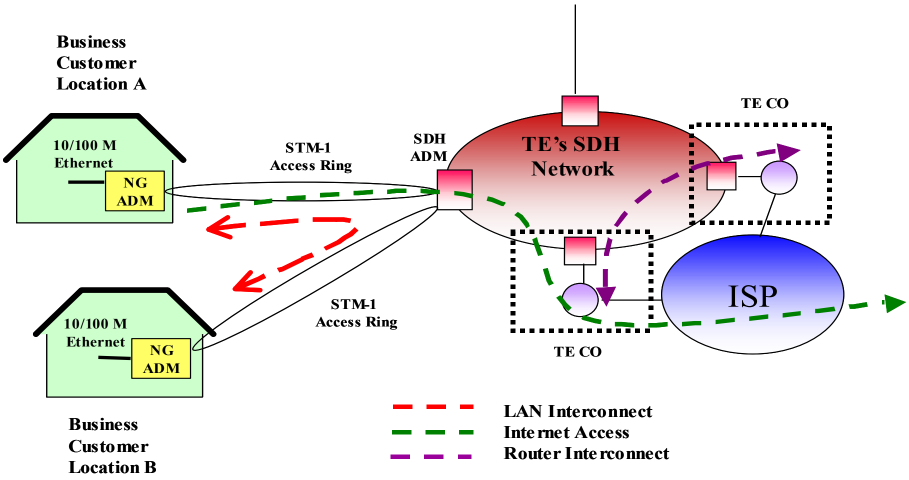

Figure 1.13: Optical Ethernet Trial Architecture

1.2.6.2 PON Trial

As mentioned earlier, PON's primary advantage is its economic use of fiber in the access network. In a metro area that is fiber poor relative to expected demand, PON is the ideal architecture. It is the primary architecture that the large service providers in the US are pursuing to reach residential customers because of the number of homes and the relatively low bandwidth expected (100-200 Mbps), see Figure 1.14 below.

A PON trial in Egypt will service the following objectives:

- Evaluate the technology, especially the outdoor elements of the architecture
- Test the high-end broadband services (e.g. VoD) to residential customers as well as the business applications
- Gain better understanding of the different topologies and cost of fiber deployment to the end points

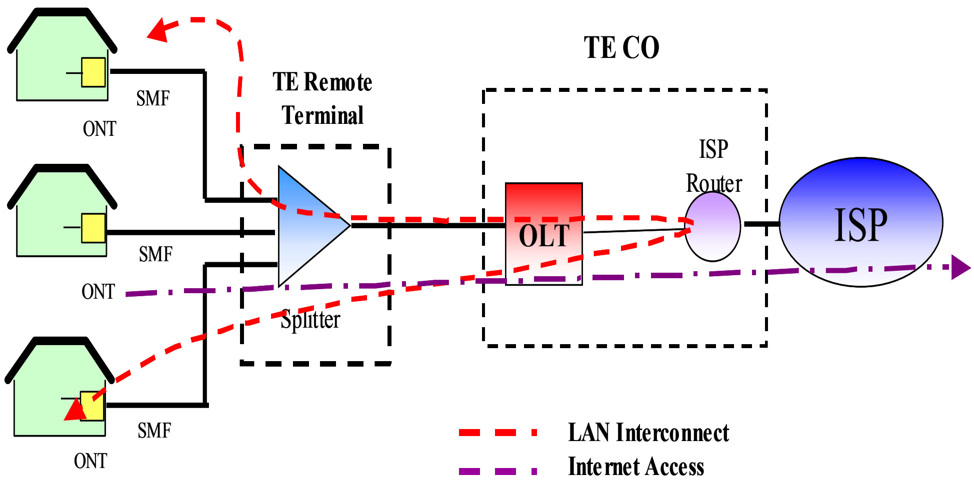

Figure 1.14: PON Trial Architecture

1.2.7 Regulatory Considerations for Egypt

One of the key questions for NTRA is whether the FTTP infrastructure, if deployed by TE, should be unbundled or not. In other words, should TE tariff individual fiber pairs as a standalone network element (much like the copper loop tariff that already exists) or should it keep it bundled as part of its overall network infrastructure. Such a question has seen extensive regulatory debate in the US and the FCC seems inclined at present to leave the FTTP "loops" bundled to encourage the Incumbent Local Exchange Carriers (Verizon, SBC, BellSouth and Qwest) to invest the massive amount of money required for a ubiquitous deployment. A similar question, but in a different context, is fiber deployed over electrical power transmission towers and/or in utility pipes.

1.2.8 Summary

FTTP is a significant component of any Broadband strategy. The technology is still relatively new and equipment prices are bound to go down over the next few years. Yet, it is important to for Egypt to start a series of activities in this area, including detailed economic studies and planning for a trial.

1.3 CONCLUSION

Both VDSL and FTTP represent the next frontier in Broadband Access offering higher speeds than available today using ADSL, Cable Modem or Wi-Fi to end users. The technology and standards for both technologies are still evolving. VDSL, however, may be a little ahead of FTTP, especially in terms of product availability, applications and suitability to the Egyptian market. FTTP has a place in the Egyptian telecom infrastructure as well, though our view at this point is that it makes more sense to use it as a backbone technology, for example to interconnect ISP routers, as opposed to an access technology given the limited metro fiber deployment that exists in Egypt today.

We proposed a market trial with each technology, though we suggest to start first with the VDSL one. However, since the two technologies address different applications, network segments and end-users, it may be possible to hold both at the same time, assuming that enough resources within MCIT, TE and the other entities are available to manage them properly.

It is important, though, to realize that even a limited market trial requires a large amount of coordination effort and investment on the part of the trial team. Hence, good preparation for the trial is critical to insure that the objectives are met. Otherwise, they may end up being a total waste of time and money.

1.4 REFERENCES

[1] ITU-T Recommendation G.993.1, Very High-Speed Digital Subscriber Line Foundation, 2001

[2] IEEE 802.3ah standard – http://www.metroethernetforum.org/

[3] Broadband Strategy for Egypt – Infocom technology, December 2003

[3] Ethernet Forum, Metro Ethernet Services, A Technical Overview, April 2003

APPENDIX A

A.1 VDSL

Table A-1: DSL Technology Options

	2 or 4-wire Symmetry	Share copper pair with POTS	Line Code or Modulation	Bit-rate vs. Distance	Applications
IDSL	2-Wire Symmetric	No	2B1Q (4B3T)	160 Kbps (2B+d+overhead) over 18 kft	Data or non-switched voice
HDSL	4-Wire Symmetric	No	2B1Q or CAP	1.544 over 12kft on 24 ga (784 kbps per copper pair)	DS1 transport (Repeaterless T1)
SDSL	2-Wire Symmetric	No	2B1Q or CAP	64 kbps to 2.3 Mbps over 18 kft.	Business Access
ADSL	2-Wire Asymmetric	Yes	DMT (Full Rate, G.Lite)	1.5Mbps / 64kbps over 18 kft 6Mbps / 640kbps over 9kft, 12kft	Consumer-oriented data service, or business data service plus POTS
HDSL2	2-Wire Symmetric	No	TC PAM (OPTIS)	1.544 over 12kft on 24 gauge	DS1 transport (Repeaterless T1)
SHDSL	2-Wire Symmetric	No	TC PAM	Up to 2320 kbps	ATM or Frame Relay, Nx64kps, VF Pairgain
VDSL	2-Wire Asymmetric, Symmetric	Yes	QAM or DMT	13Mbps, 26Mbps, 52 Mbps DS to 4500 ft., 3000kft., 1000kft., resp. 1.5Mbps - 26 Mbps US	Digital video and/or data (requires FTTN or FTTC)

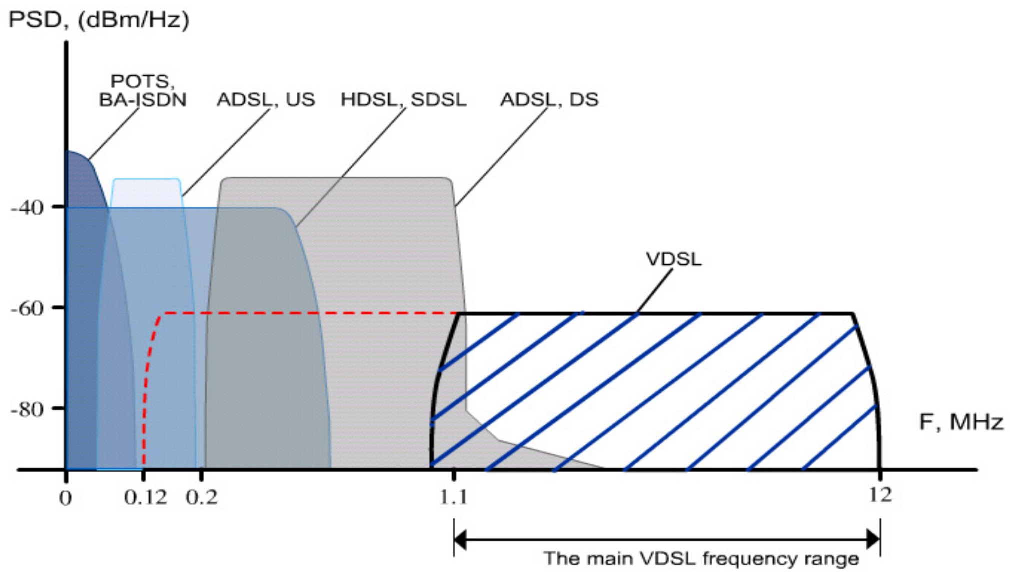

Figure A-1: VDSL Spectrum Allocation

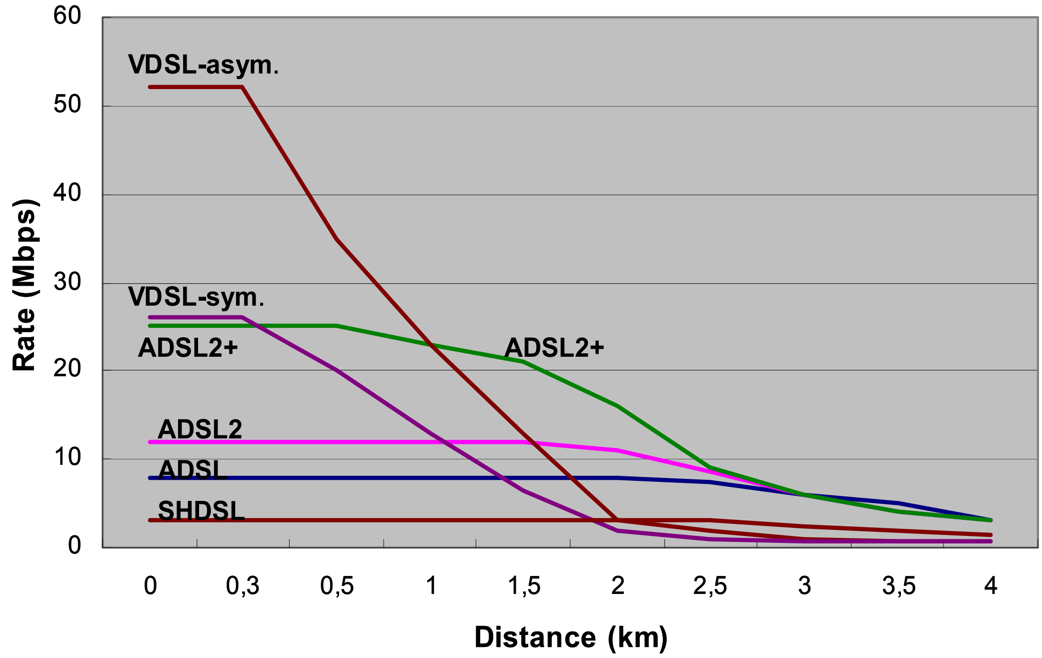

Figure A-2: Rate vs Distance of Key DSL Technologies

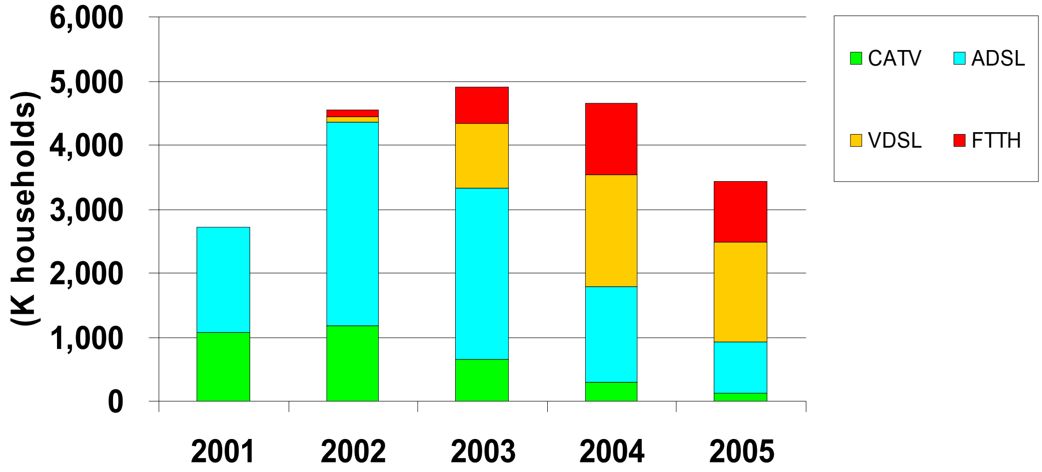

Figure A-3: Deployment of VDSL in Japan
Source: Ministry of Public Management, Home Affairs, Posts and Telecommunications

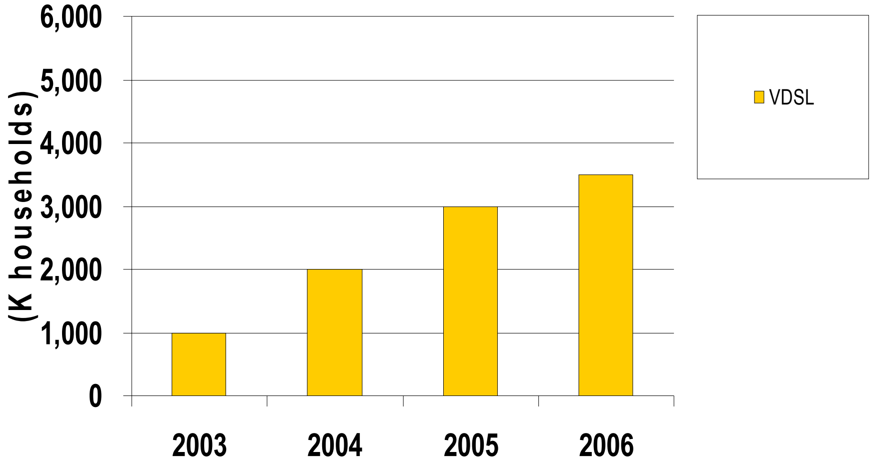

Figure A-4: Deployment of VDSL in Japan
Source: Companies, Goodmorning Shinhan Securities Estimates

A.2 FTTP

Ethernet Forecasts

1. Ethernet Services:

The worldwide metro Ethernet services revenue projection (of $26.5B in 2006) is based on Table A-2 below (IDC report)

Table A-2: Worldwide Metro Ethernet Services Revenue

Year	2001	2002	2003	2004	2005	2006	2001-2006 CAGR (%)
Services Revenue ($M)	477.9	2,042.5	5,136.9	9,978.2	18,251.8	26,528.3	123.3

2. Ethernet Equipment:

The worldwide metro Ethernet equipment revenue (of $4.4B in 2006) is also from the same IDC report. See Table A-3 below.

Table A-3: Worldwide Metro Ethernet Equipment Revenue

Year	2001	2002	2003	2004	2005	2006	2007	2001-2007 CAGR (%)
Equipment Revenue ($M)	486.1	842.3	1,442.5	2,410.3	3,422.1	3,928.5	4,367.8	39.0

The worldwide Ethernet port projection is listed in Table A-4 below

Table A-4: Worldwide Ethernet Port Projection

Year	2001	2002	2003	2004	2005	2006
Ports	209,376	194,224	285,051	409,920	571,077	763,249

2 Wi-Fi

PREFACE

This chapter addresses one aspect of Egypt's broadband initiative: wireless access technology based on the IEEE 802.11 family of protocols, a technology termed Wireless Fidelity, or simply Wi-Fi. This technology is one of other key broadband technologies being addressed by Infocom Technology for MCIT. Other chapters are addressing other technologies, DSL, Cable Modems, last mile access, and 3G mobile communications.

The purpose of this Wi-Fi study has been to assess the application of wideband wireless access technology to MCIT's objectives for providing increased broadband access to the Internet for consumers and business and governmental enterprises. In this Chapter, we discuss the still-emerging worldwide market for Wi-Fi, as well as the on-going evolution of Wi-Fi technology, services, and business models. Based on this study and discussions held with key broadband players in Egypt in September 2003, we provide recommendations as to how Egypt can benefit from this technology in the next three years.

The recommendations presented in this chapter are based on current information, and it must be emphasized that the Wi-Fi industry is evolving rapidly, with product and service pricing, service business models, and business alignments changing almost daily. Thus, as the market evolves and Egypt takes initial steps toward implementation of this and other elements of the Broadband Initiative, the recommendations will have to be revisited and updated accordingly.

The recommendations contained in this document are based on current information, business environment and regulatory constraints in Egypt. As those change over time, there will be a need to revisit the recommendations and update them accordingly.

SUMMARY

The re-emergence and rapid expansion of IEEE-802.11-based Wireless LAN technology and business provides several options for use of this "Wi-Fi" technology in expansion, within Egypt, of broadband access to the Internet. While the rapid growth in the Wi-Fi market has been driven primarily by the demands of business travelers and increasingly mobile consumers, the more recent emergence of the IEEE 802.16 standard and consequent Wi-Max initiative for Fixed Broadband Wireless Access appear to usher in a wider range of applications for broadband wireless communications.

To date, the rapid growth in Wi-Fi products and services has consisted of the wide proliferation of Public WLAN access points, commonly termed *hotspots*, typically deployed in retail venues, hotels, airports, and university campuses. Some industry observers forecast continued vigorous growth in the worldwide number of public hotspots, e. g., more that 50 per cent annual growth over the next five years (IDC report, June 2003[1]). However, this industry is still in an early stage of development, and as in the early days of any emerging technology development, the complexion of the industry is evolving and shifting rapidly. While the number of public hotspots and the number of users have grown rapidly, the worldwide market is still very small relative to the now-familiar almost universal use of mobile phone services. The relationship that PWLAN services will have to the popular cellular phone services is uncertain and will bear continued scrutiny as the cellular industry migrates to fuller deployment of 3G services, another alternative for broadband Internet access.

With respect to the introduction of Wi-Fi technology as part of the Broadband Strategy for Egypt, we recommend that MCIT begin addressing critical issues of in-building signal penetration and cost of backhaul provisioning by sponsoring a Wi-Fi trial deployment in Cairo. In particular, we recommend:

1. MCIT sponsors a Wi-Fi access pilot trial in a medium-size business office setting in Cairo. The physical arrangement of the trial site should be chosen to provide useful experience as to access point installation, in-building signal penetration, backhaul provisioning, *etc*. (An alternative venue might be a large apartment house, though this might not provide a sufficient degree of variability in user traffic rates, session times, *etc*.)
2. MCIT considers fielding another pilot trial in a setting likely to exhibit greater mobility of users, for example, on a university campus. Such a trial will enable assessment of such issues as signal coverage in a combination of indoor and outdoor user locations, signal range, shadowing, *etc*. This will also provide the advantage of gathering information on experience of a population of users that are especially technically knowledgeable.
3. NTRA to issue experimental licenses to provision and operate these trials and any additional pilot deployments as they see fit. NTRA should require that Wi-Fi products employed in Egypt have been certified for 802.11x conformance and for interoperability, by the international Wi-Fi Alliance.
4. In anticipation of eventual fuller deployments of Wi-Fi equipment and services, we recommend that NTRA undertake deliberations aimed at structuring a "minimum regulation" posture with respect to Wi-Fi technology. These deliberations should encompass detailed examination of experiences to date in the US, Asia/Pacific

Region, and other regions where minimum regulatory policies have been followed. A product-certification policy, based on the US FCC model is suggested.

5. We also recommend MCIT initiate a study of WiMax (802.16) technology for application in Egypt. The study should encompass not only the use of WiMax as an adjunct to Wi-Fi technology (*e. g.*, as an element of backhaul), but also as an alternative to Wi-Fi for broadband wireless access at distances greater than can be supported by Wi-Fi. We also recommend undertaking a study of on-going research and development of range-extension techniques for Wi-Fi.

In summary, the rapidly evolving market for Wi-Fi in developed nations provides an attractive and convenient option for broadband access to the Internet. A broad manufacturing base is developing, providing an expanding array of Wi-Fi products, with industry competition providing steady downward pressure on prices. Installation of access points and network connections is relatively simple, allowing for convenient provisioning of pilot trials in selected scenarios. Such trials will provide valuable information on the use of Wi-Fi technology – technical information on signal coverage and penetration, interference, *etc*. – as well as experience with patterns of usage by different groups of users in varied business, academic, and residential environments. While such trials are in progress, attention can be given to the formulation of an appropriate regulatory posture with respect to expanded use of this important technology.

2.1 WI-FI APPLICATIONS

Stated in simplest terms, Wi-Fi is a wireless access technology providing an alternative to traditional 802.3 Ethernet cable connections to wired LANs, and thereby to the Internet. Wi-Fi has its origins in the early development of Wireless LANs, which were intended to serve as a cable-replacement technology in office environments. The industry initiatives toward defining the 802.11xx family of protocols, together with the rapidly growing popularity of laptop computers, has stimulated the growth of Wi-Fi and at least three areas of application for this technology:

1. *Public WLANs*: These networks employ wireless access points, commonly called **hotspots**, installed in public areas such as retail venues, hotels, airports, *etc.*, providing Internet access for users on a pay-per-session basis or by subscription with a Wi-Fi service provider.
2. *Privately deployed WLANs*: These networks are typically installed in offices, manufacturing facilities, and university campuses, and provide wireless access to the local computer resources of the enterprise and thereby to the Internet as well. These networks are increasingly common on campuses in the US, where the use of wireless access is often integrated into the delivery of academic course content, and in some instances is leading to innovations in teaching methods.
3. *In-home WLANs*: There is increasing use of wireless networking in residences and at-home offices. This includes the use of a widening array of Wi-Fi devices, including access points, routers and switches for interconnecting desktop and laptop computers, printers, scanners, and cable and wireline modems. The interest in in-home wireless networking is being further stimulated by the use of wireless devices to link the home computer with home entertainment devices, the computer in effect serving as a computing/communication/entertainment control center.

As an element of Egypt's Broadband Initiative, Wi-Fi offers opportunities in the near term for conveniently and economically broadening the options available to Egypt's citizens for broadband access to the Internet and to the expanding array of e-services being put into place by the government. The Wi-Fi component of the broadband initiative can be viewed as addressing at least three areas of application:

1. Wireless Internet access for small/intermediate size business offices and for homes: The use in business office settings represent the now-traditional kinds of applications for WLANs, particularly in situations where wireless networking provides a lower-cost alternative to hard-wired cabling of office LANs. Similarly, in many home environments, Wi-Fi can provide a lower-cost alternative to replacement of poor quality copper loops and provisioning of DSL. Simultaneously, Wi-Fi installations in homes will directly complement Egypt's **Free Internet** and **PC for Every Home** programs, facilitating increased broadband access by citizens.
2. Wi-Fi networking on university campuses: This application will yield at least two important benefits. First, increasing broadband access for students, faculty and administrators will bring the technology to the attention of users who, on the whole, are likely to be knowledgeable adopters of new technology. Also, faculty can be encouraged to find innovative ways of incorporating this technology into the education process itself, as many educations institutions in the US are already doing. Exposing this population segment to wireless networking technology can go a long

way toward increasing its awareness in the larger population of Egypt. (Here, we recognize that the full use of this technology will at first be somewhat limited by the limited penetration to date of laptop computers, but as pricing comes down and awareness increases, this situation will eventually change.)

3. Public WLANS, or "hotspots" deployed in public settings, such as hotels, airports, and retail venues. (At least one such deployment is already in place, in the Cairo Conrad Hotel [2].) From our September 2003 discussions with MCIT, we recognize that provision of commercial hotspots is not a high priority in the broadband initiative. However, it should be recognized that availability of PWLANs in situations likely to be visited by many international business travelers and tourists can serve to highlight Egypt's serious intentions regarding the introduction of advanced telecommunications technology throughout the country.

In the remainder of this Chapter, we summarize the status of 802.11-based WLAN technology, and the newly emerging 802.16-based technology. We then review the status of Wi-Fi market for PWLAN services, including developments in major geographical regions of the world. This market must be considered as very much in a developmental phase, with many changes on-going as this is written. We also review the various business models that are evolving in the Wi-Fi market, and analyze the trends we see in progress. We also examine regulatory issues in the context of Egypt's existing structure and experience in other countries. Finally, we make recommendations for initial steps in the introduction of Wi-Fi technology under the broadband initiative.

2.2 WLAN TECHNOLOGY

2.2.1 Background

Wireless Local Area Network (WLAN) technology emerged about 30 years ago but languished for a number of years, due in large part to a lack of standardization in radio access protocols. Also, there was for a long time a rather limited perception in the industry of the potential applicability of WLAN technology. In early days, the market was seen as primarily as a wireless alternative for connecting desktop PCs to existing wired LANs in offices and factories, on university campuses, convention and conference venues, *etc*. However, the IEEE 802.11 standardization initiatives, beginning with the July 1999 adoption of 802.11b, have re-energized interest in WLANs, aided also by the simultaneous rapid growth in popularity of lap-top computers. In 1999, the Wireless Fidelity (Wi-Fi) Alliance was formed to certify interoperability of WLAN products based on the 802.11 protocols and to promote the growth of the 802.11 market. Thus the name Wi-Fi has come to be synonymous with 802.11 protocols, all of which provide wireless interoperability with legacy wired Ethernet LANs and access to the Internet. The user demand for increasingly high data rates has driven the evolution from 802.11 (1.2 Mb/s) to 802.11b and 802.11a and 802.11g (up to 54 Mb/s). See the tables in the next subsection.

To date, the rapid growth in Wi-Fi products and services has consisted of the wide proliferation of Public WLAN (PWLAN) access points, commonly termed *hotspots*, typically deployed in retail venues, hotels, airports, and on university campuses. The popularity of hotspot services has been driven thus far by the demand for Internet access from laptops and, lately, PDAs, the users typically characterized as "tech-savvy" business travelers, professionals and students. Chip manufacturers are supporting the growth by developing and releasing 802.11 chips: a prominent example is the Intel Centrino chip. Laptop manufacturers are increasingly marketing “Wi-Fi – ready” products. In addition to Wi-Fi equipped laptops and Wi-Fi cards for desktop PCs, many other affordable products are becoming available, including access points, switches, and routers. Many of these products are being purchased for residential and home-office applications, including home wireless networks linking the home computer with family entertainment appliances.

The use of WLANs gives rise to a number of technical issues that are not typically encountered with traditional wired LANs:

Signal range vs. data rate – signal propagation range is limited to about 300 feet at the lowest data rates, and to shorter ranges at higher data rates. Increasing the size of signal-coverage “footprints” implies increased cost in the provision of backhaul infrastructure.

Interference: Increasing deployment and use of WLANs will raise concerns about signal interference among users of any access point and interference from and to other signal transmissions sharing the same frequency bands.

Security, authentication, and roaming: These all need solutions harmonized across the industry, which is not the situation at present.

It is likely that for the foreseeable future, the market for various Wi-Fi products will continue to be driven by the pattern of proliferation of commercial hotspots and the continuing growth in popularity of laptops. Some industry observers are forecasting continued vigorous growth in the worldwide number of public hotspots, *e. g*., more that 50 per cent annual growth over the next five years. However, this industry is still in an early stage of evolution, and as in the early days of any emerging technology development, the complexion of the industry is evolving and shifting rapidly. While the number of public hotspots and the number of users have grown rapidly, the worldwide market is still very small relative to the now-familiar almost-universal use of mobile phone services. The relationship that PWLAN services will have to the popular cellular phone services is uncertain and will bear continued scrutiny as the cellular industry migrates to fuller deployment of 3G services, another alternative for broadband Internet access.

The industry is also seeing much ongoing convergence of Wi-Fi with other services, particularly cellular services. A recent article concerning T-Mobile, a major Wi-Fi service provider, quotes T-Mobile as seeing Wi-Fi services as a way of gaining visibility for their cellular service and attracting customers who might become subscribers to both services, with the convenience of single billing.

2.2.2 The 802.11 Family of Standards

The standardization of mass-market Wireless WLAN (WLAN) products began with the original 802.11 standard developed in 1997 by the Institute of Electrical and Electronics Engineers (IEEE). That foundation standard continues to be enhanced through additions, each of which designated by a letter following the 802.11 name, such as 802.11b, 802.11a, or 802.11g. The letter suffix represents the IEEE task group that defines the corresponding extension to the standard [IEEE 802].

We should note that the IEEE standards body does not validate interoperability or compliance with any given technical standard. In the case of these WLAN standards, the industry association Wireless Fidelity Alliance, known simply as Wi-Fi, performs these certification tasks for the WLAN manufacturing industry. [WiFi] The Wi-Fi Alliance certifies products by actually testing them against a set of compliance guidelines. . At this writing, the Wi-Fi Alliance comprises 186 member companies worldwide, and about 800 products have received Wi-Fi® certification. [WiFi]

These enhancements have defined increases in data rate and functionality in IEEE 802.11, in response to market demands that have evolved as the WLAN market has grown. Table 2.1 below briefly summarizes the successive enhancements related to data rate (at the WLAN physical layer).

Table 2.1: Summary of IEEE 802.11 Specifications

	802.11b	**802.11a**	**802.11g**
Standard Approved	July 1999	July 1999	June 2003
Maximum data rate	11 Mbps	54 Mbps	54 Mbps
Modulation	CCK	OFDM	OFDM and CCK
Data rates	1, 2, 5.5, 11 Mbps	6, 9, 12, 24, 36, 48, 54 Mbps	CCK: 1, 2, 5.5, 11 OFDM: 6, 9, 12, 24, 36, 48, 54 Mbps
Frequencies	2.4 – 2.497 GHz	5.150 - 5.350 GHz 5.425 - 5.675 GHz 5.725 - 5.875 GHz	2.4 – 2.497 GHz

Here we briefly summarize the key characteristics of each of the IEEE 802.11 extensions.

2.2.2.1 IEEE 802.11b

Ratified by the IEEE in July 1999, 802.11b extends the original IEEE 802.11 direct sequence spread spectrum (DSSS) standard to operate at data rates up to 11 Mbps in the 2.4-GHz unlicensed band using Complementary Code Keying (CCK) modulation. [See insert below.] The four data rates of 1, 2, 5.5, and 11 Mbps are specified on up to three non-overlapping channels, and the lowest two rates are also allowed on up to 13 overlapping channels. A good description of the 802.11b standard can be found in [Van99]. The maximum data rate of 11 Mbps allows data rates comparable to legacy Ethernet wired LANs. The 802.11b standard has been referred to as 802.11 High Rate, and in the last few years, the 802.11b standard has come to be synonymous with "Wi-Fi".

Complementary Code Keying (CCK)

In order to achieve the 11 Mb/s data rate in 802.11b, a modulation method known as Complementary Code Keying is used. With CCK, the input data bits are grouped into blocks of 6 and 2 bits. The 6bit blocks are used to select one of $2^6 = 64$ unique 8-chip spreading-code symbols. The other 2 bits are used for differential QPSK (DQPSK) modulation of the entire symbol. Overall the symbol rate (code word rate) for CCK is 1.375 Mbps with a chipping rate of 11 x 10^6 chips per second. Since each symbol is a 6-bit block, this translates into an 11 Mbps data rate. Multiplying this by 2 MHz (the null-to-null bandwidth of a chip) for QPSK encoding yields a 22-MHz signal bandwidth in the 2.4 GHz band. [Van99]

The 802.11b protocol quickly became the industry standard for WLANs has been gaining market acceptance as the first wireless networking products with acceptable speeds, affordable prices, and universal compatibility as certified by the Wi-Fi Alliance. More than 95% ***of today's WLAN infrastructure includes 802.11b products, and the marketing identity "Wi-Fi capable" can be interpreted as signifying compatibility with (at least) the IEEE 802.11b standard.

2.2.2.2 IEEE 802.11a

Ratified by the IEEE at the same time as 802.11b, the IEEE 802.11a standard operates in the 5-GHz band. The 802.11a standard was designed for higher bandwidth applications than those served by 802.11b, and includes data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps using Orthogonal Frequency Division Multiplexing (OFDM) modulation on up to 12 discrete channels. Fis00]. In contrast with direct-sequence modulation, OFDM divides a high data rate stream into multiple lower-rate streams, which are then transmitted on multiple subcarriers [Van00].

The first 802.11a based products became available late 2001, answering market demands for higher-data-rate capability. However, even though this extension provides for higher data rates, it has had limited marketplace acceptance. This has been interpreted as being due primarily to its lack of backward compatibility with 802.11b products, shorter signal range, and higher deployment costs.

2.2.2.3 IEEE 802.11g

In July 1999, the IEEE 802.11g subcommittee was tasked to extend the data rate capability to rates beyond 20 Mbps for operation in the 2.4-GHz unlicensed band. The resulting 802.11g standard was ratified in June 2003. The 802.11g standard provides optional data rates as high as 54 Mbps, and requires backward compatibility with 802.11b devices in order to protect the substantial investments in the increasingly popular 802.11b WLAN installations. The 802.11g standard includes both mandatory and optional components. It specifies OFDM (the same modulation format as used in 802.11a) and CCK as the mandatory modulation schemes with 24 Mbps as the mandatory maximum data rate, but it also provides for optional higher data rates of 36, 48, and 54 Mbps. At the highest data rates, the standard also allows a transmission format called Packet Binary Convolutional Coding (PBCC). [11g ref]

The 802.11g specification appears to be getting established as the next mainstream wireless LAN standard. This standard satisfies the bandwidth needs of the market globally and economically, while remaining compatible with the extensive installed base of 8-2.11b products. Note: The term "backward compatibility" with 802.11b means that when a 802.11b client connects with an 802.11g access point, all the connections on that access point adjust downward to the 802.11b data rates.

2.2.2.4 Other 802.11 Standards Activities

Other related standards activities under the purview of IEEE 802.11 address various extensions of the 802.11 initiative. These include 802.11e, 802.11i, 802.11h and 802.11n, summarized below.

- **802.11e**: This standard provides Quality of Service (QoS) support for WLANs. It is expected that QoS capability will become increasingly important as WLANs are used with delay-sensitive applications such as Voice over Wireless IP (VoWIP). The standard provides classes of service with managed levels of QoS for data, voice, and video applications. The standard employs a priority-provisioning mechanism to enforce "fairness" when collocated WLANs share a radio channel. [Man02]
- **802.11i:** This supplemental draft standard is intended to improve WLAN security. It describes the encrypted transmission of data between systems of 802.11a and 802.11b WLANs. It defines new encryption key protocols including the Temporal Key Integrity Protocol (TKIP) and the Advanced Encryption Standard (AES). AES will require new hardware when it is completed. The Wi-Fi Alliance has developed a pre-80.11i interoperable encryption specification called Wi-Fi Protected Access (WPA). [WiFi site]
- **802.11h**: This standard is supplementary to the 802.11 Medium Access Control (MAC) layer to comply with European regulations for 5GHz WLANs. (See discussion of ETSI standards, below.) European radio regulations for the 5GHz band require products to have transmission power control (TPC) and dynamic frequency selection (DFS). TPC limits the transmitted power to the minimum needed to reach the furthest user. DFS selects the radio channel at the access point to minimize interference with other systems, particularly radar. Pan-European approval of 802.11h is still pending.
- **802.11n:** It has been reported by the Wi-Fi Alliance that this standard will provide data rates in excess of 100 Mbps. This is work in progress, and no official announcements have been made with respect to targeted completion date.

2.2.3 Related Standards Activities

Other on-going standards activities relate to technical issues that will become increasingly important as the Wi-Fi market expands. A few of these activities, relating to security and to the transport of voice traffic over WLANs, are summarized here.

Wi-Fi Protected Access (WPA): The Wi-Fi Alliance, working in conjunction with the IEEE, has developed and brought to market an interoperable Wi-Fi security specification called Wi-Fi Protected Access (WPA). The WPA specification overcomes known weaknesses of the original 802.11 security scheme called Wireless Equivalent Privacy (WEP). The improvements include user authentication and the provision of dynamic keys. WPA will be forward-compatible with 802.11i, and is in fact a subset of a draft of the 802.11i specification, adopting certain portions of the 802.11i draft that were judged ready for market.

Voice over Wireless IP (VoWIP): Combining Voice over IP (VoIP) with 802.11 wireless LANs to create a wireless telephone system for offices is an emerging market segment. VoWIP enables voice communications over WLANs enabling the merging of voice and data traffic over a single wireless backbone. From a network perspective, VoWIP applications require some reservation of bandwidth to support the real-time nature of voice. As noted earlier in this Chapter, the IEEE is developing the 802.11e standard for managing Quality of Service in WLANs.

2.2.4 European WLAN Standards

Beginning in 1992, the RES-10 subcommittee of the European Telecommunications Standards Institute (ETSI) began work on a Pan-European standard for WLANs, to be known as High Performance Radio Local Area Network (HIPERLAN). Unlike the IEEE 802.11 initiatives, which have been based on manufacturers' product design, the HIPERLAN standardization work has been based upon functional requirements specified by ETSI

In 1997 this effort produced its first standard, called HIPERLAN-1, which provides communications at up to 20 Mbps in the 5 GHz band. . In April 200, ETSI issued the first release of the HIPERLAN-2 standard, which provides communications at up to 54 Mbps in the 5 GHz band. Products based on the HIPERLAN standards have been used chiefly in European countries. Table 2.2 provides comparisons among the HIPERLAN and 802.11 standards.

Table 2.2: Comparison of HIPERLAN and 802.11 Standards

Parameters	**IEEE 802.11g**	**IEEE 802.11b**	**IEEE 802.11a**	**HIPERLAN/2**	**HIPERLAN/1**
Freq. Band	5 GHz	2.4 GHz	5 GHz		5 GHz
PHY, modulation	OFDM & CCK:	DSSS: CCK	OFDM		GMSK
Data rate (Mbps)	CCK: 1,2, 5.5, 11 OFDM: 6,9,12,24,36 ,48,54 Mbps	1, 2, 5.5, 11 Mbps	6, 9, 12, 18, 24, 36, 54 Mbps		23.5 Mbps
Access method	Distributed control, CSMA/CA or RTS/CTS			Central control. Reservation based access	Active contention resolution, Priority signalling

HIPERLAN-1 uses Gaussian Minimum Shift Keying (GMSK) modulation with Decision Feedback Equalization (DFE) at the receiver to support data rates up to 23.5Mbps. IEEE 802.11a and HIPERLAN-2 use OFDM in the physical layer to support data rates up to 54Mbps. The access method for all 802.11 standards is the same and includes CSMA/CA, PCF, and RTS/CTS (see the Glossary at the end of this Chapter).

The access method used for HIPERLAN-1 is along the lines of the 802.11 specification, but the access method for HIPERLAN-2 is a voice-oriented access technique that is suitable for integration of voice and data services.

2.2.5 WPAN and WMAN Standards Developments

While our focus in this study is on the use of WLAN technology in the Broadband Initiative, it is worthwhile to note parallel developments on-going the wireless industry, which might be considered for longer-range incorporation into future broadband planning in Egypt. In the broadband planning process, these technologies may also have to be studied with respect to coexistence issues. These technologies include Wireless Personal Area Networks (WPANS) and Wireless Metropolitan Area Networks (WMANs)

2.2.5.1 IEEE 802.15 for WPANs

The IEEE 802.15 WPAN™ effort is focused on the development of standards for Personal Area Networks or short distance wireless networks. These WPANs address wireless networking of portable and mobile computing devices such as PCs, Personal Digital Assistants (PDAs), peripherals, cell phones, pagers, and consumer electronics; allowing these devices to communicate and interoperate with one another. The goal is to publish standards, recommended practices, or guides that have broad market applicability and deal effectively with the issues of coexistence and interoperability with other wired and wireless networking solutions. The IEEE 802.15 Working Group is part of the 802 Local and Metropolitan Area Network Standards Committee of the IEEE Computer Society.

2.2.5.2 IEEE 802.16 for WMANs

The IEEE 802.16 committee was formed for the purpose of developing standards for broadband point-to-point wireless access. Their first release was the 802.16-2001 standard, released in December 2001 as a point-to-multipoint broadband wireless access standard for systems operating in the frequency range 10-66 GHz. This initial standard opened the way for fixed Broadband Wireless Access (BWA), which could provide wireless network access to buildings, with data rates approaching those offered by high-speed fiber optic networks.

In the IEEE 802.16 vision, carriers would set up base stations connected to a public network. Each base station would support hundreds of fixed subscriber stations, probably mounted on rooftops. The base stations would then use the standard's medium access control (MAC) layer to nearly instantaneously allocate uplink and downlink bandwidth to subscribers according to their needs.

The 802.16 specification is very comprehensive, designed to address fixed broadband wireless access needs in a variety of situations. There are provisions for different physical layers for different frequency bands and country-specific restrictions on frequency use. MAC layer options in the specification allow better QoS management than has been provided in legacy protocols, enabling greater transmission range than provided by the 802.11 standards. One of the areas of application envisioned specifically in the 802.16 development was range enhancement beyond the capability of 802.11-based hotspots.

An issue with the original 802.16 standard was that the 10-66 GHz spectrum is strictly line-of-sight. Thus the IEEE developed the 802.16a amendment, approved in April 2002. The amendment addresses the low-frequency 2-11 GHz spectrum, some of which is unlicensed, and which allows for non-line-of-sight operation. The 802.16a standard defines three physical layer modes. It retains the single-carrier access method for special-purpose networks, but adds a 256-carrier OFDM layer, which splits the radio signal into multiple subchannels that are then transmitted simultaneously on different subcarriers to the receiver, thus reducing multipath effects. The standard also defines a 2,048-carrier OFDMA, or orthogonal frequency division multiple access, layer, which offers advanced multiplexing in tiered MANs and supports selective multicast

Just as the Wi-Fi Alliance was formed as an industry initiative to insure and certify the interoperability of 802.11-based products, the WiMAX Forum has been formed to serve a similar role with respect to 802.16-based products. The WiMAX technology can provide not only broadband access to users but also a wideband backhaul capability. Therefore WiMAX bears further study as a candidate approach to addressing the goals of MCIT's wireless wideband access project.

2.2.6 Future Trends

The telecommunications industry is multi-faceted and in the last few decades has become especially responsive to market demands for new services and capabilities. This has been particularly true of the wireless segment of the industry, which has seen explosive growth from cordless phones and first-generation analog cellular networks through 2G digital networks, low-speed mobile data networks, paging systems, and now 3G technologies that provide improved voice quality and integration of data with voice services. It has always been difficult to predict the future of the wireless communications industry, but there are certain trends that one can discern and try to project. Here we comment briefly on a few trends perceived by us as having some eventual impact on Egypt's Broadband Initiative.

2.2.6.1 WAN and WLAN Integration

With respect to the critical issue of spectrum allocation and administration, we see 3G Wide-Area Network (WAN) systems operating in licensed bands, where service providers must make large investments to secure access to those licenses. On the other hand, WLANs and WPANs operate in unlicensed bands, where one does not need to purchase spectrum and where the user in unencumbered by regulatory rules and regulations. However, there is also no regulatory control of signal interference in the unlicensed bands, and thus connectivity and link performance can often be problematic. It would not be wise to predict that all wireless communications will migrate to unlicensed bands, but it is accurate to say that the last several years have witnessed a renewed interest and vigorous growth in the use of unlicensed-band systems. One possible migration path is the eventual integration of WANs with WLANs in unlicensed bands.

2.2.6.2 Mesh Networking

Another important evolving technology is mobile *ad-hoc* networking, also called "mesh networking." The basic concept of *ad-hoc* networking is to employ a distributed network topology having the capability for network reconfiguration without the need for a fixed infrastructure. This technology was developed for military networking requirements, but is finding some application in commercial voice and data services. The mesh networking topology is suitable, as an example, for rapid deployment of any wireless network in a mobile or fixed environment.

Some observers have characterized a mesh network as a miniature version of the Internet. Each station on a mesh network not only receives and transmits its own traffic, but it also acts as a router that forwards messages destined for other stations. Because each node on a mesh network only has to make contact with its immediate neighbor and not a distant base station, it can transmit at a very low power; frequencies used by one node can be reused by another only a short distance away. Mesh networks are also inherently robust, as new routes can be found if any one node goes down. There isn't normally just one point of failure.

In the US, mesh networking is attracting considerable attention, and some wireless equipment manufacturers have begun implementing mesh-networking software in their products. [EET03]

2.2.7 802.11 Performance Characteristics

The 802.11b, 802.11a, and 802.11g standards exhibit different characteristics as to their achievable data rate and signal range, due to differences in operating frequency, modulation method, and the array of data rates provided in each of the three standards.

The 802.11 standards all support multiple data rates to allow clients to communicate at the best possible speed. Data rate selection is a tradeoff between obtaining the highest possible data rate and attempting to minimize the number of communication errors. Whenever errors are detected in the received data, the systems must spend time to retransmit the data until it is error free. (The error-recovery function resides in the 802.11 MAC layer, which is common to all three versions of the standard.) Each 802.11 client performs a procedure to select the best data rate. Of the three standards, the 802.11g clients can select from the widest possible range of both OFDM data rates of 54, 48, 36, 24, 18, 12, 9, and 6 Mbps, and the CCK rates of 11, 5.5, 2, and 1 Mbps.

While in principle it is possible to calculate performance predictions for the various selections of transmission rate, modulation schemes and coding options, it must be emphasized that such calculations will not give highly accurate indicators of performance actually achievable in realistic system settings. We shall try to illuminate this point with brief discussion of key issues at work in real-world WLAN installations.

2.2.7.1 Wireless Media

Unlike wired communication circuits, wireless paths are difficult to control due to the dynamics of signals propagated over the paths. This is particularly true for the 802.11 family of WLANs, since, for one thing, they operate in unlicensed bands, where other user signals and interference sources (such as microwave ovens) can be operating simultaneously with our system. In addition to the noted possibility of interference, important factors are multipath effects and path loss characteristics.

2.2.7.2 Multipah Eeffects

Multipath is a major concern for WLANs installed in indoor locations, but it can also be a problem in some outdoor settings, depending upon the physical surroundings. Multipath effects occur when a direct signal path, say client to access point, is combined with multiple reflected signal paths. The multiple appearances of the signal are superimposed and due to the various phase relationships among the signals, the composite received signal is subject to amplitude and phase variations. This generally degrades performance relative to an ideal steady-signal case. The relative delay between the direct signal path and a reflected signal path is called delay spread. Delay spread is the parameter commonly used to the extent of multipath time dispersion in a given setting. [Pah95] Observed indoor delay spreads will typically be different installation settings, the larger the room or building dimensions, the greater the multipath delay spread. Some typical delay spreads are shown in the Table 2.3 below.

Table 2.3: Typical Indoor Multipath Delay Spreads

Environment	**Delay Spread**
Home	< 50 nsec
Office	~ 100 nsec
Factory Floor	200-300 nsec

Contributors to the delay spread include furniture, metal doors and door frames, walls, shelving and machinery*, etc*. The critical determinant for assessing the potential degree of impairment to link performance is the ratio of the delay spread to a signaling element in the link transmission. For example, for an RMS delay spread of 100 nanoseconds, the time-dispersed portion of the received signal is about one half the duration of an 8-chip CCK code word. Multipath causes the energy transmitted in one signal element to interfere with adjacent neighbor signal elements, an effect known as intersymbol interference (ISI). In a DSSS system, where a channel symbol is transmitted as a sequence of “chips,” we can also speak about intersymbol interference (ISI).

The principal techniques for dealing with the effects of multipath are RAKE receivers and adaptive equalizers. Broadly speaking, RAKE receivers are typically used where there is ICI, but the delay spread is not substantial relative to the symbol duration. In situations where there is ISI, adaptive equalizers are typically used [IEEE][Pro01].

2.2.7.3 Path Loss

Another key factor in assessing WLAN performance is signal coverage range relative to path loss. This is a key element in determining signal coverage, and positioning of WLAN access points where an extended area of operation is needed. Path loss calculations are also important in determining radio receiver sensitivity, transmit power level, and received signal-to-noise ratio (SNR). In transmission of a radio signal, the signal power is attenuated (ideal free-space model) as the square of distance from the transmitter. As the receiver moves away from the transmitter, the received signal power decreases until it reaches the receiver noise floor, at which point the received bit error rate becomes unacceptable. For indoor WLAN links beyond about 20 feet, path loss decreases at a rate around 30 dB per 100 feet. This is due to the aggregate attenuation by walls, ceilings, furniture, *etc*., in the WLAN coverage area. A good estimate useful at the 2.4 GHz ISM band is that each sheet rock wall typically attenuates the signal by 6 dB and a cement block wall attenuates by about 4 dB. However, in the 5 GHz region, additional path losses of as much as 5 to 10 dB may be observed, resulting in shrinking of the signal coverage radius. Additional path losses can occur as a result of multipath fading, discussed in the next paragraph. The principles of path-loss modeling for wireless networks are treated in detail in [Pah95] and [Pah02].

2.2.7.4 Multipath Fading

Another important source of signal power loss is multipath fading. Multipath fading occurs when the multiple reflected signals arriving at a receiving point are changing with time, perhaps due to movement of a client node or movements of objects or people in the vicinity of the transmitter-to-receiver path. The result is that the composite of the signals arriving at the receiver undergoes temporal fluctuations, commonly called multipath fading. The statistical variation in received signal strength degrades the link performance (e. g. bit error rate vs. SNR). Multipath is a long-known and well-understood characteristic of long-range radio transmission and microwave line-of-sight transmission, and the same underlying principles apply to WLAN signal transmission as well. With respect to 802.11-based WLANs, it is now generally accepted that signal coverage ranges observed in actual installations often fail to meet the manufacturers' installation guidelines, and in many such cases, the coverage shortfall is due to the effects of multipath fading.

2.2.7.5 In-Building Penetration

If MCIT is to consider the use of Wi-Fi in multi-unit residential buildings and mid- and small-business locations, it will be necessary to deal with the issues of in-building signal penetration and propagation characteristics within buildings. In recent years, a considerable amount of research and experimentation has been devoted to these issues, and useful results are available in the literature [Pah95] [Rap02]. For example [Rap02] provides an extensive compilation of path loss for a wide range of building materials and items commonly found in office and manufacturing environments. This body of published data can provide a starting point for planning pilot trials of WLAN systems of the sort mentioned above.

2.2.8 Performance Comparisons

2.2.8.1 Signal Ranges and Data Rates

As stated in an earlier paragraph, the 802.11-based standards each provide multiple data rates, and the protocol will allow the automatic selection of the best rate for reliable operation of the link. Thus, as the distance between the access point and the client increases, the link data rate will be reduced as needed to maintain connectivity.

Because the 802.11g standard and the 802.11b standard operate in the same 2.4 GHz band, and hence share the same path loss characteristics (earlier discussion), we should expect that at longer path lengths, where the lower data rates are invoked, the two standards should exhibit about the same data rate vs. range characteristics. This can in fact be observed in Figure 2.1 below, which shows expected data rates vs. distance from an access point for the three 802.11 standards. The figure is based upon ideal steady-signal assumptions [Bcom].

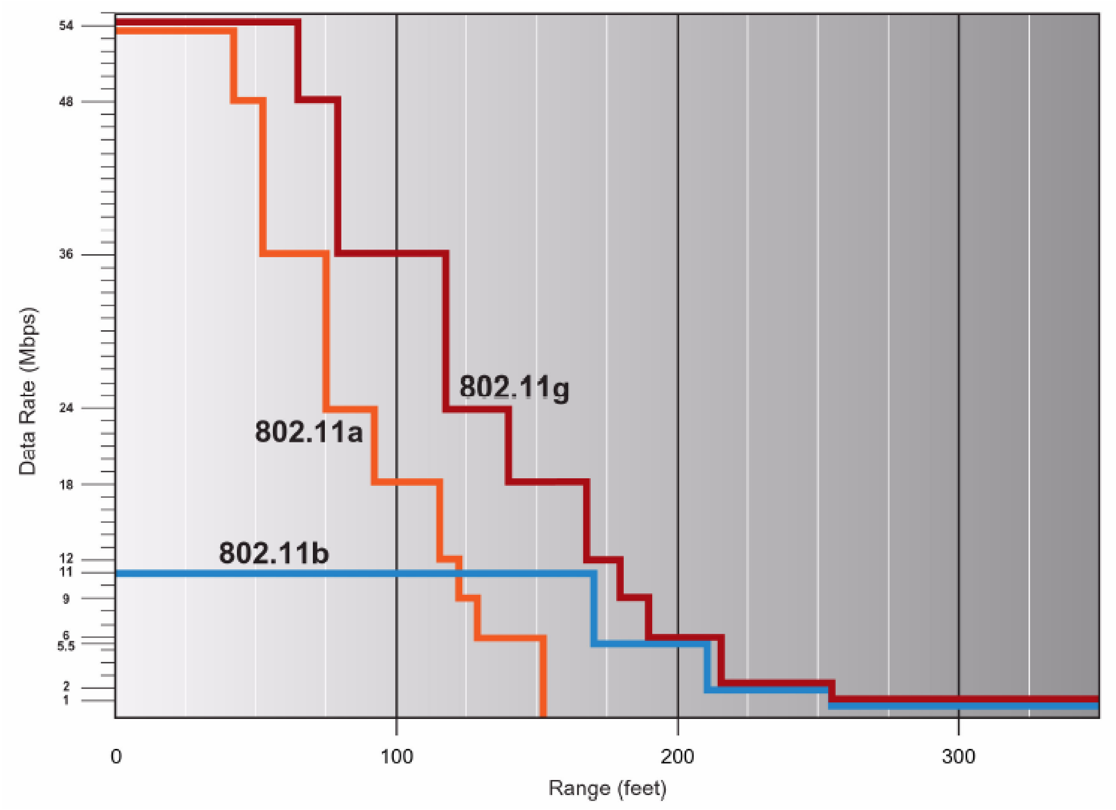

Figure 2.1: Predicted 802.11a, 802.11b & 802.11g Rates vs Distance from Access Point

We can see from the Figure 2.1 that the maximum signal range for 802.11b and 802.11g are in the vicinity of 250 to 300 feet, the latter number being the range limit commonly quoted for these standards. At short ranges, the 802.11g standard of course provides the higher data rates, but because 802.11b has a more limited range of rates available, it cannot take advantage of better signal quality on short paths. It is important to mention that rate-range measurements that have been made in actual WLAN installation setting have shown range reductions of about 50 per cent from these ideal characteristics.

The figure includes the rate-range characteristic for 802.11a, where we see that the maximum range is limited to about half that achievable with 802.11b and 802.11g, owing to the greater path loss experienced at 5 GHz. It is also important to note that each of the 802.11b and 802.11g performance curves pertains, respectively, to an 802.11b-only or 802.11g-only connection, and neither curve pertains to the mixed case of b/g interoperation.

2.2.8.2 Data Rate Definitions

In examining such data rate and range figures as these, it is important to understand how the data rates are defined. The IEEE 802.11 standard defines data rate in terms of **available bit rate**, or simply **data rate**. (The vertical scale in the rate-range figure shown above is to be interpreted as available bit rate.) This rate is be distinguished from a lower value called the **aggregate data throughput rate**. This throughput rate takes into account the overhead associated with the protocol frame structure, collisions, and implementation delays associated with processing of protocol frames.

Calculating the aggregate throughput can be a tedious process, but fortunately the IEEE provides useful guidelines: "A good rule of thumb for estimating the average aggregate throughput of an IEEE 802.11 wireless network is 75 % of the data rate for DCF operation, and 85 % of the data rate for PCF." [IEEE] [NB: DCF = Distribute Coordination Function, and PCF = Point Coordination Function. These are the two coordination options available in the MAC layer of 802.11. DCF is contention-based, while PCF is contention-free. Controlled coordination yields higher throughput.]

2.2.8.3 802.11b and 802.11g Network Considerations

As discussed earlier, the IEEE 802.11g standard is structured to provide for interoperability with 802.11b devices. At all 802.11b rates, 802.11b devices communicate with 802.11g products as if they were 802.11b products. However, 802.11g products behave differently when using OFDM data rates if there are 802.11b devices in the network environment. It is important to understand these distinctions if mixed b/g networks are to be deployed. This will be less of an issue in Greenfield situations, where build-out can be implemented solely with 802.11g products. We should also note that the presence of an 802.11a 5-GHz network has no effect on these scenarios, given the frequency separation. Here we briefly discuss a few scenarios to show how the type of network environment is determined both by the network infrastructure and client devices [Bcom]

802.11b-only network

When the WLAN access point and all clients are 802.11b devices, communication occurs at 802.11b data rates. Overhead communication between the devices effectively limits the maximum TCP (transport layer) throughput to 5.8 Mbps. [NB: This is somewhat more than half the maximum data rate indicated for 802.11b in the figure shown earlier, due to the factors already discussed.] When the devices are communicating at greater distances the throughput decreases with increasing range, as we have observed.

802.11g –only network

The throughput of 802.11g networks can depend on whether there are 802.11b devices operating nearby. Performance is best in environments where an 802.11g access point is communicating only with 802.11g clients in a homogeneous WLAN. In these environments, the data rate within 75 feet is 54 Mbps and the throughput is 22–24 Mbps when using Transmission Control Protocol (TCP). In the interest of maximizing performance in the presence of 802.11b devices, the 802.11g access points coordinate the use of the transmission medium with protection mechanisms specified in the 802.11g standard. Because the protection mechanisms require overhead communication, compatibility is provided at the expense of throughput. The CTS-to-self protection mechanism lowers the maximum TCP throughput (at transport layer) to approximately 15 Mbps, as shown in the Table 2.4.

Table 2.4: Expected Maximum Throughput (Mbps) for IEEE 802.11 Environments

Distance (feet)	**802.11b only**	**802.11a**	**802.11g only**	**802.11g Mixed, with CTS-to-self**	**802.11g Mixed, with RTS/CTS**
10	5.8	24.7	24.7	14.7	11.8
50	5.8	19.8	24.7	14.7	11.8
100	5.8	12.4	19.8	12.7	10.6
150	5.8	4.9	12.4	9.1	8.0
200	3.7	0	4.9	4.2	4.1
250	1.6	0	1.6	1.6	1.6
300	0.9	0	0.9	0.9	0.9

The notations "CTS-to-self" and "RTS/CTS" refer to protocol options available in the MAC layer of 802.11. Detailed descriptions of 802.11 MAC layer functionality can be found in the IEEE handbook [IEEE] and the textbook by Geier [Gei99].

802.11g access point with mixed clients

Let us briefly consider mixed b/g cases, starting with the case in which the access point is a 802.11g device and there is a mixture of 802.11g clients and 802.11b clients on the network. Here the access point senses that both technologies on the network. The 802.11g access point then instructs 802.11g clients to use a protection mechanism (the 802.11g standard specifies several). Effectively, 802.11g clients function at reduced 802.11g TCP throughput (up to 15 Mbps), which is faster than the 802.11b client that communicates at a maximum (aggregate) throughput of up to 5.8 Mbps.

802.11b access point, 802.11g client

When the access point is a 802.11b device and the client is an 802.11g device, the 802.11g client is able to successfully associate and communicate with the 802.11b access point. Communication between the 802.11b access point and the 802.11g client uses CCK modulation and achieves typical 802.11b speeds. An 802.11g client can always function as an 802.11b client.

Multiple 802.11g clients with mixed clients

When there are multiple 802.11g access points and a single 802.11b client on the same channel, all overlapping 802.11g access points signal the use of the protection mechanism. Effectively, 802.11g clients function at a reduced 802.11g TCP aggregate throughput (up to 15 Mbps), which is faster than the 802.11b client, which communicates at a typical 802.11b TCP throughput (up to 5.8 Mbps). The access points can also be configured to use different channels for their 802.11g clients so that the 802.11g-only networks do not need to use a protection mechanism. This allows 802.11g clients to have full TCP throughput as if they were in an 802.11g-only network.

2.3 WI-FI STATUS

2.3.1 Overview

While worldwide growth of PWLAN business has been impressive, the patterns of growth have been very different from one region of the world to another. In the US, the market is still in early stages of development, and the service provider business models are very much in evolution.

The US market, now serving about 30,000 customers, has placed initial emphasis on wireless Internet access in public commercial locations, such as coffee shops, restaurants, retail malls, and college campuses. New companies continue to enter the market mix, but, generally speaking, these businesses have not been profitable to date. The patchwork nature of the US market, with spotty geographic coverage, non-standard and sometimes complicated service-access procedures, has produced a discernable move toward integration of service providers through wholesaling, roaming and customer-service alliances, and the emergence of **hotspot aggregators** and **Managed WISPs**. Also, a few wireline and wireless carriers are beginning to offer hotspot access service as service enhancements for their legacy Internet access customers. (Customer-retention strategies are likely also at work here.) Some industry observers predict that the wireline operators will have increasing influence on the eventual landscape of hotspot deployments. At this writing, it is fair to say that the US PWLAN market is still in it infancy with business models, industry alignments, and marketing and pricing strategies in a state of evolution.

In contrast with the US market, the **Asia/Pacific** region includes some of the fastest-growing markets for PWLAN service, with **Korea** distinctly in the lead. For example, Korea Telecom is the world's largest operator of PWLANs, as measured by deployed hotspots. This parallels Korea's well-known enthusiasm for new adoption of new technologies and services. In Korea, we can see that the wireline operators are promoting the use of wireless access as a way of increasing usage of their DSL facilities. In Japan, the incumbent wireline operator appears to be targeting general customers with its hotspot services. In South Korea and Japan, the future for the PWLAN business is considered uncertain in view of the wide array of high-speed network access technologies already available to customers, including cellular technologies.

In **Australia**, it has been the ISPs who have taken the lead in PWLAN services, while wireless operators have been emphasizing their cellular service businesses thus far. However, incumbent Telestra has joined other nations in the region in forming an alliance for roaming and other service enhancements, called the WLAN Union. The region has also seen differences in regulatory approaches to the emerging PWLAN service business. In Singapore, regulators have been very helpful in facilitating the development of the industry. India, in contrast, has a schedule of licensing fees and import duties, which to date have made WLAN deployments very costly, and the licensing delays, are unduly long as well.

Western Europe, with the exception of the **Nordic** countries, has experienced relatively slow deployment of PWLAN services. Thus far, the lead has been taken by specialized WLAN access providers, and there has been relatively little movement toward formation of roaming agreements among providers. However, in 2003, some initiatives toward multi-national consolidation has been seen, including acquisitions by Swisscom. There has also been some movement toward bundling WLAN access with other communications services, including GSM service. Some trends toward liberalization of frequency regulation are being observed. In the Nordic countries, the national mobile telephone operators have led the deployment of PWLAN services

In all geographic regions, the factors limiting the growth of PWLAN markets are at least similar and even identical in some instances. The limited signal range for 802.11- based connectivity means that hotspot footprints are relatively small (<300 ft.) and thus signal coverage is far from seamless. This parallels the early days of cellular deployment, when dead zones in signal coverage led to customer dissatisfaction with the quality of service. Thus the cellular industry had to place early priority on geographic coverage in the engineering of their networks. Furthermore, the expectation of customers for greater mobility led soon to the establishment of roaming agreements among cellular providers, billing and payment reconciliation being handled by separate service bureaus. One can see similar trends in the PWLAN service industry, and industry observers estimate that in the next several years, emphasis will be placed on expansion of access footprint areas, and the formation of agreements and alliances for roaming, harmonization of access procedures, authentication, billing, *etc*. It may well be that the incumbent wireline and wireless operators will play the dominant role in this phase of PWLAN consolidation, given the ubiquity of their backbone networks and their experience and in-place infrastructure for back-office customer support.

Another issue for deployment of PWLANs with large continuous footprints is cost. Because of the limited signal propagation range of 802-11 signals, the cost for covering completely a particular geographic area is likely to be significantly greater than coverage of the same area with, e. g., a cellular network. In this regard, the incumbent wireline and cellular networks, with their already-embedded infrastructure, may provide the basis for build-out of PWLAN services.

2.3.2 Wi-Fi in Egypt

Several important technical issues remain in the way of wide-scale deployment of PWLAN service in Egypt. One is the problem of inadequate infrastructure for backhaul of broadband traffic. It appears that in the wired network, there has been rather limited progress in deployment of DSL, a leading candidate for broadband backhaul. In the existing cellular networks, there has not been evidence of migration to 3G services (which could provide the needed backhaul infrastructure). A second and very important issue for Egypt is the limited signal penetration capability for 802.11- based wireless transmission. This second issue becomes critical in considering Wi-Fi for broadband access from PCs located within buildings constructed with masonry materials. This signal penetration problem, in turn, leads us to examine the new IEEE 802.16 standard and related industry initiative called WiMAX.

Wi-Fi or 802.11 is currently in a trial phase by a couple of service providers in Egypt. To our knowledge, no service provider has any plans yet to deploy this. ***Cairo airport + hotel***

2.3.3 Wi-Fi in Other Countries

While worldwide growth of Wi-Fi business has been impressive, the patterns of growth have been very different from one region of the world to another.

While the US emphasis on Wi-Fi access for mobile and nomadic users does not transfer directly to MCIT's emphasis on in-place business and residential users, the evolution of the US market will yield important insights as to challenges to be faced with respect to infrastructure ownership and costs, customer-support costs, service pricing, and profitability.

2.3.4 Where is the Wi-Fi Market Headed?

The worldwide market for PWLAN services must be regarded as still in an early phase of development, with business models shifting in ways that echo, to some degree, the early days of the cellular telephone industry and the wireless data business.

The "lessons of history" in the wireless data business may provide a useful guide to understanding the Wi-Fi service business, where business models are very much in a state of evolution. Early wireless data services (Ardis, Ram/Mobitex, CDPD) originated as specialized services including (Ardis and Ram) dedicated data-service networks, and those business did not fare well as they tried to expand. Service price resistance was considerable, and geographic coverage was inadequate for many prospective customers. When the specialized providers tried to expand, they did not have the needed capital, and these businesses were simply absorbed into established cellular companies. At the same time, the cellular industry moved ahead with standardizing and deploying cellular-based data bearer services. (In the US, the cellular data business is still regarded as disappointing, and higher-rate 3G services are looked to as the needed stimulant for producing growth.)

The "lessons of history" with respect to the cellular business are similar. Early customers were typically dissatisfied with dead zones in signal coverage and this led to customer dissatisfaction with the quality of service. Thus the cellular industry had to place early priority on geographic coverage in the engineering of their networks. Furthermore, the expectation of customers for greater mobility led soon to the establishment of roaming agreements among cellular providers, billing and payment reconciliation being handled by separate service bureaus.

One can see similar trends in the PWLAN service industry, and industry observers estimate that in the next several years, emphasis will be placed on expansion of access footprint areas, and the formation of agreements and alliances for roaming, harmonization of access procedures, authentication, billing, *etc*.

It may well be that the incumbent wireline and wireless operators will play the dominant role in this phase of PWLAN consolidation, given the ubiquity of their backbone networks and their experience and in-place infrastructure for back-office customer support.

Another issue for deployment of PWLAN s with large continuous footprints is cost. Because of the limited signal propagation range of 802-11 signals, the cost for covering completely a particular geographic area is likely to be significantly greater than coverage of the same area with, e. g., a cellular network. In this regard, the incumbent wireline and cellular networks, with their already-embedded infrastructure, may provide the basis for build-out of PWLAN services.

The next several years are likely to see emphasis placed on (a) widening and filling-in of Wi-Fi service footprints, (b) business consolidation moves, ranging from roaming agreements to unified service branding to absorption of Wi-Fi operators into TELCOs and cellular service companies.

As cellular operators in some geographic regions roll out 3G services, the Wi-Fi access providers will likely face direct competition from high-speed 3G data service offerings. (This parallels the history of digital cellular data services as direct competition to specialized mobile data services.)

2.3.5 Regulatory Issues

At this early stage of evolution of the market, there is considerable variation in the regulatory approaches taken with respect to WLAN products and network operations. In this section we briefly discuss the rationale for regulation and make some observations regarding regulation for Wi-Fi.

Since the early days of its development, the telecommunications industry has been accustomed to government regulation. In the domain of radio or wireless communications, regulation is embodied in spectrum management policy. One can identify two fundamental rationales for spectrum management policy. (Admittedly, this is a very simplified view, but it is useful in the consideration of broadband wireless communications.) The first rationale is that spectrum is a scarce commodity that must be allocated appropriately among various commercial, military, and public safety uses. Coupled with allocation policy is the need for "fair" assignment of portions of spectrum to various users or groups of users. Of course, the spectrum allocation issue is largely dependent upon the laws of physics (simplifying again) governing signal propagation characteristics in various frequency bands. The issue of spectrum assignment is usually in terms of "licensed" versus "unlicensed" use, and there are a number of variations of licensed and unlicensed models of spectrum usage.

Of course, most regions of the radio spectrum are licensed by means of "exclusive" licenses held by radio and TV broadcasters, cellular system operators, military organizations, and public safety agencies, to name prominent examples. In some allocated frequency bands, such as the amateur radio bands, multiple licensed users can share use of a band, with certain restrictions on transmissions and types of communication. Along with spectrum allocations and assignments as just outlined, regulatory agencies also impose technical restrictions, such as spectral masks, and adjacent-channel interference levels, on transmitted signals in order to control interference among users of neighboring bands or channels. The situation is very different for "unlicensed" operation.

2.3.5.1 The Unlicensed Environment in the US

The Industrial, Scientific and Industrial (ISM) bands (902-928 MHz, 2400-2483 MZ, and 5725-5875 MHz) are allocated (in the US and many other countries) for unlicensed operation of specified categories of devices, including industrial microwave ovens, cordless telephones, and communications transmitters such as Wi-Fi using spread-spectrum signaling. Communication systems operate in these bands with the known risk that they may be subject to interference from other transmitters or from other allowed non-communication devices. In the context of ISM bands, "unlicensed" does not mean "purely unregulated." That is, in the administration of these bands in most countries, there is no service-provider licensing or user licensing (as in the case of Amateur Radio), but instead the regulatory function takes the form of product certification. That is, as applied in the US at least, before a manufacturer can offer a communications product for sale, it must be certified for conformance to regulations on transmitted power level and on spectrum spreading, thereby putting some limits on the potential for interference among multiple equipments operating in the same band.

In the US, this approach of product certification is regarded as having worked very successfully with respect to WLAN products. The power limitations (under FCC Part 15 rules) have worked very effectively to permit operation of WLANs, free of interference, with reasonable numbers of users in settings where these networks have proved to be most useful – offices, factories, warehouses, college campuses, *etc*. The prescribed power limitations of course limit the signal range, but the achievable signal ranges have been adequate for the typical installations, most often inside buildings. At the same time, the typical in-building installations of WLANs have had the benefit of "containing" transmitted signals, further lessening the likelihood of interference with WLANs in neighboring areas.

The emergence of public WLANs, utilizing Wi-Fi hotspots in retail venues and other public areas, has provided experience with non-traditional settings, but thus far there has been no evidence of significant observed interference either into Wi-Fi networks or caused by Wi-Fi transmissions.

It has been clear to observers in the US that the availability of free, unlicensed spectrum has been a major ingredient in the growth of hotspot installations. With freedom from having to purchase spectrum or to deal with licensing applications and approvals, together with the relatively low cost of Wi-Fi access equipment, many independent Wi-Fi operators have been able to quickly establish Wi-Fi access businesses. (It should be noted that these same advantages have made it possible for many in the US to install access points for "free" Wi-Fi connectivity in their neighborhoods, public parks, *etc*. Notable examples include NYCwireless, a non-profit volunteer organization in New York City that has installed free public hotspots in several of the city's parks [3]. Other similar free public access networks have been established in San Francisco CA, Seattle WA, and Portland OR. In Athens GA, the University of Georgia has funded a network of Wi-Fi hotspots covering the entire downtown area.

Clearly, in the US, freedom from spectrum licensing has enabled rapid formation of Wi-Fi service provider companies, as well as public community-access services, and now the increasingly common inclusion of Wi-Fi capability in laptops and PDAs. One also sees in the US a proliferation of home-networking use of Wi-Fi hubs and often-innovative applications of Wi-Fi technology, including networking of home entertainment devices with computers.

The product-certification approach taken by the FCC has also encouraged other innovative applications of unlicensed-band wireless technology. For example, Loudoun County in the mountainous northern region of the State of Virginia is the site of a new business venture to implement a wireless network providing Internet access to a few hundred rural households and a number of small businesses, using only unlicensed spectrum. The network, called Roadstar, uses a number of point-to-point links for the long legs of the network, and Wi-Fi access points to subscribers. The long-distance point-to-point links operate at 5 GHz, and have become fairly standard in the US for rural Wireless Internet Service Providers (WISPs) serving larger population "pockets." The FCC rules under Part 15 allow operators to provision point-to-point links at 5.725-5.825 GHz using narrow-beam transmissions without having to reduce transmitter output power. The Roadstar networks makes the last-mile connections within neighborhoods using Wi-Fi access points modified with sectorized high-gain antennas. These last-mile links operate in the 2.4 GHz band and with careful link engineering reach as far as two to three miles. We emphasize again that this innovative network design and many others like it in the US operate in an unlicensed manner simply with conformance to the FCC Part 15 rules [4].

The successful exploitation of unlicensed spectrum under product-certification rules in the US has prompted the FCC to examine the possibility of allowing unlicensed operation in additional frequency bands. The expressed view of the FCC is that such reforms of spectrum regulation policy can provide stimulus for further technology innovations. Thus many observers in the US see a definite trend toward greater use of unlicensed spectrum.

One might well conjecture that some of the technical innovations being developed for WiFi networks, such as designs for range-extension, might create new possibilities for interference between networks. However, there are other developments underway, some grouped under the heading of "smart receiver" techniques, that promise to make networks less vulnerable to sources of interference. On balance, it seems reasonable to project that spectrum regulatory policy will continue to move in the direction of greater reliance on unlicensed spectrum usage.

2.3.5.2 Regulation in Other Countries

Other regions of the world have seen differences in regulatory approaches to the use of WI-FI networks. In Singapore, regulators have been very helpful in facilitating the development of the industry. India, in contrast, has a schedule of licensing fees and import duties, which to date has made WLAN deployments very costly, and the licensing delays are unduly long as well.

At a more detailed level, we see some differences in the ways in which different countries regulate the separate bands used in Wi-Fi networks. In many countries, for example, Wi-Fi has been restricted to private use, though allowance of public access networks is becoming more common. In 2003, the government of India de-licensed the 2.4 GHz band, and this has encouraged companies to move ahead with hotspot deployments.

France, in late 2002, liberalized its spectrum regulations to allow public WLAN services to operate in the 2.4 GHz band. Their policy also allows WLAN equipment to be connected to existing public networks without government authorization. In a spirit similar to that of US FCC Part 15 rules, France's regulations specify limits on maximum radiated power, 100mW for indoor operation and 100 mW or 10 mW for outdoor operation, for the lower and upper halves, respectively, of the 2.4 GHz band [5]. Use of the 5 GHz band is at this time restricted to indoor use.

Some European countries require licenses for operation of public WLANs, and a few countries prohibit operation of public WLANs altogether.

In Egypt, the issues of service and product licensing as well as spectrum regulation are under study. Given that Egypt has thus far witnessed only limited introduction of Wi-Fi, we recommend that NTRA take a posture of minimum regulation with respect to the deployment of Wi-Fi access services. We suggest that NTRA follow the lead of the US and address Wi-Fi from a product-certification approach, for products operating in ISM bands. The rollout of Wi-Fi services should be encouraged by the issuance of experimental licenses to interested business entities. Given the very limited use of Wi-Fi in the country at this time, there appears to be no good reason for making distinctions between indoor and outdoor uses of Wi-Fi bands.

2.3.6 Evolving Business Models

Business models for commercial Wi-Fi service providers will continue to evolve for the next several years. The business models currently emerging are categorized below. However, it is important to understand that the Wi-Fi business is still very much in a state of flux, and the landscape is changing week by week.

Independent retail hotspot operator: This is the model with which the commercial Wi-Fi service business started. The operator can establish a service business with relatively little investment in access equipment, entering into an agreement with the site property owner, and arranging for backhaul (such as DSL) and the Internet access that will be used by end users visiting the site. There can be any of a variety financial arrangements with the property owner, ranging from a fixed annual fee to an income-sharing arrangement based on usage. Here, the operator seeks to generate revenue significantly above his fixed costs, and thus the profitability of each service site depends strongly upon customer traffic flow and usage session patterns. In this model, the Wi-Fi operator "owns" the customer, and is responsible for customer acquisition and support, and billing. Of course, billing might be handled by a separate service bureau. The hotspot operator might form direct partnerships with other operators, accepting access by each partner's own customers, with some revenue-sharing arrangement.

Wholesaler/Retailer model: This is the business model that rapidly evolved in the Wi-Fi service business, as independent hotspot operators found that customers were dissatisfied with the limitations of being "tied" to a single service provider. (This was analogous to the early days of ATM machines, when a customer could use no ATM machines other than those belonging to his or her bank.) In the wholesale/retail model, a *hotspot aggregator* makes wholesale access agreements with multiple hotspot operators, aggregating their hot spots into a single network that provides roaming and makes the service appears seamless to the end user. The aggregator pays wholesale connect fees to the hotspot operators, based on user access. At the same time, the aggregator/wholesaler provides a single service network to the brand-name retailer that "owns" the customer's account. The retailer *e. g*., T-Mobile, Sprint, or AT&T Wireless as an example, pays roaming provider fees for network aggregation, settlement, etc., and collects revenue from the end user.

Integrated, facilities-based service provider: The Wi-Fi business is also beginning to see some examples of a more integrated business model in which the brand-name retailer also owns hotspot facilities, still utilizing the services of aggregators to provide roaming among the retailer's own hotspots and hotspots owned by other operators. Such a brand-name retailer might be a wireless or wireline carrier, and ISP, or a cable company, for example. In integrated models such as this, the retailer/operator will typically have its expertise and experience in network management, customer support, billing, etc. to support the Wi-Fi access service.

These three business models are illustrative, and as the Wi-Fi business grows and evolves, many variations of these models will surely appear on the scene.

2.4 STRATEGY AND RECOMMENDATIONS

2.4.1 Strategy

In Infocom Technology's discussions with the Egypt broadband players, it became clear that at present there is not a significant customer demand for wireless access to Internet services. Based on our study of the growth of the hotspot markets in the US and Pacific region, it seems reasonable to conjecture that this low demand is related to the relative low usage to date of laptop computers and PDAs in Egypt. (Another issue is cost of DSL service, the wired broadband access technology of choice, addressed in an accompanying Infocom volume.) Thus we should look at the introduction of Wi-Fi services into Egypt as a Greenfield situation, and consider the Ministry's overall Broadband objectives.

In our discussions with the Ministry in wrapping up the September 20-25 interviews, MCIT defined the priorities for the introduction of Wi-Fi services, giving medium priority to provision of hotspot services for mobile laptop users and top priority to providing broadband Internet access for small and medium-size businesses and residential users, while addressing the problems of poor quality customer-premises wiring in many business and residential buildings. (It is interesting to note that these categories of applications are much the same as were being addressed by the early developers of WLAN products.) These are certainly appropriate applications for Wi-Fi technology, though important technical issues such as cost and provision of backhaul infrastructure, and in-building signal penetration, will have to be addressed.

With respect to the problem of infrastructure for backhaul of broadband traffic. It is clear that in the wired network, there has been rather limited progress in deployment of DSL, a leading candidate for broadband backhaul. Also, in the existing cellular networks, there has not been evidence of migration to 3G services (which could provide the needed backhaul infrastructure). A second and very important issue for Egypt is the limited signal penetration capability for 802.11-based wireless transmission. This second issue becomes critical in considering Wi-Fi for broadband access from PCs located within buildings constructed with masonry materials. This signal penetration problem, suggests examination in a later phase of this study of on-going research and development of range-extension techniques, as well as the new IEEE 802.16 standard and related industry initiative called WiMAX.

2.4.2 First Steps for Egypt

With respect to the introduction of Wi-Fi technology as part of the Broadband Strategy for Egypt, we recommend:

- MCIT sponsors a Wi-Fi access pilot trial in a medium-size business office setting in Cairo. The physical arrangement of the trial site should be chosen to provide useful experience as to access point installation, in-building signal penetration, backhaul provisioning, *etc*. (An alternative venue might be a large apartment house, though this might not provide a sufficient degree of variability in user traffic rates, session times, *etc*.).
- MCIT considers fielding another pilot trial in a setting likely to exhibit greater mobility of users, for example, on a university campus. Such a trial will enable assessment of such issues as signal coverage in a combination of indoor and outdoor user locations, signal range, shadowing, *etc*. This will also provide the advantage of

gathering information on experience of a population of users that are especially technically knowledgeable.

- NTRA to issue experimental licenses to provision and operate these trials and any additional pilot deployments as they see fit. NTRA should require that Wi-Fi products employed in Egypt have been certified for 802.11x conformance and for interoperability, by the international Wi-Fi Alliance.
- In anticipation of eventual fuller deployments of Wi-Fi equipment and services, we recommend that NTRA undertake deliberations aimed at structuring a "minimum regulation" posture with respect to Wi-Fi technology. These deliberations should encompass detailed examination of experiences to date in the US, Asia/Pacific Region, and other regions where minimum regulatory policies have been followed. A product-certification policy, based on the US FCC model is suggested.
- We also recommend MCIT initiate a study of WiMax (802.16) technology for application in Egypt. The study should encompass not only the use of WiMax as an adjunct to Wi-Fi technology (*e. g.*, as an element of backhaul), but also as an alternative to Wi-Fi for broadband wireless access at distances greater than can be supported by Wi-Fi. We also recommend undertaking a study of on-going research and development of range-extension techniques for Wi-Fi.

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2.6 GLOSSARY

CCK	Complementary Code Keying
CSMA/CA	Carrier-Sense Multiple Access with Collision Avoidance
CTS	Clear to Send
DCF	Distributed Coordination Function,
DSL	Digital Subscriber Line
DSSS	Direct Sequence Spread Spectrum
ETSI	European Technical Standards Institute
GMSK	Gaussian Minimum Shift Keying
HIPERLAN	High Performance Radio Local Area Network
ICI	Interchip Interference
ISI	Intersymbol Interference
ISM	Industrial, Scientific and Medical
ISP	Internet Service Provider
MAC	Medium Access Control
MAN	Metropolitan Area Network
OFDM	.Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PBCC	Packet Binary Convolutional Coding
PCF	Point Coordination Function
PDA	Personal Digital Assistants
PDA	Personal Data Assistant
PWLAN	Public WLAN
PWLAN	Public Wireless Local Area Network
QOS	Quality of Service
RMS	Root Mean Square

RTS/CTS	Request to Send / Clear to Send
TCP	Transmission Control Protocol
TELCO	Telephone Company
TPC	Transmission Power Control
NTRA	National Telecommunications Regulatory Authority
VoIP	Voice over IP
WEP	Wireless Equivalent Privacy
Wi-Fi	Wireless Fidelity
WiMAX	World Wide Interoperability for Microwave Access
WiMAX	Worldwide Interoperability of Microwave Access
WISP	Wireless Internet Service Provider
WLAN	Wireless Local Area Network
WLL	Wireless Local Loop
WMAN	Wireless Metropolitan Area Networks
WPA	Wi-Fi Protected Access
WPAN	Wireless Personal Area Network

3 Cable TV (CATV)

SUMMARY

Egypt's Ministry of Communications and Information Technology and Telecom Egypt (MCIT/TE) has embarked on developing a broadband strategy. A comprehensive broadband strategy must consider four main technologies as potential contributors: xDSL, Cable TV (CATV), Direct Broadcast Satellite (DBS), and Wi-Fi.

This chapter starts with an overview of the technological, societal, and economic trends that are necessitating broadband services across the globe. We then presents a brief survey of the CATV industry, globally, finding it in its most advanced form in North America.

We further discuss and present competitive forces of CATV visa vie other competing broadband access technologies such as xDSL, DBS, and WiFi. Though xDSL appears to be the primary vehicle for broadband in other countries such as Far Eastern countries, we conclude that CATV has enabled North America to rapidly and cost effectively offer broadband services. We also discuss some interesting trends where CATV's Hybrid Fiber Cable (HFC) architecture is strategically put above the xDSL alternatives.

We will cover the state of broadband access in South Korea, considered the most advanced in the world in this area, and present factors contributing to this leadership position. *We further present South Korea's new Next Generation Converged Network (NGcN) initiative where a new commitment is made to Hybrid Fiber Cable (HFC) architecture. This is of particular importance since South Korea has been known as a VDSL advocate, while CATV MSOs in the US has advocated HFC. This development comes at the heels of creation of Multimedia Over Cable Alliance (MoCA) were industry titans see new future for coaxial cable [26].*

We have reviewed various regulatory approaches and found one of the reasons behind CATV's success in North America has been minimal regulatory constraints, and the market driven nature of the industry. Potential regulatory framework supporting and advancing strategic broadband initiatives are also presented.

We did meet with senior executives of the following organizations in Egypt: Ministry of Communications and Information Technology (MCIT), Egyptian Radio & TV Union (ERTU), National Telecom Regulatory Authority (NTRA), and Telecom Egypt (TE). We found these executives to be enthusiastic and open minded about the prospects of a sound CATV industry policy. They further consider CATV to be a potential contributor to the country's future broadband leadership position in the region.

Based on our initial conversations in Egypt, and knowledge of the industry, we also recommend a controlled pilot of CATV services in Egypt to further analyze Egypt specific issues. We have provided a preliminary outline, along with various issues and parameters involved in conducting such a pilot, at the end of this Chapter.

3.1 INTRODUCTION

Egypt's Ministry of Communications and Information Technology and Telecom Egypt (MCIT/TE) has embarked on developing a broadband strategy. A comprehensive broadband strategy must consider four main technologies as potential contributors: xDSL, Cable TV (CATV), Direct Broadcast Satellite (DBS), and WiFi.

Future Trends

Future trends in broadband technology can be divided in four general categories: Economic, Societal, Technological, and regulatory. In the following sections we present our view of these four categories.

a) Economic

Globalization of the markets has created a need for speed in transactions and sharing of information. Advances in telecommunications and computing technologies has not only increased the capabilities of networks and computing infrastructures, but also reduced the costs of such services. This has made the concept of computing anytime/ anywhere a reality.

In turn the demands for bandwidth and therefore broadband services have multiplied. On Nov. 21, 2003, the U.S. Commerce Dept. announced yet another blowout quarter for online shopping. E-commerce sales hit $13.3 billion, rising 6.6% over the prior quarter. That outpaced the overall retail sales growth of 1.6%. Even more impressive, the online tally increased 27% year-over-year from the third quarter of 2002. While online shopping still represents only 1.5% of total retail sales today, Web retailing could grab 10% of the total pie by 2006 if current trends continue.

In the business transaction arena we have seen the same growth patterns. Companies like Dell and Cisco have improved their profitability by doing all their business on-line. This has put pressure on suppliers and trade partners to keep up. Countries and/or companies without these capabilities will be left behind.

Large corporations, a major source of foreign currency, are no longer satisfied with the availability of natural resources, low cost labor, and transportation infrastructure alone. They carefully evaluate the availability of broadband capabilities of their host countries when making investment decisions. One such example is the British company TESCO. TESCO is now offering its most advanced on-line services to the South Korean markets first. Due to the high availability of low cost broadband services, South Korean consumers can have a much better on-line shopping experience leading to TESCO's introduction of new products and services tailored to such consumers. These products and services carry higher profit margins therefore improving TESCO's competitive posture.

b) Societal

E-mail, Instant Messaging (IM), Chat rooms, and downloading of music and video have become some of the most popular applications on the Internet. There is also online banking, search for information, travel planning, and auctions, which are also rapidly growing.

A recent report by Pew Internet and American Life Project indicates that Instant Messaging has grown to 52 million users and is the most popular amongst teenagers. On line news consumption during tense international situations is also highly popular.

Figure 3.1 shows the Internet usage by age in the US. It is our opinion that these trends in usage can easily be transposed on other countries.

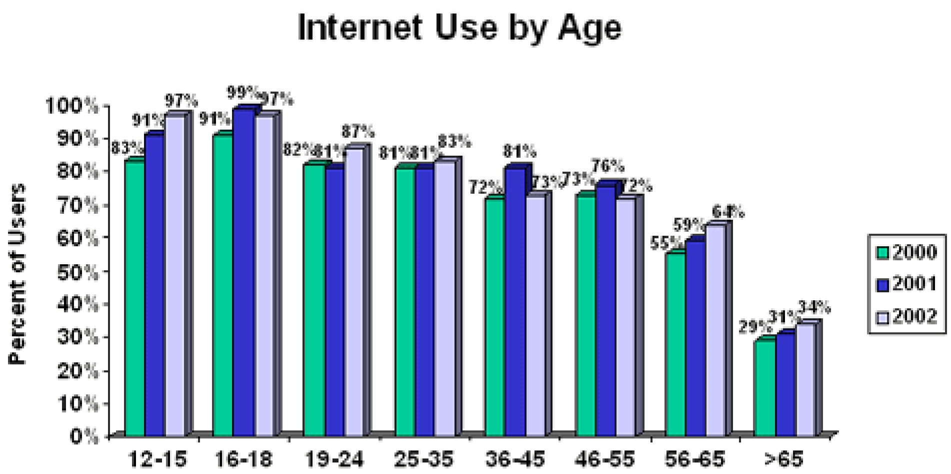

Figure 3.1: Internet Usage Trends in the US

There is also the growth in services such as TiVo in the US, which enable consumers to view their favorite programs on their schedule and not the "networks". Several CATV operators through Digital Video Recording (DVR) technologies are now offering this service.

While these new services are taking hold, socially, there are policy and regulatory challenges that must be addressed. There are currently countless court cases in the US and Europe pitting Music and entertainment industry against various service providers. These cases argue various forms of freedom against industry financial concerns.

c) Technological

The quest for higher bandwidths has created new data compression techniques and new coding and signaling algorithms. This has caused the distinctions between various technologies to fast disappear (from the end-users' point of view) and led to what is referred to as "convergence" (Figure 3.2).

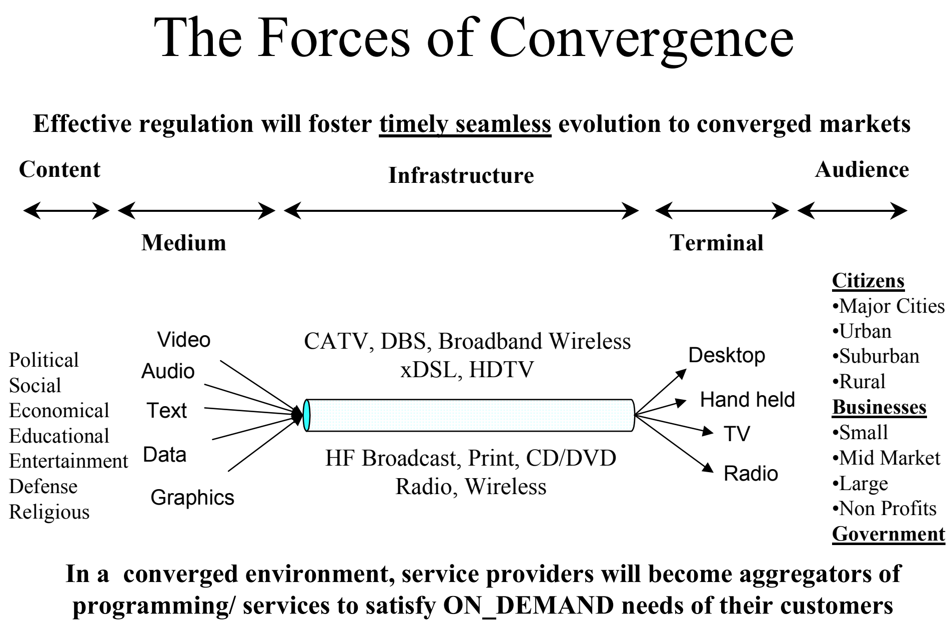

Figure 3.2: Distinction Between Various Technologies

Convergence means that it is more and more difficult to distinguish a telecommunication carrier from an MSO (CATV Operator) or a DBS operator. Convergence in network technology will create a CORE network capable of carrying multitude of voice, data, video traffic, while various access technologies will compete on price, bandwidth, reach, and service parameters. What is referred to as “Triple-Play” in the industry is now technically feasible and attainable. . The future industry leaders will be those who will aggregate various services at the most reasonable cost while meeting the market and customer needs.

Currently there is a battle between MSOs and Telcos to provide telephone services. MSOs and some third party providers are using HFC architecture to provide VoIP in direct competition with Telcos. These operators are bundling features and services, on a flat rate per month basis, for less than $40 per month. This has created a new challenge for the debt ridden Telcos in the US. Telcos are not only suffering from competition amongst themselves, but now faced with convergence operators, which further puts their very existence in question.

d) Regulatory

The trends presented in the preceding three sections, namely economic, societal, and technological are having a major impact on the regulatory frameworks around the globe. Nations are looking for new regulatory framework for this new era of telecommunications to ensure a smooth transition to new services while protecting national and public interests.

The quantum leap from the old telephone monopoly model to open, standard based internet-computer-software model requires a new thinking away from one pipe optimized for one application to multiple venues to the end users. This could include all forms of Ultra broadband technologies.

The regulatory framework must incent the free radical thinking and investments needed to build a robust alternate digital platform. The most radical paradigm shift is that the applications are independent of the delivery platforms. Gone are the days of the pre-divestiture AT&T, where by a government mandate from the 1900s the network was optimized to provide one and only one service: Voice. Gone are the days of the tight market and price controls impeding innovation to provide minimal service capabilities to all. Today's companies, such as Vonage, can create a plethora of services without owning the infrastructure. This creates competitive forces and expedites time to market opportunities not seen in previous centuries.

There are currently major deregulation efforts in progress across various developing nations. The most advance state of deregulation is seen in G8 countries, even though in countries as advanced as the US, there are major issues to be addressed and resolved. It appears that most state telecommunication monopolies will be replaced by free enterprise concerns by 2005.

It is critical to develop a broadband strategy to capitalize on the strength of various technologies while providing the best services at the most reasonable cost to the end users. From a government and regulatory perspective, it is also important to recognize convergence and develop policies to promote rapid deployment of broadband services. We will discuss this further in the Regulatory Approaches section.

One of the major issues to be addressed is unbundling, where incumbent carriers are forced to offer their networks to competitors. To make matters even more complicated there has been different treatments under these rules for Telecommunication carriers visa vies MSOs. While MSOs are free of unbundling requirements, at least for now, traditional carriers are saddled with the expense of "Equal Access". A new development is New Zealand worth noting. New England regulators have decided not to mandate unbundling for the Telecom Corp., the countries main fixed line carrier. Regulators sited lessons learned from other countries where the benefits of the legislated unbundling did not outweigh the cost (source USTA Dec. 23,03).

In the following sections we will see that South Korea, through interventionist policies, has successfully reduced the cost of broadband service while increasing the reach of such services.

This Chapter focuses on investigating the following:

- State of CATV around the globe
- Regulatory issues surrounding CATV
- Competitive aspects of CATV in a broadband access environment
- How to approach CATV as a broadband player in Egypt
- Preliminary plan for a pilot of CATV services

3.2 STATE OF CATV AROUND THE GLOBE

Below is a survey of broadband services in North America, Europe, Far East, Middle East, and Africa. A report by In-Stat/ MDR (August 2003) shows the global state of broadband subscribers (Table 3.1).

Table 3.1: Worldwide Broadband Subscribers
(Numbers in thousands; * Projected)

Technology	1999	2000	2001	2002	2003*	2004*
Cable Modem	2,345	7,200	12,605	23,119	34,310	43,459
xDSL	1,447	4,899	11,479	36,364	56,247	76,624
Fixed Wireless	145	210	556	1,117	1,970	3,103
Fiber-to-the-Home	3	10	201	505	975	1,994
Satellite (DBS)	82	88	205	380	685	1,320
Total Subscribers	**4,022**	**12,407**	**25,046**	**61,485**	**94,187**	**126,500**

Table 3.1 shows that Cable and xDSL are two technologies widely used, globally, to provide broadband services. Broadband Cable has a higher penetration in the North America whereas xDSL enjoys more popularity in the Far East. In North America the open market and minimal regulation has encouraged the private sector to invest heavily in CATV as a major competitive alternative to phone company services. In other countries the government sponsored telecommunication monopoly has seen no need to invest in technologies other than the ones needed in delivery of their Plain Old Telephone Services (POTS).

Generally speaking we found that most developing nations have relied on Direct Broadcast Satellite (DBS) for their entertainment programming needs. DBS does not offer a cost effective broadband alternative, as seen in limited penetration numbers shown in Table 3.1.

3.2.1 North America

Open competition and absence of a central planning organization has mostly contributed to a thriving CATV industry in the North America. CATV has effectively met the needs of the market for multitude of entertainment and programming needs. CATV has also successfully challenged the traditional Telecommunication companies (Regional Bell Operating Companies) in the areas of broadband services.

As of April 2003, there were 106,641,910 households with Televisions in the US. 96.6% of these households are passed by CATV networks. 67.4% of these households actually subscribe to CATV. (Source A.C. Nielsen Media Research).

Cable companies have spent upward of $75 billion dollars over the past several years to upgrade their cable plant to a Hybrid Fiber Cable (HFC) digital infrastructure. This upgrade was done to support additional services deemed strategic to the flourishing CATV presence in the US. Digital cable supports services such as Video-on-Demand (VoD), Digital Video Recording (DVR), Internet access, and Voice-over-IP (VoIP).

In the following Figures 3.3, 3.4, and 3.5, we will present three sets of statistics. It should be noted here the exponential growth shown in the growth of newly subscribed cable-based broadband services. This growth is a direct result of concise strategic planning and massive capital commitment by the cable companies.

Figure 3.3, illustrates the growth in the digital cable subscription rates. The growth in the ranks of digital cable subscribers is due to premium services offered. It is interesting to point out that these premium services cost more, yet the subscribers are willing to pay for the value they receive. This premium is not only helping the bottom line at the MSOs but also improving their competitive stance against traditional telecommunication carriers and satellite service providers.

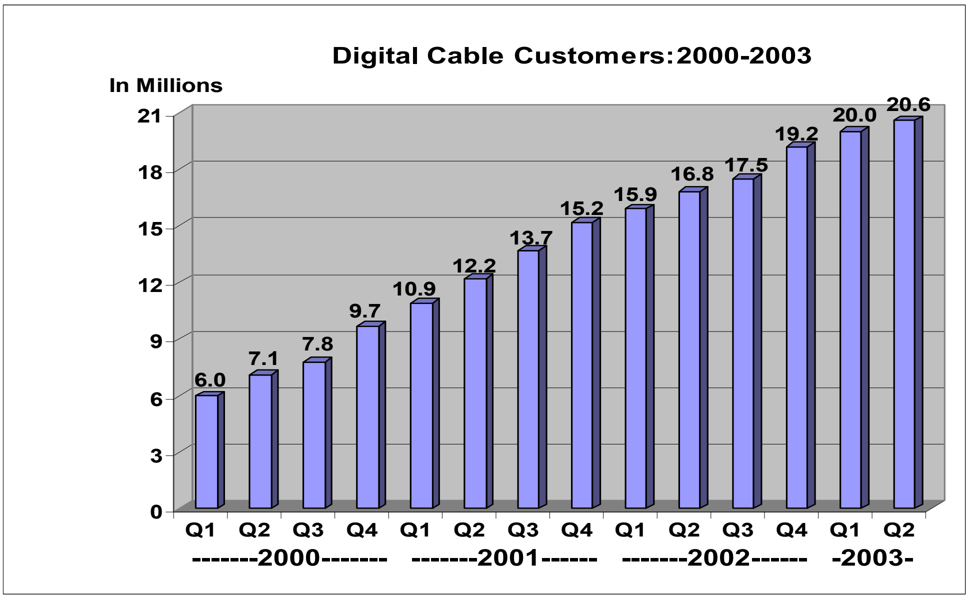

Figure 3.3: Digital Cable Customers 2000-2003
(Source NCTA, 2003)

Figure 3.4 illustrates the rate of growth in Internet access services by the cable companies. Cable companies currently have a 2 to 1 advantage over other forms of Internet access (xDSL and DBS) in the US.

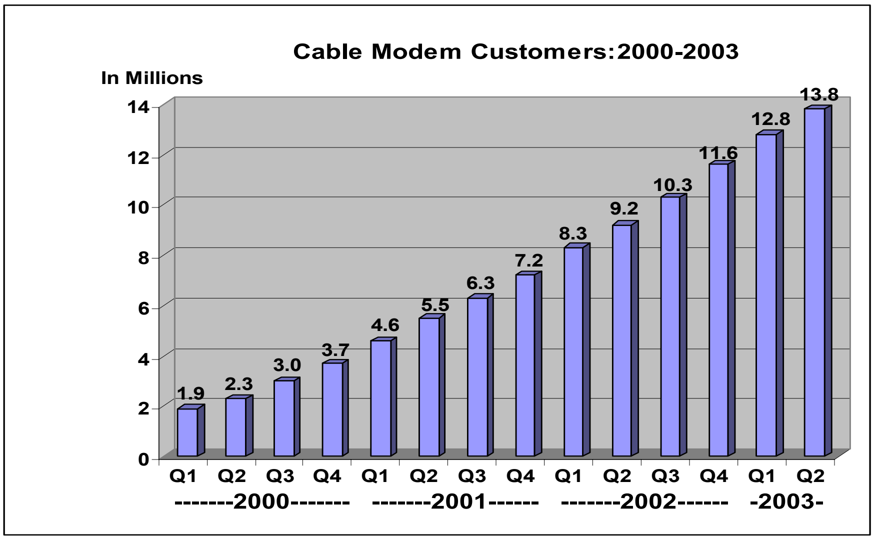

Figure 3.4: US Cable Modem Customer 2002-2003
(Source NCTA, 2003)

Subscriptions to digital cable services and Internet access have further facilitated entry into other services such as telephony. Cable telephony offers flexibility, low rates for the customers, while providing high profit margins to the MSOs. Initially MSOs tried to offer telephony services via proprietary technologies, but the soon realized that with open standard IP based technology they can have a faster market penetration. The leader in this industry, currently, is Vonage of Edison New Jersey. Vonage is providing VoIP in 47 states in the US. They are spending 35 million dollars in the next year to bring additional 3 states in the US, Canada, and several western European countries into their network. Figure 3.5, illustrates the rate of growth in Cable Telephony in the US.

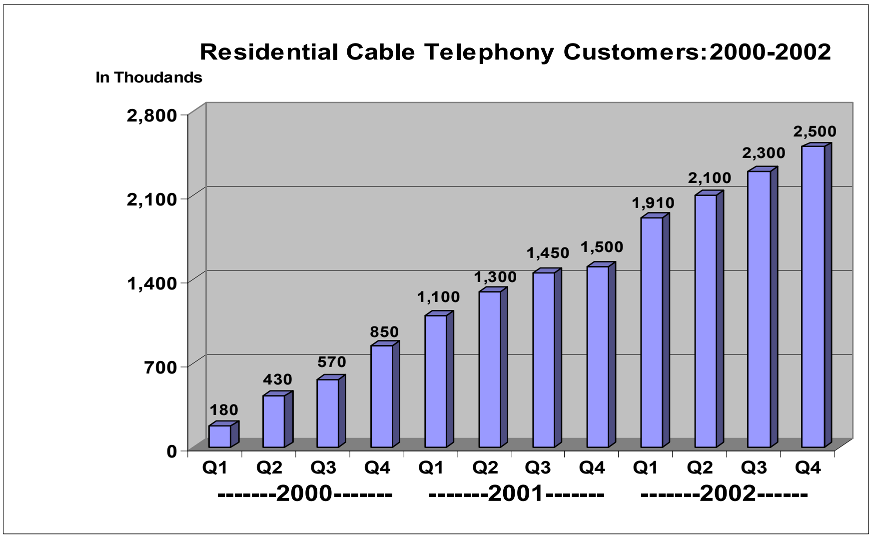

Figure 3.5: Residential Cable Telephony Customers 2000-2002
(Source NCTA, 2003)

Cable companies now hold 64% share of the broadband market vs. 36% DSL offered by the RBOCs. CATV infrastructure is now being used to offer new services such as VoIP further endangering the financial health of the traditional phone companies and eroding their market presence.

The success of CATV companies is due to several factors: one, lack of interference and burdensome regulation. Two, excellent strategic planning in converting the Cable infrastructure to two way digital capable of carrying up to 900 channels of entertainment, and additional services. Third, ability to understand the customer needs and offer pricing and service bundle options to meet those needs.

3.2.2 Latin America

Broadband service offerings are gaining momentum in Latin America [22]. Managed services that include IP-based services are the forefront of this trend, primarily to serve midsize and large businesses. Also in contention- but for consumers and micro and small businesses- are ADSL and cable modem. All these services are the underpinning of a movement to satisfy significant demand for Internet services in the region.

In Mexico and the rest of Latin America, densely populated areas and major business districts are well served with Fiber. These areas have experienced a reduction in broadband service prices.

CATV infrastructure in Latin America is very fragmented and the operators tend to be small. Large operators stepping in or consolidation amongst small operators could overcome this lack of scale.

3.2.3 Europe

Historically Europe seems to have mostly relied on state monopolies for telecommunication services and satellites and/or broadcast networks for its entertainment distribution. European markets are beginning to show the kind of appetite for variety of entertainment options we see in the North America. At the same time, the need for broadband services is being pushed by business enterprises and various government agencies. According to David Edmonds of Oftel: “in the last five years the internet has moved from the margins to the mass market, with half of all UK households and two-thirds of business now on Line” (BBC, December 11,2003). UK’s e-minister, Stephen Timms has indicated that by 2005 UK will have a broadband penetration of 100%. This has instigated a change in the way BT and its competitors operate. BT used a business model, where they converted/ upgraded exchanges deemed to be commercially viable for broadband access. The number of applications received for broadband capabilities determined viability. BT has decided to discontinue this methodology, and make the necessary conversions to all its exchanges to achieve 100% coverage.

In UK there are several firms vying for broadband leadership. Some of the high profile ones are BT, NTL, and Telewest. NTL has major stake in CATV services. Firms such as Pipe Media are utilizing local loop unbundling to offer broadband services at a cost of 29 to 35 British pound. There are also several Wi-Fi pilots in UK, which are targeted at rural areas.

Though xDSL (in particular ADSL), as a natural outgrowth of Telecommunication carriers' broadband strategies, has a larger market share of broadband access services, CATV still has an opportunity to compete. One indication of this trend is the projected growth rate, from 2002 to 2006, in cable modem shipments in Western Europe of 20.6%, and Easter Europe of 14.5% as shown in Tables 3.2 and 3.3 [21]

Table 3.2: Western Europe- Cable Modem Shipments 1999-2006, reference [21]

	1999	2000	2001	2002	2003	2004	2005	2006	CAGR 2002-2006
Shipments (K)	363	943	1,384	1,746	1,952	3,035	3,492	3,696	20.6%

Table 3.3: Eastern Europe- Cable Modem Shipments 1999-2006, reference [21]

	1999	2000	2001	2002	2003	2004	2005	2006	CAGR 2002-2006
Shipments (K)	15.5	15.5	28.1	33.7	36.7	56.0	72.8	58.1	14.5%

3.2.4 Far East

The growth in demand for broadband services in the Far East is driven mostly by "content". On line game communities in South Korea, Instant Messaging (IM) in china, horse racing (i-horse channel) in Hong Kong, and VOD services in many countries has fueled demand for higher speed access capabilities.

Far Eastern countries have elected to offer broadband through a combination of Fiber to the curb and VDSL to the home. Though new strategic initiatives in South Korea lean more towards an HFC type architecture.

China is expected to have 150,000,000 users by 2005. Many other countries such as Malaysia and Singapore have stated their goal of becoming regional leaders in the broadband services markets. Japan is offering low broadband access charges, yet the market penetration is around 10%.

CATV is well penetrated into several markets, especially Taiwan, and will act as an initial bar to the takeup of undifferentiated content offering from carriers [23].

Korea in particular seems to enjoy the most success. In November 2002, there were 10 million households with high-speed broadband access in South Korea. This represents a 75% penetration rate. We estimate that in 2003 this rate has been increased to over 90%. This impressive result has been made more spectacular through one of the lowest monthly fees in the world (around $30 per month or less).

South Korea, due to its broadband leadership position, deserves more attention. This leadership position is not just due to government policies but the factors specific to South Korea's geo-social composure. South Korea is in many ways perfect for broadband deployment: [24]

1. South Korea is densely populated, with much of the population in urban areas. Nearly one-half of the population lives in the greater Seoul area. Distance between the central offices and homes are small and typically within the range of xDSL technologies. Many South Koreans live in uniform groups of multistory apartment complexes with

a central connection point for all resident apartments. By running fiber to this connection point, Hanro, the second largest DSL operator, has been able to roll out ADSL unencumbered by Korea Telecom (KT). Hanaro usually locates its DSLAMs at this central point. Therefore, despite having no local loop unbundling, Hanaro Telecom can get access to the “last-mile” to offer xDSL. With such a dense urban environment, the truck-roll-cost per customer can also be kept low.

2. 90% of Korean Internet traffic is domestic, which results in South Korea having one of the lowest costs for international connectivity.
3. Penetration of gaming and entertainment on the Internet keeps the users online and has been a factor in promotion and rapid adoption of broadband- for which there is no metered time element.
4. Real competition at every level of the value chain has been key. This gave South Korea an edge compared to most Asian countries where incumbents could control the available services and/or technologies.
5. Competitive pricing of broadband vs. narrowband encourages the uptake of broadband services.

Being the world’s leading broadband nation, South Korea finds itself in a position to deal with development issues ahead of other countries [25]. In August 2003, The ministry of communication (MIC) announced the Broadband Convergence Network (BCN) to take the country’s information network to the next level: “Next Generation-Converged Network (NGcN)”. The major points in this new initiative are:

1. NGcN will deliver seamless converged triple play (video, data, voice)
2. Access network will be capable of delivering up to 100 Mbps to majority of South Korean households
3. HFC will be the architecture of choice.

The MIC has taken the unusual step, for a government authority independent of telecom industry, of designating HFC (same network architecture used by CATV MSO operators in the US) as the most appropriate architecture for delivering this new vision.

This is perhaps the most controversial art of this strategy, given South Korea’s biggest broadband carrier KT does not have an HFC network and uses primarily DSL and, more recently, Very-high-bit-rate DSL (VDSL) to offer broadband.

3.2.5 Middle East

Middles East does not have a major “official” CATV presence. There are sporadic service providers who bundle satellite provided channels into small distribution networks, yet broadband services are planned for and offered through telecommunication carriers through xDSL. Most of these carriers are still state-operated monopolies.

Some of the Middle Eastern countries have experimented with wireless implementation of broadband services. After completion of these expensive systems, they have found out that interference from other terrestrial and celestial services makes the quality of such services unacceptable. These systems were then scrapped in favor of land based networks.

It is interesting to note that Gartner Dataquest projects a 27.8% growth rate in the shipment of cable modems in the Middle East and African regions for 2002 through 2006 (Table 3.4). In the absence of any stated official strategy for broadband cable in these regions, we consider this growth rate to be due to hobbyist/ entrepreneurs in search of better access technologies.

Table 3.4: Middle East and Africa- Cable Modem Shipments 1999-2006, reference [21]

	1999	2000	2001	2002	2003	2004	2005	2006	CAGR 2002-2006
Shipments (K)	_	7.7	18.7	23.4	28.6	43.6	53.7	62.5	27.8%

3.2.6 Africa

Satellites seem to be the best mode of communications amongst African countries due to the geographic characteristics of Africa. Egypt is one of the few countries that have taken a proactive stance on promoting Internet access and computer use. Furthermore, Egypt's plans on offering broadband access are ahead of any of its neighbors in the region.

Within Egypt, there is no stated CATV policy at this time. Currently, there is no CATV infrastructure in Egypt. There is one sole provider, who offers bouquets of TV channels via satellite. This provider is licensed by ERTU, which also owns 51% of the business. In 2001, there were some plans to introduce CATV in Egypt. A proposal was submitted, to MCIT and ERTU, by an Irish company to establish CATV services. Since, the proposal did not adequately address many important issues, such as alliances, magnitude of investment, service/ product mix, etc., the issue was not pursued.

There are scattered providers of CATV type "programming" services in parts of Egypt, but these providers operate on an "Entrepreneurial" basis. Most of these "networks!" are one way analog networks and have to be upgraded to two-way digital networks to be capable of offering broadband services. These operators use the DBS satellites as the source of "content" and programming.

There is also the issue of licensing/ franchising. This is key in attracting investors to the industry. As CATV experience in the US indicates, this is a very capital-intensive industry and the investors need to see competitive returns on their capital.

There is also a curious lack of penetration of broadband Internet services in Egypt. Even though the government has been proactive and aggressive in offering pioneering programs such as affordable PC, and low cost Internet, the penetration numbers for broadband services don't seem to be impressive.

3.3 COMPETITIVENESS OF CATV

There are two dimensions to CATV competitive position: One technology, the other the state of companies involved in the industry, namely MSOs vs. Telecos.

In case of MSOs vs. Telcos, the following must be considered:

1. Majority of Telcos are either currently protected monopolies (outside US) and/ or have had a history of operating as such (AT&T and Baby Bells in US up to 1984). This tradition has impeded the sense of strategic investment in competitive environment therefore eschewing the view of the future. In particular Telcos have not experienced much success in being at the cutting edge of meeting customer needs. Case in point is introduction of IP based services.

2. Telcos have also not shown prowess in content type services. As it turns out MSOs have had much more experience in procuring, developing, and packaging content. In the new competitive environment this experience is a valuable asset.

Telcos have constantly been guided by trying to save as much of the copper plant in the ground as possible. This has led them to subscribe to a general rule that when penetration exceeds 20%, people start to think when as opposed to why they should subscribe. This view has been key in phased upgrade of exchanges in BT territory. As it turns out BT has abandoned in approach in favor of “If you build it, they will come”. MSOs have been operating in this fashion for a long time. This adds to the edge that MSOs will always have, short of new visionary leadership at Telcos.

As far as the technology goes, in general there are six possible way of providing access to the home (end user which may also be a business enterprise). These access pathways, as shown in Figure 3.6, are Mobile/ Fixed radio, Direct Broadcast Satellite (DBS), Power Lines, Optical Fiber (such as Fiber To The Home FTTH), Telephone copper wire, and Cable. For the purpose of this Chapter we do not directly consider the business enterprises. Due to economy of scale, business enterprises can devise private networks (virtual or otherwise) to gain access to high-speed networks.

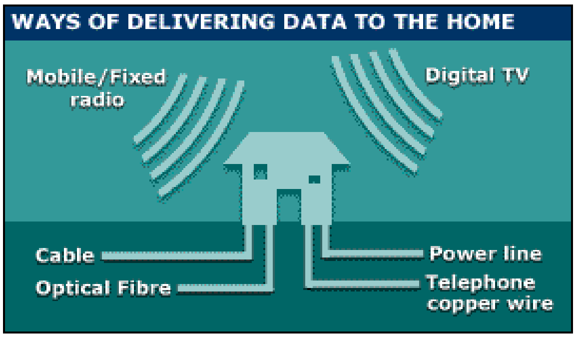

Figure 3.6: Access Technologies to the Home

3.3.1 Mobile / Fixed Radio

Mobile and Fixed radio technologies, such as Wi Fi, hold much promise in the long run. Research carried out by Ovum for the European Union suggests that number of mobile subscribers will outstrip the number of standard fixed telephone lines by 2004. Fixed lines are set to rise from 192 million in 1997 to 211 million, while mobile customers will rise from 52 million to 251 million.

According to Forrester Research, Wi Fi market is facing natural limits. In Europe only 10% of the population have portable computers. There is also a limit on the availability of Hot Spots where these technologies can be used. Roaming is not as easily achieved between Hot spots as does in mobile telephone networks. UK is expected to have 4000 hot spots by the end of next year.

Though there is a place for Wi Fi, in our opinion, CATV and xDSL technologies will offer better and more diverse alternatives.

3.3.2 Direct Broadcast Satellite

Direct broadcast satellites, mostly used in Europe and developing nations, had already created a foothold in entertainment video programming. Figure 3.7 shows DBS subscription rates vs. Cable amongst US households.

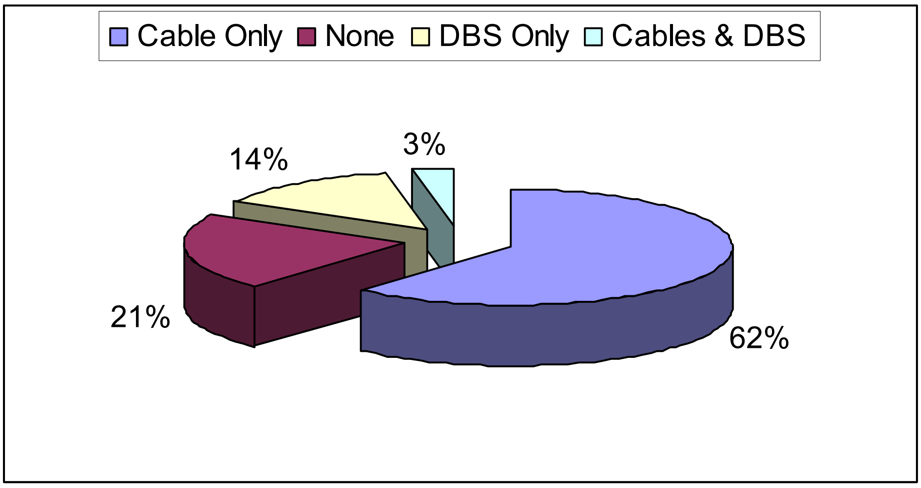

Figure 3.7: Multi-Channel Video Subscription in Areas with Available Cables

DBS networks are now attempting to offer interactive video and broadband access. The cost of such services is much higher than DSL and/ or cable where available. We do not see this picture improving for DBS anytime soon. DBS networks may enjoy a reasonable bandwidth for their down links, but they are always limited and at the mercy of the land based network for their return path.

3.3.3 Power Lines

This option has been and continues to be considered by energy companies, but as of yet it stays in the realm of esoteric. The high bandwidth necessary to compete effectively with CATV (or xDSL) has not yet been commercially materialized.

3.3.4 Optical Fiber (FTTH)

Considered the most flexible and capable of all networks where an end-to-end fiber allows for maximum bandwidth and flexibility. Yet this promise is impeded by high cost, land long implementation/ network conversion lead times.

As of 2003 the number of homes passed by FTTH in the US and Canada was about 315,000. The number of homes actually connected is much less at 38,000. Comparing these low penetration numbers with CATV’s HFC networks, and the weak balance sheets of telcos make the rapid implementation of this access option improbable in the short run.

Figure 3.8 illustrates the rate of growth in FTTH [26].

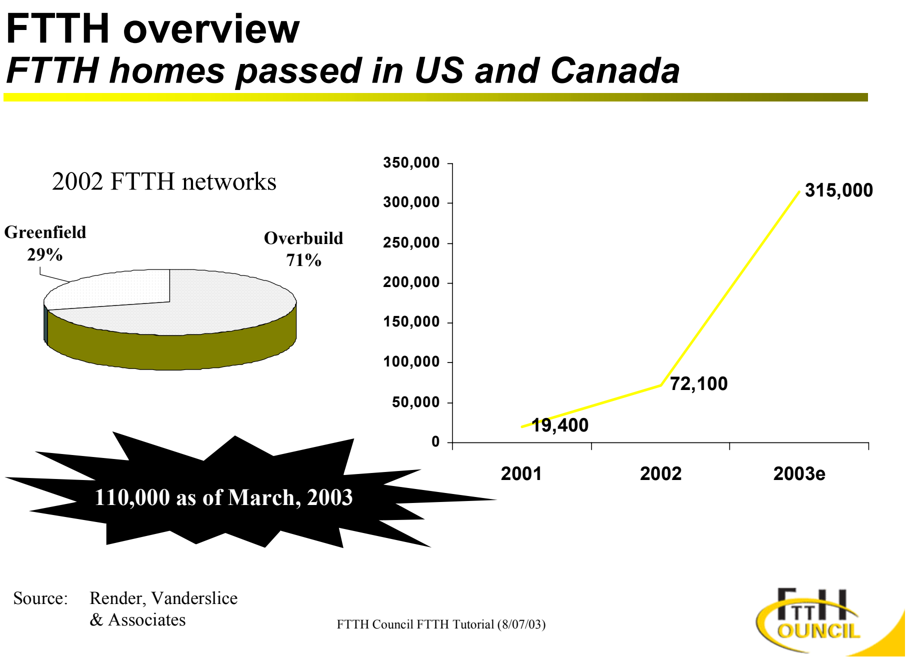

Figure 3.8: FTTH Growth Rate in US and Canada

3.3.5 Telephone Copper Wire

Copper wire is one of the oldest technologies where the networks were optimized to carry voice. Since its inception this network was constantly tweaked to carry and accommodate new services for video and data. The high capital invested in these networks have impeded the Telcos in implementing out-of-the-box technology/ services where the rate of return has not been complementary to these imbedded base networks/ services. Current xDSL technologies are the latest technique to extend the life of the copper plant.

3.3.6 Cable

The first CATV license was granted in US in 1948. Since then up to mid and early nineties, CATV networks were considered to be vehicles for one way entertainment programming. In late 80s and early 90s, the regional carriers in the US started to look at ways of providing high margin unregulated services, such as video to homes. Given the heavy infrastructure investment in the Copper plant their first goal was to capitalize on the existing network. At the same time these carriers were upgrading their "CORE" network to high bandwidth Fiber facilities with ATM and optical switches. The challenge to these carriers to provide "Triple Play" (namely Voice, Data, and video) has been the last mile.

While carriers and new start-ups began to invest in DSL type technologies, the cable companies upgraded their network to a digital Hybrid Fiber Cable (HFC) architecture, as shown in Figure 3.9 (Source: River Stone Networks). This allows up to 900 channels of video and audio programming while adding broadband Internet access, Voice over IP (VoIP) and Video on Demand (VoD).

There are several interesting items that should be pointed out in Figure 3.9:

- The SONET ring is also a major component in the carrier networks. The commonality of fiber in telecommunication carrier networks and cable networks points to the convergence of "CORE NETWORK".
- The last mile coax within CATV networks offers a cost-effective way to distribute services. This technology is well developed and available from variety of sources making their cost amongst the lowest of alternate access.
- It appears that of the xDSL technologies VDSL offers the highest theoretical bandwidth (150 Mbps). Assuming this capability will be successfully commercialized and marketed at a reasonable price point to the end users, the battle for the last mile may very well be fought between CATV and VDSL.

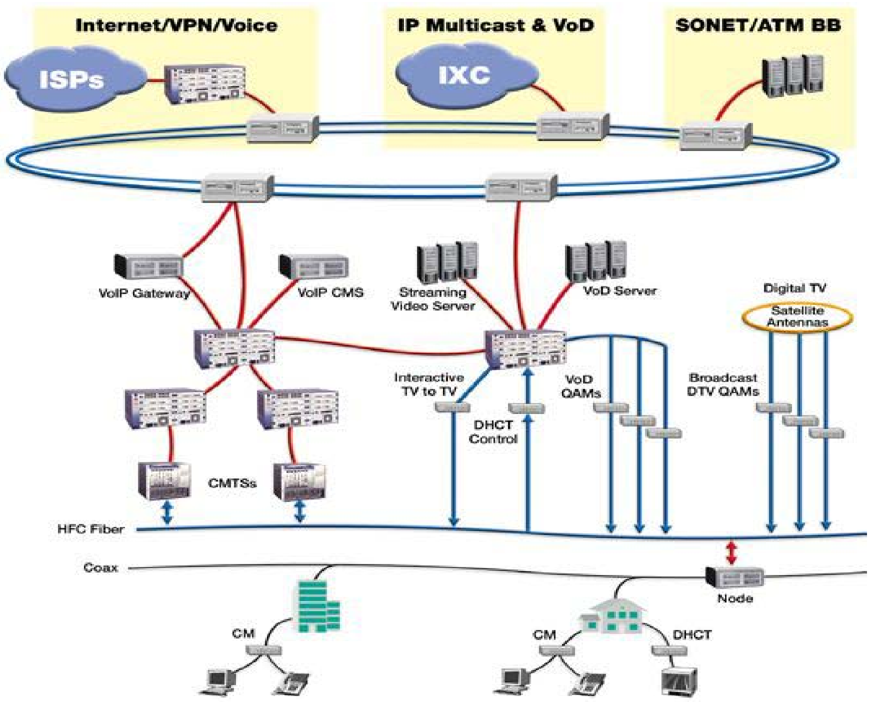

Figure 3.9: Cable TV HFC Infrastructure, (Source: River Stone)

Today, most developing nations are betting on xDSL along with a core fiber distribution network for their broadband. CATV still leads in the shear number of video channels and higher bandwidth compared to any DSL plan. As time goes on this picture may change.

As of September 30th, 2003, as reported by C/net, Cable companies accounted for 64 percent of the overall US residential broadband market against DSL's 36 percent. Figure 3.10 illustrates the major players in the US and their corresponding number of subscribers.

	Subscribers total	New subscribers
Cable:		
Comcast	4,861,000	472,700
Time Warner	3,046,000	190,000
Cox	1,844,125	169,290
Charter	1,489,700	140,700
Cablevision	984,800	63,695
Adelphia	876,890	95,890
DSL:		
SBC	3,139,000	365,000
Verizon	2,116,000	185,000
Bell South	1,336,000	111,000
*Qwest	570,000	10,000
Covad	491,000	38,000

*Estimate

Figure 3.10: Top Broadband Providers in North America, reference [8]

While DSL providers are offering promotional programs and lowering their monthly fees, the MSOs are betting that the customers want higher bandwidth, therefore offering up to 25 Mbps capacities to their subscribers. In our opinion, MSOs have operated in a market drivern competitive environment longer than DSL carriers. This may determine the outcome of the fight for the broadband subscribers. Furthermore, the MSOs are now offering VoIP at much lower cost than Carriers. This will further weaken the position of the traditional carriers in the North America.

3.4 REGULATORY APPROACHES

State regulation of CATV first came under consideration in 1954, when the Cokeville Radio and Electric Company in Wyoming applied for a permit from the state's Public Service Commission to run a master antenna system. Why the company asked the commission for permission is problematic, since there was no law on the books regulating cable television. The request, which listed the cable system's assets as $2,144 and the number of potential subscribers as 50, raised legal discussion in Wyoming for a short time as to the commission's authority over CATV. It was decided that Section 64-101 of the Wyoming State Code, which defines a public utility as any entity for the "transmission of intelligence by electricity" was applicable. So the permit was granted and the case was closed. *The complexity of the issues surrounding CATV has escalated many times since 1954.* (Seiden, Martin H.; Cable Television U.S.A., An Analysis of Government Policy; Praeger, 1972)

FCC handles and regulates all matters relating to telecommunication and cable TV networks in the US. Though most licenses for telecommunication services are handled at federal level, CATV franchises are offered and managed at local levels. CATV has been left pretty much unregulated in the US. This is due to the heavy lobby efforts of NCTA and a general belief that a successful CATV infrastructure requires heavy capital commitments. To encourage the private sector in assuming the risks of such investment FCC has offered much flexibility.

At the same time, FCC has developed mechanisms to monitor and adjust policies as deemed necessary. One such mechanism is Section 706, where the deployment of various services are monitored per Zip codes and matched against expected demographics. Any data out of the norm is flagged and studied further. These studies can result in further investigation of the underlying service provider and may result in mandated action.

However, the judiciary in the US has taken an active role in taking up several key arguments amongst various industry players. The source of most arguments can be traced to “convergence”.

The new VoIP offering of telephony services effectively makes the MSOs telecommunication carriers. Yet, they are not subject to any regulation and taxation that the traditional carriers have to abide by. This certainly is not advantageous to the traditional carriers.

In addition, there are two other issues that have been argued in the past: Equal Access, and Universal access. Though phone companies are subject to offering both, equal access to their network to competitors, and universal access to their customers, the cable companies have not been subjected to either. MSOs are voluntarily testing various Equal Access methodologies with the ISPs to avoid mandated regulation by outsiders.

In general, it is our view that the market forces have allowed the CATV to thrive and prosper while offering the most services that the customers have been demanding. In contrast the regulated telecommunication carriers have failed in many respects in satisfying their customers broadband needs in timely manner.

An important aspect of regulation is the fact that most regulatory bodies are structured such that they are not equipped to address the new converged technology advances. Therefore there is a need for new regulatory frameworks.

The old regimes of regulation have mostly been put in place as a response to abuses and/or threats from industry players. Much of the antitrust laws in the US dates back to monopolistic firms ran by JP Morgan, including several consent decrees with wide reaching implications against AT&T. Today’s Equal Access rules against the traditional carriers in the US can be attributed to such cases. This is what we refer to as a vertical regulation framework as the purpose of the regulation is to manage the behavior of mammoth vertically integrated entities.

As technology advances and convergence takes hold new services will be offered which will no longer fit the vertically integrated framework. For example, in Figure 3.9 we illustrated a CATV network. You will notice that parts of the network, such as SONET ring, fiber facilities are not just specific to CATV network. Network infrastructure can carry content whether that content is a movie or a voice conversation. As such, we distinguish four distinct horizontal layers: Network Facilities, Network Services, Applications Services, and Content Service as shown in Figure 3.11.

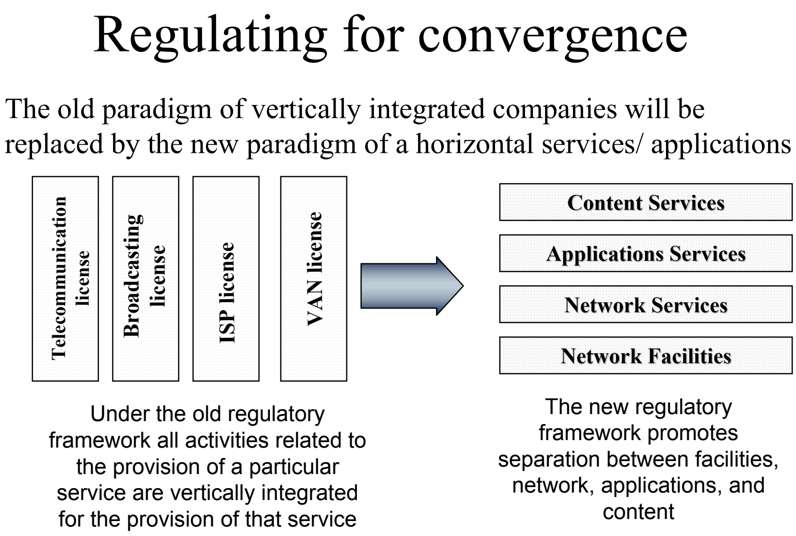

Figure 3.11: New Regulatory Framework for the Converged Technologies

In our opinion, this framework allows for faster identification of issues and trends in each category while managing the industry players. This in no way implies that access and entry should be restricted to and from each horizontal service category.

Network Facilities are the most capital intensive of all industries and they probably require the longest cycle for implementation and realization. Example of such a player is the Telecom Egypt (TE) who owns all facilities in Egypt.

Network Services are services offered by third parties using the network facilities. All VoIP carriers can be categorized as Network Service providers. ISPs are another example of such operators.

Application Services are those hosted by the service provider such as E-mail and pay-per-use applications such as hosting, financial accounting, etc.

Content Services are services similar to Yahoo and/or the current programming services offered by the MSO. These are merely a customer-oriented aggregation from variety of content sources.

We advocate that the regulatory environment must provide maximum flexibility to any market entrants as how to price and offer their services, yet a firm presence to prosecute any abuses and/or mediate any disputes must exist.

Furthermore, regulation has three important dimensions, as shown in Figure 3.12.

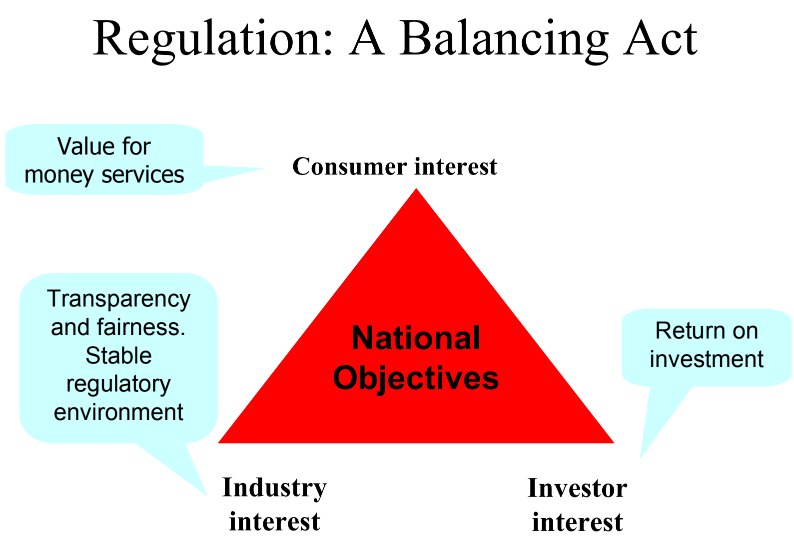

Figure 3.12: Regulators Need to Balance Conflicting Requirements

This creates a challenge for any regulator, as they need to balance and optimize amongst conflicting requirements at times. Decisions such as the extent of government involvement and degree of free market competition can affect the cost and timeliness of offering key services and capabilities, which may impact the competitive positioning of the nation. There are many factors to consider. What industries and/or businesses should be promoted in the nation or internationally? What segments of the society need to be covered? What are the national security implications? What is the prestige/ market oriented goals? What type of investors should be attracted? What levels of risk are acceptable?

One example of such balancing act is the goal set by South Korea to provide broadband access to its citizens as rapidly and cheaply as possible. This was accomplished by allowing many players in the field. Players who tried to buy market share and expand their market penetration. Now that the network and services are in place, many of these players find themselves financially stretched. The government now is offering incentives for these firms to consolidate!

Our converged regulatory framework is nicely complemented by a layered view of broadband services, as shown in Figure 3.13. The Figure outlines and delineates areas of responsibility amongst stakeholders such as government, industry bodies (forums), private enterprise, and individuals.

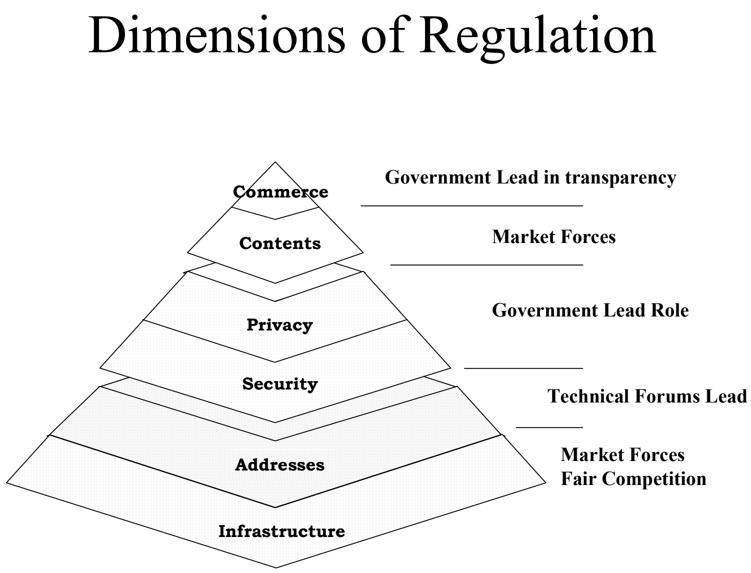

Figure 3.13: Regulation Model for Broadband Services in Egypt

Based on this model, we see government role in the infrastructure to be limited to promotion of free enterprise, ensuring fair and adequate competition along with speedy resolution of complaints and disputes.

Government regulation must protect and enforce privacy and security. These laws must be developed and implemented to offer protection for all stakeholders. This protection is key in creating confidence, which is a major ingredient in attracting investment and promoting use of broadband services. These issues have been under intense study in the broadband pioneer nations, and the laws continue to evolve.

In the commerce arena, the government must ensure the integrity of the financial systems and transactions. Government must also take an active role in promoting use of such services through tax incentives. The tax moratorium placed in the US on Internet based transactions has had a major contribution to creation of new Internet based transaction services.

All network (IP address) issues must be left to industry forums and volunteer expert organization. IEEE and several other industry forums have done a great job in promoting non-partisan standards. This tradition can easily be capitalized on by actively participating in such forums.

Content development and aggregation should be left to the discretion of its producers, though a rating mechanism should be in place to identify the appropriateness for such content for various audiences.

3.5 CATV FOR EGYPT

In our conversation with ERTU, MCIT, TE, and NTRA we concluded the following:

- All parties are enthusiastic for implementation of sound broadband strategies including inclusion of CATV as part of this strategy
- There are currently several “illegal” cable operators in parts of Egyptian towns. These operators can be characterized as “Hacker” entrepreneurs! With no concerted plans to grow and/or expand
- There are serious reservations about pulling new cable through bustling streets of Cairo!
- TE has a fiber optic ring connecting most major switching centers. This ring can be utilized in offering additional services such as CATV programming
- Successful introduction several novel programs such as “Affordable PC” and “Free Internet” have set the stage for the increase in Information Technology (IT) penetration within the Egyptian Society. It is urgent, as the next logical step, to continue on this path with promotion and increased availability of affordable broadband access.

Figure 3.14 illustrates the stakeholders in any CATV planning/ implementation project. Of these stakeholders the private sector plays a key role in success of any such venture. We did review a proposal submitted to Egypt in 2001 by an Irish company to establish CATV services. This proposal does not seem to adequately address many important issues, such as alliances, magnitude of investment, service/ product mix, etc.

Given the extent of the unknown information and many country specific variables to be identified, we recommend a phased approach to CATV, with the first and starting phase being that of a pilot program. In the next section we will elaborate on the objectives and the process of such pilot program.

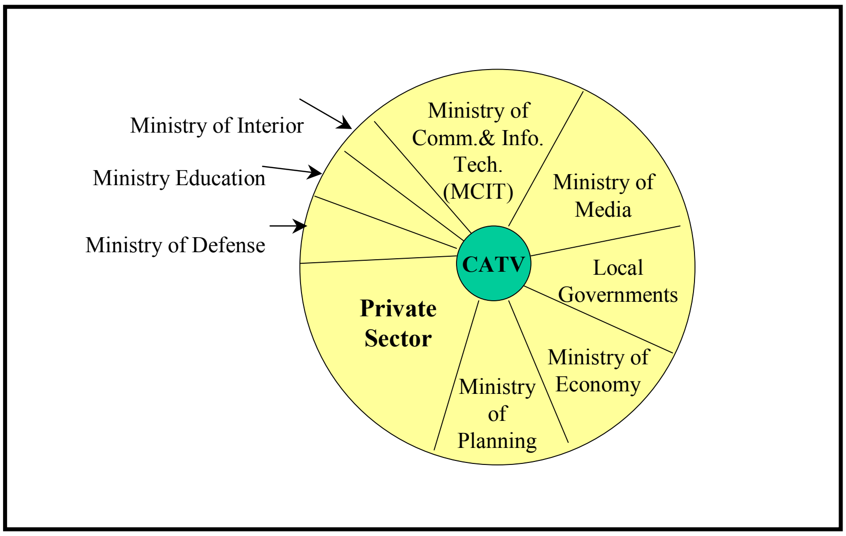

Figure 3.14: CATV Stakeholders

In general, we believe that Egypt should include CATV as a major component of their national broadband strategy. This will uniquely position Egypt to offer a more diverse and capable broadband infrastructure. We further recommend that the specific technology vehicle decision be left to the market forces. Egypt Telecom can supply infrastructure capacity to any potential provider whether Cable, xDSL, or other.

Egypt should also pursue a less regulated market environment. Modeling a regulatory model such as FCC in the US with some specific modification tailored to Egypt judicial and legal environment makes sense. Enforcement and public interest can be carried out through monitoring vehicles such as FCC section 706, as discussed in previous sections.

Another important consideration is the "Digital Divide". In the US it appears that the benefits of the Web have disproportionately gone to a class of Americans who are also mostly white and predominantly male. They're also likely to have college degrees, earn relatively high incomes, live in nice neighborhoods, and use the Internet for online banking. This contrast is even sharper in the developing nations.

There are currently discussions in the US to provide incentives/ subsidies to families of lesser means through tax cuts to expedite subscription to broadband services. Similar measures may need to be considered in Egypt. Egypt's experience with free Internet and affordable PC programs can be a good building block.

3.5.1 CATV Pilot Program

There have been many broadband pilot programs in the US. The purpose of these programs, mostly sponsored by the Telecommunication carriers, such as AT&T, has been to identify technical issues with offering Fiber-to-the-Home (FTTH). Alas, none of these costly programs have produced any meaningful commercial results. In our opinion, the reason for this has been lack of a well-defined commercial goal and concentration on novel technical issues, which have not excited the customers. This provides us with a wealth of experience, which will be beneficial to Egyptian project.

Our pilot program needs to be structured along five dimensions. These dimensions are Regulatory, Community, Services, Technical, and Financial/ Business Model. Each dimension is structured to address specific issues. The management of the pilot will be organized around these five dimensions as shown in Figure 3.15.

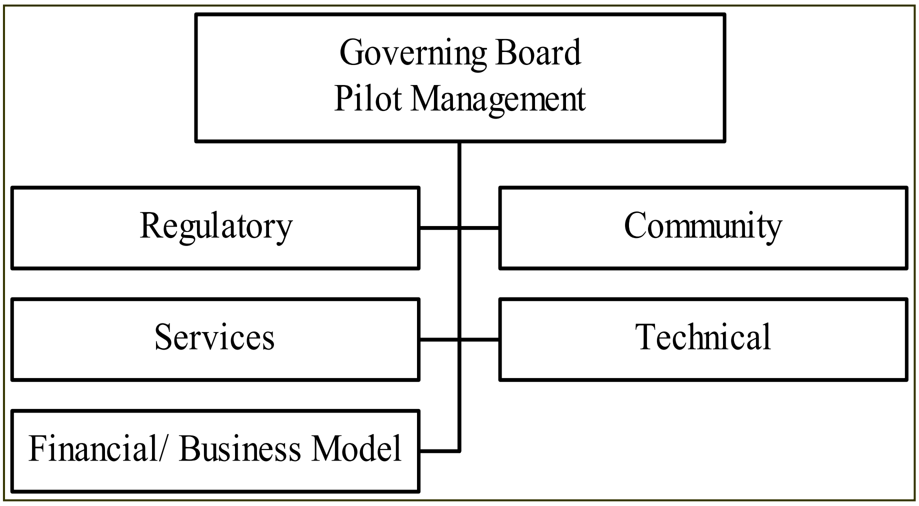

Figure 3.15: Pilot Management Organization

The five dimensions/ towers can be organized to operate simultaneously. This will allow us to document the results and create a highly responsive and agile organization key to the success of such pilot programs. In the following sections we will elaborate on each cell in Figure 3.15.

3.5.1.1 Governing Board

The following questions must be answered in the context of the governing board:

a) Structure and composition of a governing board to examine and monitor the process?

b) What are the Critical Success Factors for this trial (Profitability vs. Penetration)?

c) How much will the pilot cost?

<u>(a) Structure and composition of a governing board to examine and monitor the process?</u>

Based on Figure 3.15, the governing board should have representation from Radio & TV Union, MCIT, TE, and NRTA. There should also be a managing director/ advisor to oversee the implementation and management of the pilot while reporting to the governing board on a regular basis.

The governing board will approve all budgets, and implementation timetables. The governing board will also review and evaluate all pertinent pilot results.

Managing director/ advisor will work closely with all parties to create an organization to create Engineering, Customer Service, Facilities Management and Operation, and Customer Service organizations. This organizational structure will also be helpful in conveying human capital issues to potential investors.

<u>(b) What are the Critical Success Factors (CSF) for this trial (Profitability vs. Penetration)?</u>

As a first step in establishing the pilot project we need to identify a set of parameters to measure and gauge the success (or failure) of the project. There should also be a range of values associated with these parameters based on experience in other nations and Egypt specific statistics.

Some of the CSF parameters could be number of potential subscribers in pilot community, increase/ decrease in subscription rates in a period of six months, subscription to premium services, Internet usage, programming values, comparison to other competitive alternatives (DBS, xDSL,etc.).

Another important CSF parameter is that of network performance. This parameter will be based on network capacity and availability across TE and CATV network. As part of this pilot MTTF and MTTR measurements will be taken across the network and validated/ compared against accepted industry practices.

It is natural to expect customers to have issues during this pilot program. These issues will be cataloged and addressed through a customer services organization.

(c) How much will the pilot cost?

At this stage we do not have enough information to provide cost figures. The cost will be dependent on the location of the pilot (to be determined) and the number of projected subscribers. Furthermore, before the pilot begins much work needs to be done to set up the necessary organization for management and evaluation of the pilot results.

The network design, engineering, and implementation will also be dependent on the extent of facilities available from TE, and the new facilities to be laid out for CATV access and distribution.

3.5.1.2 Regulatory Issues

Regulatory dimension will address the following questions:

a) Licensing/ franchising models: Local vs. National

b) Which and to what extent the private sector will be involved in the initial trial?

c) Taxation mechanism

d) Investment incentives

e) Licensing conflict

As part of our pilot program we also need to convene a blue ribbon panel of industry experts, private sector leaders, and government leaders to build a consensus of what private entities should be targeted for participation in our pilot and inclusion in our circle of advisers. This panel will help us devise the right regulatory framework to address the above questions.

3.5.1.3 Community Issues

a) What are Egypt's demographics?

b) What is the history/ trends of new service penetrations/ acceptance in Egypt (Internet)?

c) Which areas/ community should be the target of these trials?

(a) What are Egypt's demographics?

We need to obtain/ develop complete demographics of Egypt. This step is key in determining what communities will be included in the pilot program. Furthermore, we will use these demographics to determine the order of communities/ regions for the follow on phases.

Demographics will also be used in developing monitoring criteria for the rate of deployment of services in the future.

(b) What is the history/ trends of new service penetrations/ acceptance in Egypt (Internet)?

The rate of penetration of Internet access and deployment of PCs and new services, including DBS, will be used in comparing the rate of adoption of new CATV services within the pilot communities. Rates higher or lower than penetration rates of previous services can assist us in spotting potential problems. We can also use these numbers in modifying the service composition and/or price baskets.

(c) Which areas/ community should be the target of these trials?

We will use the results of the previous sections in determining which areas best fit our initial pilot objectives. Mohandseen area in Cairo has been suggested as one area. Our initial preference is not to complicate the process by requiring digging of streets. We favor a new residential neighborhood in one of tourist areas as the first deployment site.

3.5.1.4 Services Issues

a) What is the right service/ programming mix?

b) What are the appropriate service pricing tiers/ mixes?

c) Who will be the content provider/ aggregator?

(a) What is the right service/ programming mix?

We suggest a survey of the potential end users as to their preferences. The outcome of this survey along with the current services available through DBS, ISPs will help us determine a reasonable mix of services.

(b) What are the appropriate service pricing tiers/ mixes**?**

We will use the results of the end users survey along with the current pricing model of existing services to derive a competitive pricing model. There will be three programming tiers: Basic, Extended, and Premium. The composition and pricing of which will be finalized once our surveys are completed.

There will also be value-added services such as Internet access, and VoIP capabilities.

(c) Who will be the content provider/ aggregator?

We also need to identify/ form an entity to operate our pilot CATV network. This entity can later be formalized as the ultimate private company to build out and expand the CATV service in Egypt.

3.5.1.5 Technical Issues

A team of engineers from TE and CATV pilot group will design the network and service delivery mechanism. Once the design is completed equipment selection will be done. Equipment needed from Cable Head-End, facilities and repeaters, servers, to set-top boxes.

3.5.1.6 Financial & Business Model

We need to determine " What is the right business model for CATV services in Egypt?"

There are many possible business models. One possibility is illustrated in Figure 3.16.

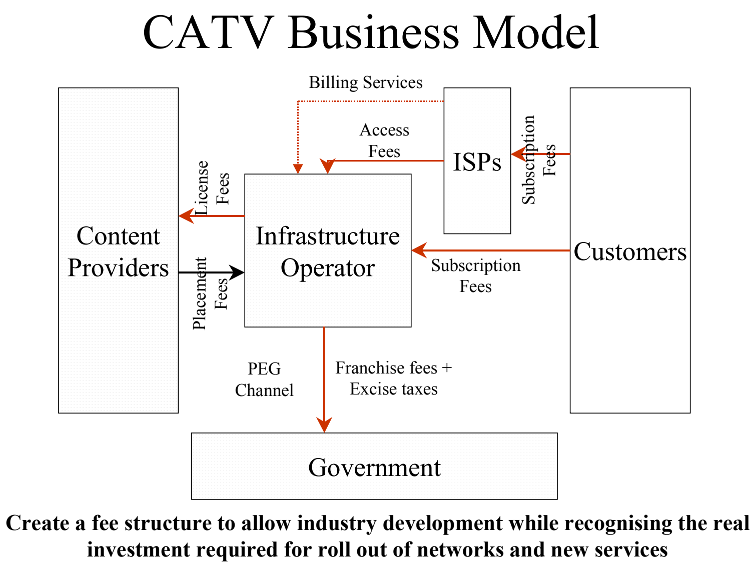

Figure 3.16: Cable TV Business Model

First and foremost the CATV operator will be granted a franchise (National License) for a limited number of years to be renewed upon meeting a preset criteria (number of subscribers, depth and breadth of services offered, et.). In return, the operator will provide a monthly fee to the government. This fee can be recaptured through the monthly subscription fees for the customers.

The operator does not necessarily own any network facilities. Telecom Egypt will manage all network facilities and capacities for a mutually agreed upon fee. The operator will provide a tiered programming service for a fee, while compensating original producers through licensing agreements. The tiered programming will be offered on the basis of basic, extended, and premium (composition of which to be decided later). Equal access for the ISPs will be tested and an access fee/ usage charge will be established.

The operator will be further required to offer one to five channels, free of charge, to government/ educational/ public (PEG) agencies.

At the end of the pilot project all the financial parameters will be derived and built into a financial business model with appropriate rate of return numbers to be presented to potential investors in a prospectus.

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APPENDIX B

Technology of CATV, Cable Modems

1. Definition

Cable modems are devices that allow high-speed access to the Internet via a cable television network. While similar in some respects to a traditional analog modem, a cable modem is significantly more powerful, capable of delivering data approximately 500 times faster.

2. Overview

This tutorial explores the high-speed access capability of cable modem technology in detail, with emphasis on mode of operation, network architecture, alternative technologies, and security issues.

3. How Cable Modems Work?

Current Internet access via a 28.8–, 33.6–, or 56–kbps modem is referred to as voiceband modem technology. Like voiceband modems, cable modems **mo**dulate and **dem**odulate data signals. However, cable modems incorporate more functionality suitable for today's high-speed Internet services. In a cable network, data from the network to the user is referred to as downstream, whereas data from the user to the network is referred to as upstream. From a user perspective, a cable modem is a 64/256 QAM RF receiver capable of delivering up to 30 to 40 Mbps of data in one 6-MHz cable channel. This is approximately 500 times faster than a 56–kbps modem. Data from a user to the network is sent in a flexible and programmable system under control of the headend. The data is modulated using a QPSK/16 QAM transmitter with data rates from 320 kbps up to 10 Mbps. The upstream and downstream data rates may be flexibly configured using cable modems to match subscriber needs. For instance, a business service can be programmed to receive as well as transmit higher bandwidth. A residential user, however, may be configured to receive higher bandwidth access to the Internet while limited to low bandwidth transmission to the network..

A subscriber can continue to receive cable television service while simultaneously receiving data on cable modems to be delivered to a personal computer (PC) with the help of a simple one-to-two splitter (see Figure B-1). The data service offered by a cable modem may be shared by up to sixteen users in a local-area network (LAN) configuration.

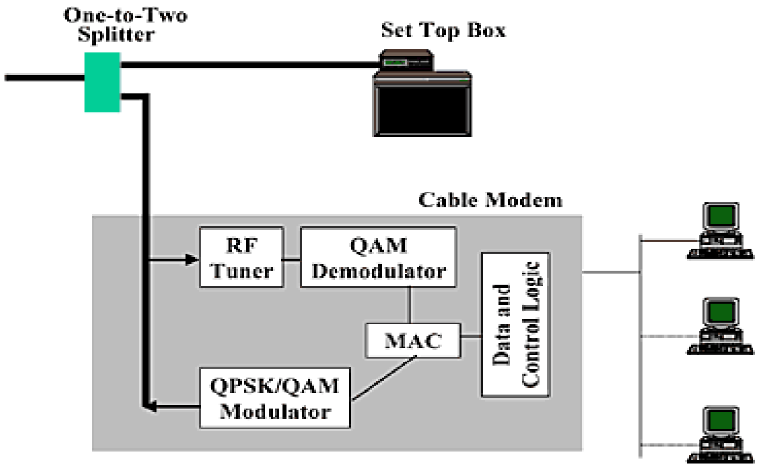


Figure B-1: Cable Modem at the Subscriber Location

Because some cable networks are suited for broadcast television services, cable modems may use either a standard telephone line or a QPSK/16 QAM modem over a two-way cable system to transmit data upstream from a user location to the network. When a telephone line is used in conjunction with a one-way broadcast network, the cable data system is referred to as a telephony return interface (TRI) system. In this mode, a satellite or wireless cable television network can also function as a data network.

At the cable headend, data from individual users is filtered by upstream demodulators (or telephone-return systems, as appropriate) for further processing by a cable modem termination system (CMTS). A CMTS is a data switching system specifically designed to route data from many cable modem users over a multiplexed network interface. Likewise, a CMTS receives data from the Internet and provides data switching necessary to route data to the cable modem users. Data from the network to a user group is sent to a 64/256 QAM modulator. The result is user data modulated into one 6-MHz channel, which is the spectrum allocated for a cable television channel such as ABC, NBC, or TBS for broadcast to all users (see Figure B-2).

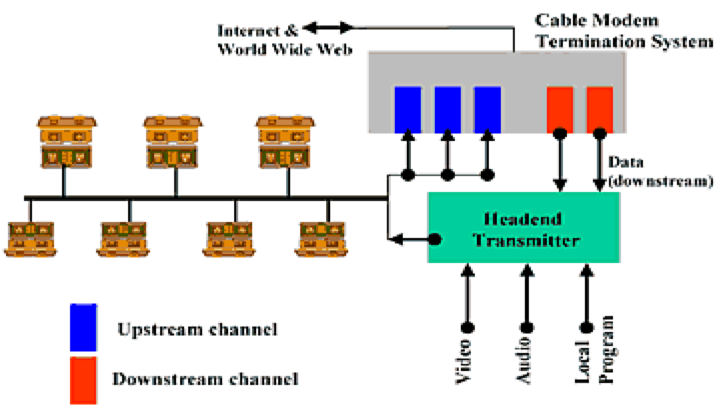


Figure B-2: Cable Modem Termination System and Cable Headend Transmission

A cable headend combines the downstream data channels with the video, pay-per-view, audio, and local advertiser programs that are received by television subscribers. The combined signal is then transmitted throughout the cable distribution network. At the user location, the television signal is received by a set-top box, while user data is separately received by a cable modem box and sent to a PC.

A CMTS is an important new element for support of data services that integrates upstream and downstream communication over a cable data network. The number of upstream and downstream channels in a given CMTS can be engineered based on serving area, number of users, data rates offered to each user, and available spectrum.

Another important element in the operations and day-to-day management of a cable data system is an element management system (EMS). An EMS is an operations system designed specifically to configure and manage a CMTS and associated cable modem subscribers. The operations tasks include provisioning, day-to-day administration, monitoring, alarms, and testing of various components of a CMTS. From a central network operations center (NOC), a single EMS can support many CMTS systems in the geographic region. See Figure B-3.

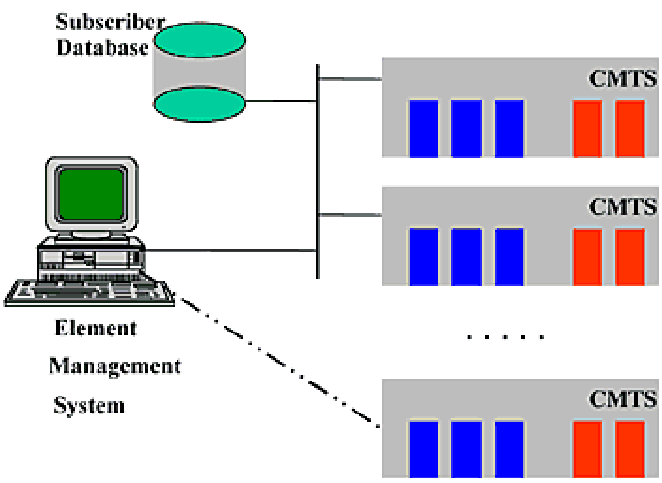


Figure B-3: Operations and Management of Cable Data Systems

4. Cable Data System Features

Beyond modulation and demodulation, a cable modem incorporates many features necessary to extend broadband communications to wide-area networks (WANs). The network layer is chosen as Internet protocol (IP) to support the Internet and World Wide Web services. The data link layer is comprised of three sublayers: logical link control sublayer, link security sublayer conforming to the security requirements, and media access control (MAC) sublayer suitable for cable system operations. Current cable modem systems use Ethernet frame format for data transmission over upstream and downstream data channels. Each of the downstream data channels and the associated upstream data channels on a cable network form an extended Ethernet WAN.

As the number of subscribers increases, a cable operator can add more upstream and downstream data channels to support demand for additional bandwidth in the cable data network. From this perspective, growth of new cable data networks can be managed in much the same fashion as the growth of Ethernet LANs within a corporate environment.

The link security sublayer requirements are further defined in three sets of requirements: baseline privacy interface (BPI), security system interface (SSI), and removable security module interface (RSMI).

BPI provides cable modem users with data privacy across the cable network by encrypting data traffic between the user's cable modem and CMTS. The operational support provided by the EMS allows a CMTS to map a cable modem identity to paying subscribers and thereby authorize subscriber access to data network services. Thus, the privacy and security requirements protect user data as well as prevent theft of cable data services.

Early discussions in the Institute of Electrical and Electronic Engineers (IEEE) 802.14 Committee referred to the use of asynchronous transfer mode (ATM) over cable data networks to facilitate multiple services including telephone, data, and video, all of which are supported over cable modems. Although current cable modem standards incorporate Ethernet over cable modem, extensions are provided in the standards for future support of ATM or other protocol data units. IP–telephony support over cable data networks is expected to be a new value-added service in the near term.

5. Cable Data Network Architecture

Cable data network architecture is similar to that of an office LAN. A CMTS provides an extended Ethernet network over a WAN with a geographic reach up to 100 miles. The cable data network may be fully managed by the local cable operations unit. Alternatively, all operations may be aggregated at a regional data center to realize economies of scale. A given geographic or metropolitan region may have a few cable television headend locations that are connected together by fiber links. The day-to-day operations and management of a cable data network may be consolidated at a single location, such as a super hub, while other headend locations may be economically managed as basic hubs (see Figure B-4).

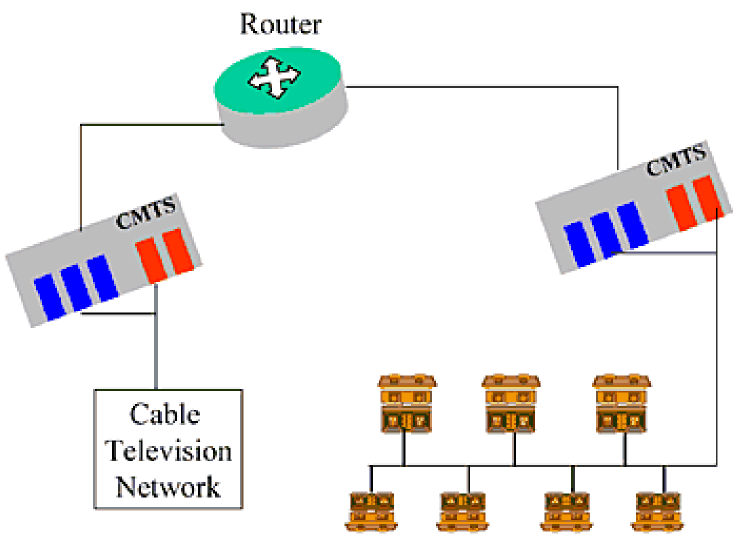


Figure B-4: Basic Distribution Hub

A basic distribution hub is a minimal data network configuration that exists within a cable television headend. A typical headend is equipped with satellite receivers, fiber connections to other regional headend locations, and upstream RF receivers for pay-per-view and data services. The minimal data network configuration includes a CMTS system capable of upstream and downstream data transport and an IP router to connect to the super hub location (see Figure B-5).

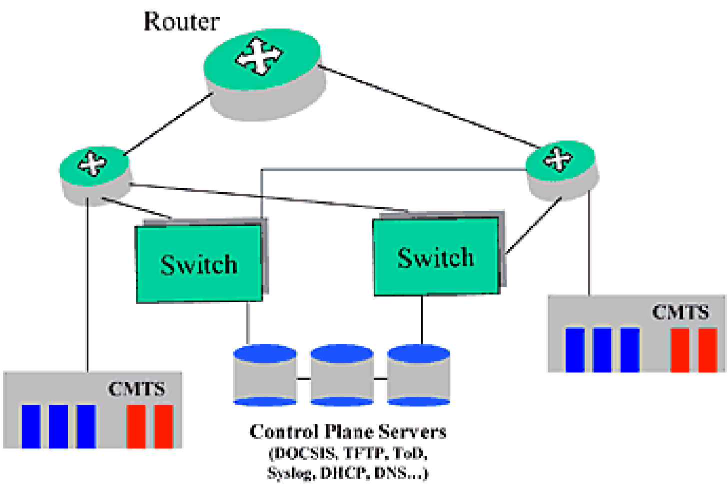


Figure B-5: Super Hub

A super hub is a cable headend location with additional temperature-controlled facilities to house a variety of computer servers, which are necessary to run cable data networks. The servers include file transfer, user authorization and accounting, log control (syslog), IP address assignment and administration (DHCP servers), DNS servers, and data over cable service interface specifications (DOCSIS) control servers. In addition, a super hub may deploy operations support and network management systems necessary for the television as well as data network operations.

User data from basic and super hub locations is received at a regional data center for further aggregation and distribution throughout the network (see Figure B-6). A super hub supports dynamic host configuration protocol (DHCP), DNS (domain name server), and log control servers necessary for the cable data network administration. A regional data center provides connectivity to the Internet and the World Wide Web and contains the server farms necessary to support Internet services. These servers include e-mail, Web hosting, news, chat, proxy, caching, and streaming media servers.

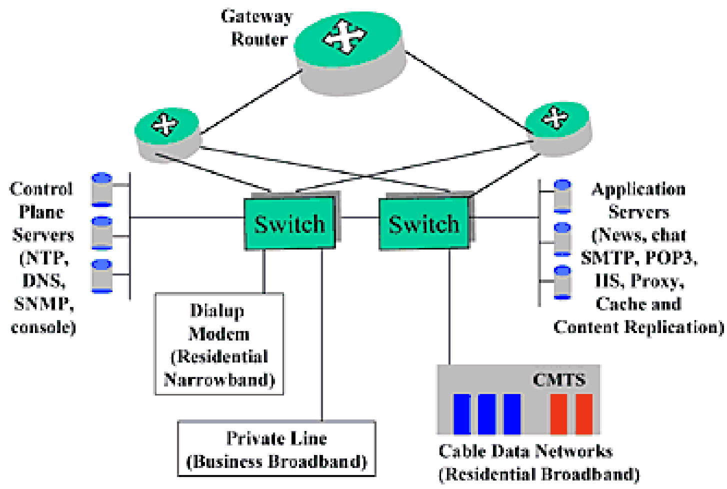


Figure B-6: Regional Data Center

In addition to cable data networks, a regional data center may also support dial-up modem services (e.g., 56–kbps service) and business-to-business Internet services. A network of switching, routers, and servers is employed at the regional data center to aggregate dial-up, high-speed, and business Internet services.

A super hub and a regional data center may be co-located and managed as a single business entity. A super hub is managed by a cable television service provider (TCI), while the regional data center is managed as a separate and independent business (@Home). In some regions, an existing Internet service provider (ISP) may provide regional data center support for many basic and super hub locations managed by independent cable data network providers.

A regional data center is connected to other regional data centers by a national backbone network (see Figure B-7). In addition, each regional data center is also connected to the Internet and World Wide Web services. Traffic between the regional networks, the Internet and all other regional networks is aggregated through the regional data center.

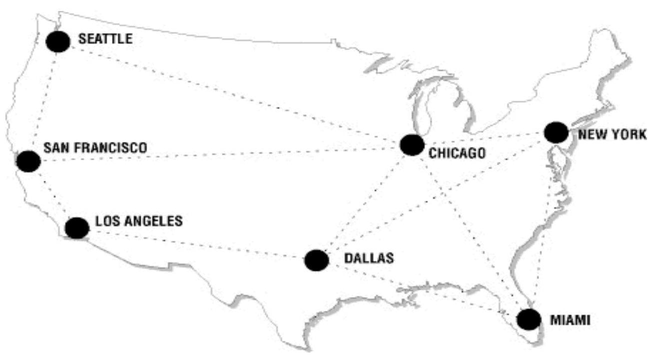


Figure B-7: National Network

6. Cable Data Network Standards

A cable data system is comprised of many different technologies and standards. To develop a mass market for cable modems, products from different vendors must be interoperable.

To accomplish the task of interoperable systems, the North American cable television operators formed a limited partnership, Multimedia Cable Network System (MCNS), and developed an initial set of cable modem requirements (DOCSIS). MCNS was initially formed by Comcast, Cox, TCI, Time Warner, Continental (now MediaOne), Rogers Cable, and CableLabs. The DOCSIS requirements are now managed by CableLabs. Vendor equipment compliance to the DOCSIS requirements and interoperability tests are administered by a CableLabs certification program.

For further details see http://www.cablemodem.com.

Some of the details of cable modem requirements are listed in the following pages.

i) Physical Layer

Downstream Data Channel

At the cable modem physical layer, downstream data channel is based on North American digital video specifications (i.e., International Telecommunications Union [ITU]–T Recommendation J.83 Annex B) and includes the following features:

- 64 and 256 QAM
- 6 MHz–occupied spectrum that coexists with other signals in cable plant
- concatenation of Reed-Solomon block code and Trellis code, supports operation in a higher percentage of the North American cable plants
- variable length interleaving supports, both latency-sensitive and latency-insensitive data services
- contiguous serial bit-stream with no implied framing, provides complete physical (PHY) and MAC layer decoupling

Upstream Data Channel

The upstream data channel is a shared channel featuring the following:

- QPSK and 16 QAM formats
- multiple symbol rates
- data rates from 320 kbps to 10 Mbps
- flexible and programmable cable modem under control of CMTS
- frequency agility
- time-division multiple access

- support of both fixed-frame and variable-length protocol data units
- programmable Reed-Solomon block coding
- programmable preambles

ii) MAC Layer

The MAC layer provides the general requirements for many cable modem subscribers to share a single upstream data channel for transmission to the network. These requirements include collision detection and retransmission. The large geographic reach of a cable data network poses special problems as a result of the transmission delay between users close to headend versus users at a distance from cable headend. To compensate for cable losses and delay as a result of distance, the MAC layer performs ranging, by which each cable modem can assess time delay in transmitting to the headend. The MAC layer supports timing and synchronization, bandwidth allocation to cable modems at the control of CMTS, error detection, handling and error recovery, and procedures for registering new cable modems.

iii) Privacy

Privacy of user data is achieved by encrypting link-layer data between cable modems and CMTS. Cable modems and CMTS headend controller encrypt the payload data of link-layer frames transmitted on the cable network. A set of security parameters including keying data is assigned to a cable modem by the Security Association (SA). All of the upstream transmissions from a cable modem travel across a single upstream data channel and are received by the CMTS. In the downstream data channel a CMTS must select appropriate SA based on the destination address of the target cable modem. Baseline privacy employs the data encryption standard (DES) block cipher for encryption of user data. The encryption can be integrated directly within the MAC hardware and software interface.

iv) Network Layer

Cable data networks use IP for communication from the cable modem to the network. The Internet Engineering Task Force (IETF) DHCP forms the basis for all IP address assignment and administration in the cable network. A network address translation (NAT) system may be used to map multiple computers that use a single high-speed access via cable modem.

v) Transport Layer

Cable data networks support both transmission control protocol (TCP) and user datagram protocol (UDP) at the transport layer.

vi) Application Layer

All of the Internet-related applications are supported here. These applications include e-mail, ftp, tftp, http, news, chat, and signaling network management protocol (SNMP). The use of SNMP provides for management of the CMTS and cable data networks.

vii) Operations System

The operations support system interface (OSSI) requirements of DOCSIS specify how a cable data network is managed. To date, the requirements specify an RF MIB. This enables system vendors to develop an EMS to support spectrum management, subscriber management, billing, and other operations.

7. Conclusion

Cable modem technology offers high-speed access to the Internet and World Wide Web services. Cable data networks integrate the elements necessary to advance beyond modem technology and provide such measures as privacy, security, data networking, Internet access, and quality-of-service features. The end-to-end network architecture enables a user cable modem to connect to a CMTS, which, in turn, connects to a regional data center for access to Internet services. Thus, through a system of network connections, a cable data network is capable of connecting users to other users anywhere in the global network.

4 The Last Mile Access

The Last Mile Bottleneck

An Approach Using Existing Underground Infrastructure

SUMMARY

Egypt has a population of 75 million and its purchasing power parity of GDP/capita is around $ 5,000. Egypt's median age is 23 years, one of the youngest in the world with over one third of all citizens under the age of 14 years, compared to that of America being 36 years. To provide a brighter future to these young people, this is the time because people need not travel to or live in the major cities of G7 nations in the world to enjoy a better standard of living by contributing to the global economy, when fast internet connections using end-to-end fiber to the homes, schools, and businesses are provided.

Egypt should consider solving its last mile bottleneck now to improve Internet penetration through broadband and the quality of life for its citizens and this is the right move and the timing could not be better. Solving the last mile also will provide a multitude of e-learning, e-government, e-medicine, e-entertainment opportunities for its young people for them to move towards a better quality of life than their parents and grandparents.

The Last-Mile is the section of a network that connects from the basement of an end-user building to the metro-area network that surrounds a city. Deployment of metro optical fiber networks to solve the last mile bottleneck requires extensive construction, usually involving excavation of city streets. These excavations cause pollution, traffic hold-ups, economic loss, and unsafe conditions to the inhabitants in every city. Even worse, the repair of the streets after excavation rarely left the streets in acceptable condition.

The novel idea of leasing space inside of existing sewers, electrical conduits, drinking water pipes, and natural gas pipes by telecommunications companies has a rather interesting appeal in that owners of these pipes get to generate a new revenue stream and telecommunication companies could install their optical fiber cables at an attractive cost. Egypt also needs to upgrade their sewers, gas pipes, and waterlines in the coming years. It appears that a viable partnership could be arranged among telcos, pipe owners, service providers, and vendors, where each party has something to gain by cost sharing.

Working in the sewer, water, heating water pipes, or gas pipe will affect the health, safety, and welfare of the people we serve and any shortsighted approach to selecting the suitable sewers or gas pipes for installing and operating optical fiber cable, would expose all those in this new industry to an enormous liability. Developing sound engineering standards to guide this new industry falls well within this obligation and ASTM international is already doing this.

We need to treat the broadband fat pipe in the last mile from the central office to its citizens as either the 5th utility or the roads leading its young people to prosperity and build it in that manner.

This chapter provides a detailed account of usual impediments to last mile construction, an overview and benefits of various technologies that could be used to lay last mile fiber in existing pipes, track record of such technologies around the world, and general cost as compared to open-cut laying of fiber cables in the last mile using American construction data.

It is highly recommended that the Egyptian government proceeds with the feasibility study of how the various technologies described in this report would apply to solving the last mile in Egypt by using existing pipes for its population with the technologies outlined in this report and implements the first project to launch its broadband plan into quick action.

The civil works is normally about 70 to 85% of the total cost of last mile and fiber to the home (FTTH). The cost of doing the civil works for the last mile fiber and FTTH in Egypt using existing pipes could be as little as **2% to 30%** of what it would cost using open cut construction. In real terms, if a suitable section of Cairo is chosen for the first project with 30,000 homes within 2 to 3 km radius of the central office with a POP, this cost of last mile fiber deployment could be about $ 200 to 500 per connection depending on the specific technology used. Clearly, to provide end to end service to the customer, additional optical communications equipment are needed and estimated to be another $ 200 to $ 1,000 for the optical equipment per connection, if the vendors are chosen carefully.

4.1 INTRODUCTION

Although the North America has one of the most modern transportation systems in the world, more than 110 million North Americans are expected to telecommute to work by 2010. This will increase our productivity and quality of life significantly. This will also save energy, reduce pollution, and re-distribute the wealth and real estate values. Turning to Cairo, Egypt, it has a resident population of 8 million and during the workweek this number swells to 15 million. The traffic congestion in Cairo causes tremendous economic loss to the Egyptian economy, its people, and companies. Unless information superhighway is made available to the masses in Egypt at an affordable cost, Egyptian people will lose much in the 21st century. For this to happen, we could turn to existing underground infrastructure to build our communication networks, so that we can avoid additional congestion underground. North America already has invested many trillions of dollars in the past century building over 7,000,000 km of pipes as shown in Table 4.1. Likewise, the Egyptician cities also have an extensive network of pipes in their cities and this needs to be documented soon. As a matter of fact the Egyptian engineers thought of building modern sewers hundreds of years ago well ahead of most other civilizations.

Table 4.1: Underground Utilities in America

Type	Km
Sanitary sewers	1,280,000
Storm drains	720,000
Combined sewers	160,000
Potable waterlines	1,360,000
Natural gas lines	1,800,000
Petroleum pipelines	480,000
Irrigation pipelines	320,000
Industrial waste lines	880,000
Total	**7,000,000**

Civil engineers have been responsible for planning, designing, constructing, operating, and maintaining this vast network of pipes below our feet. Civil engineers need to start planning now toward working more closely with telecommunication engineers in making the information age come into full bloom so that any obstacles can be removed with the team approach. This will involve sharing the underground so that the same pipes are used for multiple functions and broadband telecommunications pipe becomes the 5th utility after water, sewage, gas, and electricity. The absence of local optical fiber broadband loops in the last mile also impedes the optical Internet and indeed is a major contributing factor to the slowdown in the telecommunications industry. The utilities are well positioned to solve the last mile problems than any other players due to the fact that they have the ability and incentive to invest in a high-capital cost, low-return access network. And they already own the pathways to the very end users who crave for broadband service all over Egypt.

4.1.1 Last Mile Bottleneck Defined

In America, over 400,000 km of fiber cables are in the ground. Likewise. Even building owners have started laying fiber from their rooftop to basement; however, the missing link is still the last mile. While the entire telecommunications industry is in chaos, everyone in this industry should ask the fundamental question: "where are the “on and off” ramps to the information superhighway most companies have been building for 2 decades in optical fiber cables?" The answer is " these do not exist to and from more than 97% of the commercial real estate all across America and the picture is even more dismal for multiple tenant units and single family homes. Naturally these information superhighways with their limited points of origin with a similar tale at the other end would remain empty with no one willing to pay the toll to the owners of such long haul networks. These limitations result in a mere 5 to 10% of the long haul fiber being lit. Given how we humans always take the path of least resistance have avoided bridging the last mile, which would be the hardest and the costliest, without ever realizing that without the ultimate on and off ramps, there would be no use for such long haul routes circling the continents. The so-called fiber glut in the backbone and long haul fiber networks is mostly due to the lack of last mile fiber to provide the final link between the premises and the long haul carriers of data, voice, and video and this indeed is the case in Egypt.

4.1.2 Challenges in the Last Mile

There are numerous challenges for anyone other than local utilities or Incumbent Local Exchange Carriers (ILECS) to build the last mile fiber. Local municipalities control access of much needed rights of way. They charge franchise fees, make the permit process really difficult, and pass numerous ordinances to discourage open cut construction of fiber and even impose network build moratoriums. Some even demand free fiber, where the network provider will lose even their existing revenue from the very municipalities, while requiring that the network builder pass on to them a portion of the gross revenue from the remaining fiber. Often, the areas where municipalities are willing to let fiber construction proceed are not where demand is and even in these, municipalities enforce strict time limits. The ILECS already have infrastructure in place in most locations and only fiber laterals are left to bridge the last mile.

When local utilities enter the business of building their own fiber and running a network provider, unless the private companies join in this effort, they would find even more fierce competition in the only remaining profitable area of fiber business named the last mile. Building owners also erect hurdles such as entrance fees, connection fees while even unwilling to provide permission to many Competitive Local Exchange Carriers (CLECS). Even the regulatory environment has not given the CLECS the legal teeth they needed to compete more aggressively in the marketplace against the ILECS. The result is a mere 10% penetration by CLECS in the local access market even after 7 years of operating in the aftermath of the Telecom Act of 1996, although there is further gain in number of access lines in the last year against RBOCS. This situation of predatory behavior by one major player against others is similar in Egypt. However, the competition the Egyptian government creates needs to be carefully controlled than let too many players in this line of work.

Most significantly, the last mile fiber carrying conduit design and installation has been in the hands of mostly telecom personnel with either little or no input from civil engineers, resulting in expensive and laborious implementation adding further to the problems surrounding the last mile. If adequate civil engineering talent were involved in approaching the municipalities for access to rights of way on behalf of fiber installers, given the very municipality public works departments are managed by civil engineers, matters would have proceeded a lot quicker and cheaper.

4.1.3 Need for Broadband

Copeland and Malik [8] reported that without widespread high-speed Internet access, the technology industry and the economy would remain stalled in most countries even in the developing world.

The optical fiber industry has kept its pace of inventing better fibers and Dense Wave Division Multiplexing (DWDM) equipment. For example, Hecht [13] reports that Alcatel and NEC independently have squeezed more than 10 Tbps (terabits per sec or 10^{12} bits per sec) through a single strand of fiber in September 2002. This capacity translates to carrying over 150 million telephone calls simultaneously in a single strand of fiber. Soon, Bell labs will announce its plans to transmit 200 Tbps, enough to send the entire 10 million volume library from the University of California at Berkeley to anyone in the world in 10 seconds, all through a single fiber core that measures less than 7 microns in diameter or less than 5 % of the thickness of the human hair. Despite these major advances, an optical fiber network is only as fast as its weakest link. In America, over 400,000 km of fiber cables are in the ground covering long haul, backbone, and metro loops; however, the missing link is still the last mile of route length as short as 5 to 500 m. This has led to, for example, most companies having only 1 out of every 100 strands of fiber lit to meet the demand for their dark fiber. Would the civil engineers survive the wrath of our public had we built our infrastructures at an enormous cost only to serve at mere 1% of their design capacities?

4.1.4 Stakes Are High For Any Country

South Korea has become the global leader when it comes to broadband deployment. They have been doing it with government support and because most of their population are in major cities embracing new fashion faster than most other cultures. South Korea decided in 1995 to become a knowledge-based economy and set a national policy of connecting every home at 100+ Mps by 2004 and they have been well on their way to realize this goal. Studies indicate that by 2005, the world will have more than one billion Internet users, but most of them will be in Western Europe and Asia. Egypt needs to be in this group if it wants to come up as a global force in this new century and this would require solving the last mile as fast as possible at the lowest possible cost. In the information age, the nations that invest in a digital highway will have a major advantage. These nations will have the informational infrastructure to educate their people, have ready access to worldwide know-how, develop products, and deliver goods and services much faster than others. The opportunity for our children and adults to participate in distance learning, telecommuting, telemedicine, electronic entertainment, outsourcing will all suffer if we do not invest in the last mile connections using optical fiber.

4.1.5 Cost of Doing in Pipes and Defining a National Broadband Policy

When America built the interstate highways, it spent about $ 20 million per km. It costs over a $ 1 million per km to build underground power distribution cables in dedicated conduits, about $ 450,000 to 700,000 per km for fiber in dedicated conduits laid by open cut construction, and a small portion of this if the optical fiber is built in existing pipes, electrical conduits, or in pavements. In general terms based on American cost of fiber deployment, open cut construction for laying fiber cables cost in the range of \$ 450 to 700/m plus all the social costs, whereas the cost of laying optical fiber cables in existing pipes, micro-trenches, or occupied electrical ducts would be in the range of \$ 15 to 150/m. ***We feel that in Egypt the cost of deploying optical fiber cables in existing pipes would range from 2 to 30 % of the cost of using open cut, disruptive dedicated conduit laying***. Senator Lieberman wrote in May 2002 [52] "*Much of the technology for broadband is already at hand. Hence, there is not a major technology development challenge here, although some R&D on last mile issues is needed.*" Korea, Japan, Sweden, Belgium, Denmark, Hong Kong, Singapore, and Canada did not wait and their uptake rates ahead of America's prove that Senator Lieberman is so right.. This is only possible if there is government involvement in the form of a national broadband policy.

The Egyptian government could mold the policies to provide guidance to the owners of existing pipes, conduits, and pavements much along the way <u>the Japanese government</u> opened up the usage of sewers to carry more than sewage in 1996 and setting targets to <u>deploy a national broadband network spanning 100,000 km in existing sewers alone.</u> The government could step in to start even shifting funds from highway construction and renovation to deployment of last mile fiber, given less and less people will be driving in the coming years. Moving tax dollars that have for years funded highway projects into last mile construction in existing sewers, potable water lines, natural gas lines makes perfect sense also when we recognize that we as a nation have ignored the underground infrastructure for 100 years and we are having major problems finding adequate funds to renovate these pipes to prevent serious health problems to our citizens.

If not for the Federal Department of Transportation in America, the interstate highway system would have never materialized. Just like the road system received funding from federal, state, and local governments, the last mile construction needs help from the same governments.

4.1.6 Security, Power Grids, Lifelines, Plants, Pumps, and Compressors

If the optical fiber technology could be rolled out at a faster pace, with less hurdles in rights of way acquisition, and at a lower cost, then end-to-end optical fiber connectivity could win this race in the coming years in the last mile. For this to happen, we need to turn to existing infrastructure to build our communication networks, so that we can avoid additional congestion underground. North America already has invested many trillions of dollars in the past century building an extensive underground pipe network, electrical conduits, and roads. So had the people of Egypt over the past centuries. These underground utilities and roads were carefully engineered, constructed, operated, and maintained with mostly public funds. Most of these have been stable well-protected structures deep in the ground forming a vast network.

Egypt has similar underground pipe networks. The underground pipe network usually goes through continuous renovation and repair and this is all the more reason why a partnership among the Egyptian pipe owners and telecommunications operators would make perfect sense, where they get to pool their resources and solve their common problems. These pipes have served their intended functions meeting our needs for over 100 years. Using them for the un-intrusive housing of broadband fat pipe would speed up significantly the deployment of fiber in the most challenging last mile. These would afford us an opportunity to monitor the security of these underground lifelines. These would also provide us an opportunity to operate treatment plants, compressors, pumps, and other equipment unmanned from remote unknown locations toward better homeland security measures. The power grids also could be monitored with the use of an optical network to improve its reliability and security. Additional details on the win-win solutions from the business plans involving optical fiber deployment in existing sewers and gas pipes have been discussed in more detail in Jeyapalan [14-49] and Welch [65]. There are a number of cities around the world that have used existing utility pipes for building their broadband networks while serving their originally intended functions and Table 4.2 provides a partial list. It appears the needs of last mile, renovation of aging pipeline infrastructure, and improved sensing and surveillance could all be accomplished by municipalities taking the lead to build the last mile networks with suitable partners in existing pipeline infrastructure as outlined in Jeyapalan [14-49].

4.1.7 Synergies Among Multiple Uses Have Been Around Since 1983

Using existing conduits for multiple uses is not a new concept. Early attempts were in Paris more than 100 years ago but poor results led to abandonment of the concept of installing multiple utilities in the same underground tunnels. There also were a number of projects in America about 100 years ago where telephone companies were permitted to lay their cables inside of drinking waterlines. The innovative idea of using existing fluid conduits for additional functions not originally intended, emerged again in 1983 when Jeyapalan et al. [47-49] designed 2 high pressure hydropower penstocks of size 2.1 m in diameter to hang from the roofs of 6.4m diameter outlet tunnels at Jennings Randolph and Gathright dams in West Virginia and Virginia. These large penstocks were designed in 304L stainless steel to survive the acidic water with a pH of 3 or less flowing through the outlet tunnels.

Table 4.2: Broadband Networks in Underground Utilities

City	Length (Km)	Type
Albuquerque	9	Sewers
Almelo	50	Gas lines
Amsterdam	2	Sewers
Berlin	50	Sewers
Copenhagen	2	Sewers
Donau Ries	2	Gas lines
Forth Worth	2	Gas lines
Gevelsberg	2	Gas lines
Hamburg	100	Sewers
Hamm	11	Gas lines
Hanau	5	Sewers
Helmstedt	2	Gas lines
Himeji	5	Sewers
Indianapolis	5	Sewers
Kawasaki	37	Sewers
Kyoto	18	Sewers
Long Beach	2	Gas lines
Lunen	8	Gas lines
Madrid	1	Sewers
Minami	13	Sewers
Nagoya	18	Sewers
New York	140	Electrical
Ogaki	24	Sewers
Osaka	6	Sewers
San Vendemiano	2	Gas lines
Sapporo	21	Sewers
Sprockhovel	3	Gas lines
Taichi	250	Gas lines
Taipei	300	Gas lines
Tokushima	4	Sewers
Tokyo	850	Sewers
Toronto	5	Sewers
Vienna	400	Sewers
Wilksboro	3	Gas lines
Yodogawa	11	Sewers
Yokohama	42	Sewers

A series of hydraulic model tests were performed initially at Sogreah, Grenoble, France and then for convenience these models were moved to Alden Research Laboratory in Holden, Massachusetts. In these physical model tests, we simulated the flow conditions in the tunnel under various operating curves of the reservoir and forces acting on the penstocks were measured to ensure that the penstocks and their supporting anchors could be designed to carry the anticipated loadings on the penstock and the tunnel linings during the design life of 50 years. The impact of penstocks occupying some portion of the waterway in the tunnels was also studied in the model tests to ensure that the installation of the penstocks did not affect the originally intended functions of the existing tunnels.

There were numerous unprecedented design features that were included in these designs to provide the client the lowest possible water-to-wire cost per kilowatt of the hydropower generated, all due to the fact that the dam and the tunnels were already there. The above scheme was also chosen to prevent any disputes with environmentalists so that the project implementation could be achieved in the shortest possible time without any unnecessary delays.

4.2 TECHNOLOGY OVERVIEW AND TRACK RECORD IN OTHER COUNTRIES

4.2.1 Robots For Optical Fiber In Sewers From Japan

Shortly thereafter, the first invention for using existing sewers for installing communication cables was developed by a group of engineers from the Water Research Center (WRc) in UK. A patent was issued by the UK patent office on 16 May 1984. Subsequently, the US patent No: 4,647,251 was secured on March 3, 1987 and the assignee was Cabletime Installations Limited operating out of Washington, DC. For reasons unknown even to the current employees of WRc, this patent was allowed to expire due to nonpayment of annual dues after WRc attempting to commercialize this invention for some years. Japanese assembled a robot in 1987, following an art somewhat similar to that disclosed in the UK invention, to install optical fibers initially in Tokyo sewers, and the Japanese applied for European, Japanese, Korean, and US patents. The US patent No: 4,822,211 was issued on April 18, 1989 with Nippon Hume [54], Tokyo Metro Government [58-59], and Tokyo Metro Sewer Service Corporation as co-assignees to protect the robot shown in Figure 4.1.

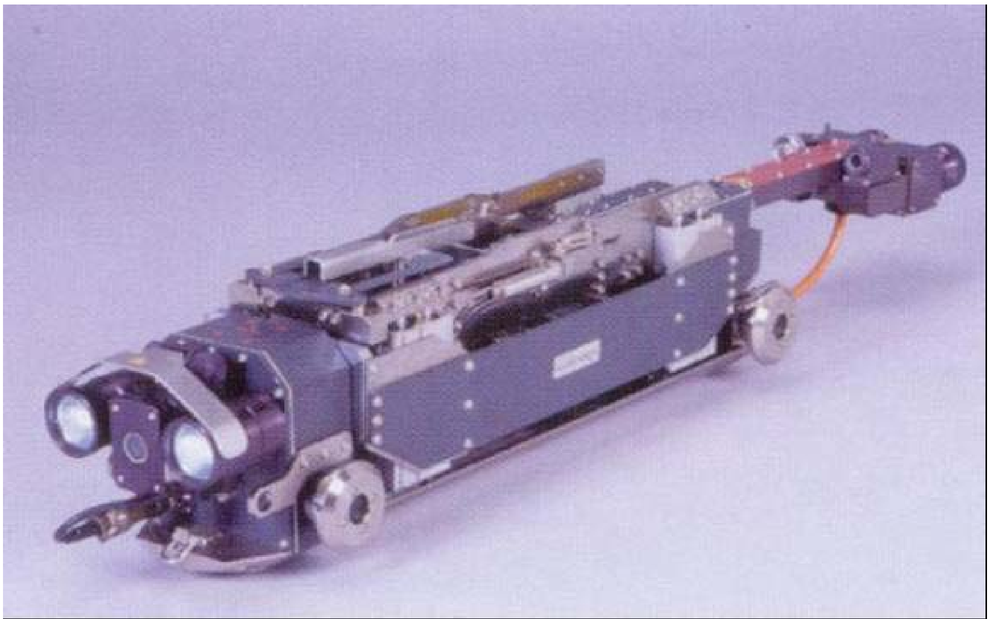


Figure 4.1: First Optical Fiber Cable Robot by Nippon Hume

The primary reason for the Japanese engineers to install optical fiber in their sewers in Tokyo in 1987 was to control sewage treatment plants remote without having to employ human power at each of these locations as given in Shinoda [57]. Tokyo Metro Government and

Tokyo Metro Sewer Service Corporation promoted this concept as their SOFT plan widely and a sampling of such efforts is evident in. Subsequently, the Japanese engineers formed JSOFTA [14] and promoted this technology for additional functions as reported in Fujiyoshi and Yoshikazu [10] and JSOFTA [55]. JSOFTA was also instrumental in changing the Japanese public law in 1996 for the sewer owners to permit materials other than sewage in their sewer system paving the way for a wider deployment of fiber in the sewer. Tokyo Metro alone has more than 850 km of fiber in the sewer, with about 140 km installed by these robots, more than any other city in the world as shown in Figure 4.2. According to Nippon Hume, the original robots had options to either be self-driven or operated by winches. Given most of the sewers in Japan were made of centrifugally cast reinforced concrete pipe, drilling into the pipe wall required significant amount of power through the umbilical cable supplying water, air, electricity, and communication circuits.

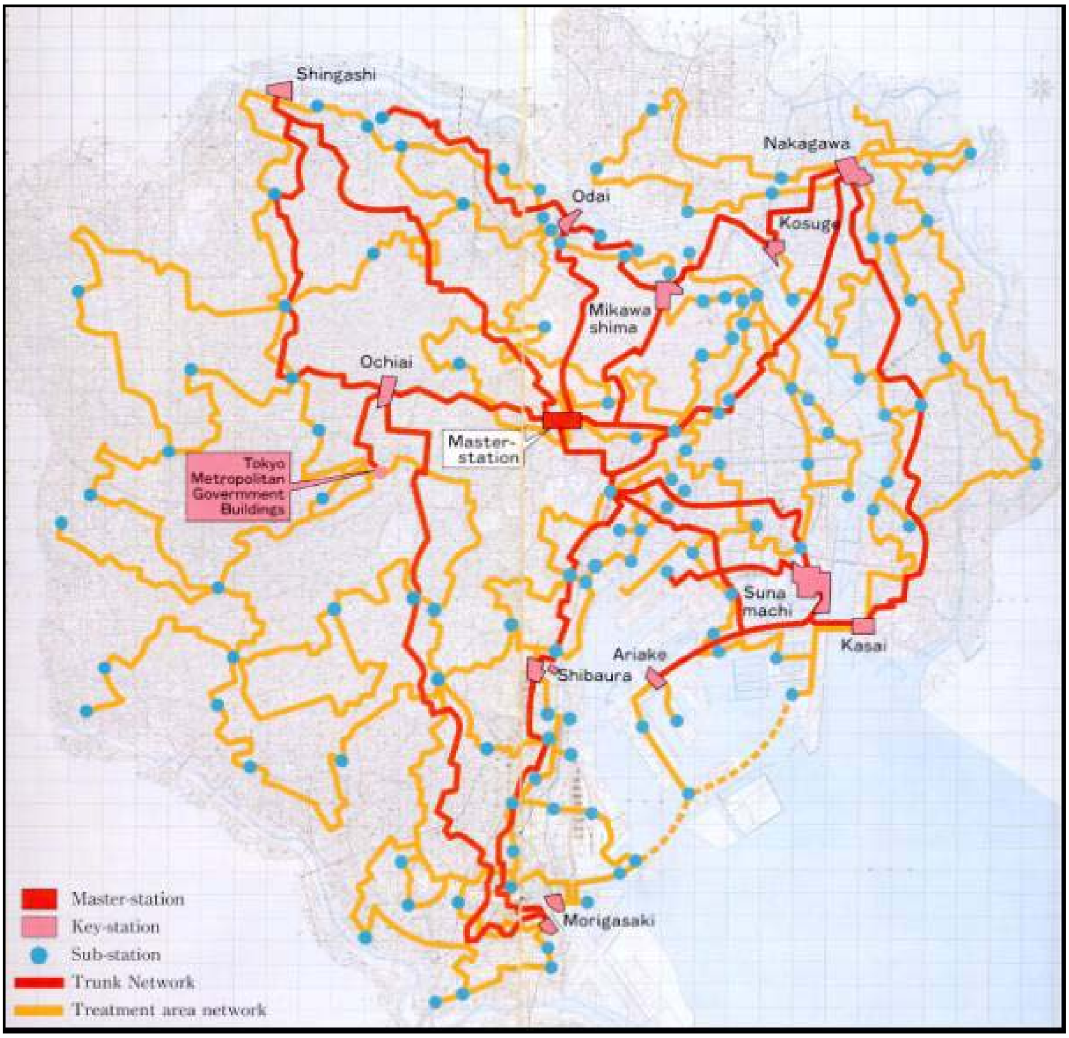


Figure 4.2: Optical Fiber Cable Network in Tokyo Sewers of Over 850 km

According to Nippon Hume, when the Tokyo Metro discovered that it was better to conserve power, self-driven robots were not the preferred option. Nippon Hume began to promote this robot system for sewer sizes 200 to 1200 mm widely as shown in Nippon Hume [54]. Recently, the Japanese Ministry of Construction has also published a goal of building

100,000 km of optical fiber networks in existing sewers all over Japan by year 2010 toward promoting the Multi-Media Society. In America, the Technology Network has called on the federal government to adopt a goal of 100 megabits per second to 100 million homes and small businesses by 2010.

Likewise, Egypt also needs specific goals for its broadband deployment program and specific planning for the last mile.

4.2.2 Berlin Using Nippon Hume Robots

BerliKomm owned by Berlin Water had an ambitious plan in 1997, in that it would provide each customer in Berlin with a broadband connection within 30 days of asking. Berlin water turned to 3 Japanese robots sold by Nippon Hume initially by setting up a new company named Robotic Cabling GmbH Kabelverlegung (RCC) owned with Marubeni and Nippon Hume and installed about 1500 m of optical fibers in its own combined sewers in Berlin in the winter of 1998. The Japanese robots used by Berlin water came in 3 sizes with various undercarriages for pipes of 250-350 mm, 400-450 mm, and 500-1200mm. The robot was steered by a control unit but was not driven by its own power, according to Beyer [5,6]. Instead, they were pulled using winches through the manholes. A special drill was used to cut a hole 6 mm dia. 15 mm deep for the J-hook anchor of the cable with its 2 part resin system that hardens in the hole after activating the plunger pin once deployed after placing the optical fiber cable in the J-hook. Berlin Water as of January 2000 solely owns this business entity and has replaced the Japanese robots with those manufactured in Germany by JT Elektronik GmbH where 2 robots could work in pipes of 200 to 1200 mm, provided the right undercarriage is used. According to Beyer and Nippon Hume, Berlin water returned the two units of second-generation robots back to Nippon Hume, but kept the third unit of the first generation.

A change from the version of the Japanese robots Berlin used is that the 3 units assembled in Berlin could propel it once inside the sewers, in a way no different from the robots Japanese had in their first generation for Tokyo Metro, installing the cable at speeds as high as 200 m/day under optimal conditions. Unfortunately, the Berlin drill and dowel anchor robot has eliminated the use of the 2 part resin bonding the Japanese system uses, in our opinion increasing the likelihood for the anchors to drop out of the holes in which they are inserted onto the floor of the sewer pipe, along with the optical fiber cable. We are also unaware of any patents protecting RCC's technology and why RCC has not been able to sell their robot technology even in Germany for use in sewers owned by any cities other than RCC's owner, Berlin Water Service. It is our understanding that more than 35 sets of robots have been manufactured and delivered by Nippon Hume over a period of 12 years, and 58 sets by Ka-te in 3 years, while RCC produced a total of 3, confirming that RCC is yet to prove marketplace acceptance for their technology.

4.2.3 Ka-Te's Fast Robot System

This technology is FAST [2] only in its name when indeed in real life, this is the slowest and most expensive. We have learned that RCC's owner Berliner Wasser Betriebe attempted to patent the very clamp and conduit system Ka-te uses. A few months after Ka-te applied for patents in Europe and elsewhere for its current clamp and conduit system, RCC's owner Berliner Wasser Betriebe applied for a system so similar to the Ka-te's system without realizing that Ka-te had already filed for the same invention ahead of RCC. It's even more incongruous, in our view view, that the words RCC's owner used in its patent application titled "Method and Device for Inserting, Positioning, and Fixing of Constructional Components in Cavities Having Different Cross Sections," to justify its application reads: *"A problem lies in the introduction and fixing of the cables, especially in the case of ducts having narrow cross sections. The use of robots for this work is well known (EP 0 251 907, Nippon Hume Patent), wherein the fixing of the cables by plugging is very (sic) disadvantageous as damaging the duct walls may cause leakage and groundwater pollution. Furthermore, the plugging technique is well known from DE 16 50 994 and DE 35 01 676. In this case, different straps are installed using the drilling/plugging techniques, which also has some (sic) disadvantages."* We found that when RCC's owner learned that Ka-te had filed for the same invention of clamp and conduit system, it withdrew its application and returned to using the very method of drilling the sewer pipe wall and plugging with a J-hook that it found to be detrimental to the sewer pipe walls and the quality of the groundwater due to possible leakage through the holes RCC's robot makes in the sewer wall. This serious concern is understandable, given a 200 mm concrete pipe has a wall thickness of only 19 mm, while the depth of the hole RCC robot makes is 15 mm. With most aged sewers of concrete pipe with a significant portion of its wall thickness missing due to sulfide corrosion, it is our position that it is possible for the drill hole to penetrate clear through the sewer wall at the most critical crown position of the sewer pipe. Support for our views has been documented in a research note titled "Data Superhighway in the Drain,"by RCC's cable partner Corning Cable Systems [9] from Munich, Germany in the following words when they introduce their MCS-Drain solution as *"The operator does not require any special tooling or even robots for this purpose. The drain pipe wall does not have to be drilled and is not therefore affected structurally."*

Ka-te's fiber robot technology shown in Figure 4.3 allows point-to-point connections while being able to also form backbone connections as either loop networks (“rings”) or mesh networks as well as connections in many different patterns to meet varying customer demands.

Figure 4.3: Optical Fiber Cable Robot FAST

Depending on the diameter of the sewer pipes, up to 9 optical fiber cables in stainless steel conduits can be installed side by side in a sewer system. These cables are of either 72, 144, or 216 fibers. The outer diameter of these protective conduits, which carry the fiber optic cables measures on the order of 11.5 to 15.5 mm. The speed of installation is on the order of 150 m/day for anywhere from 1 to 9 cables in the sewers. Because of the fact that the optical fiber cables are housed inside the conduits, if a cable needs to be replaced during the design life either for maintenance or due to significant technological advances occurring in fiber technology, it could be done readily without having to re-construct the network all over again. Work could start rather quickly compared to open-cut work. Most work is done at night when the traffic is low and the flow in the sewer is at its daily minimum. This system can install optical fiber transmission networks in non-man-entry sewage pipes with diameters from 200 to 700mm. The Ka-Te special installation robot has been developed for the laying of protective conduits carrying optical fiber cables in non-man entry sewage pipes as shown in Figure 4.4.

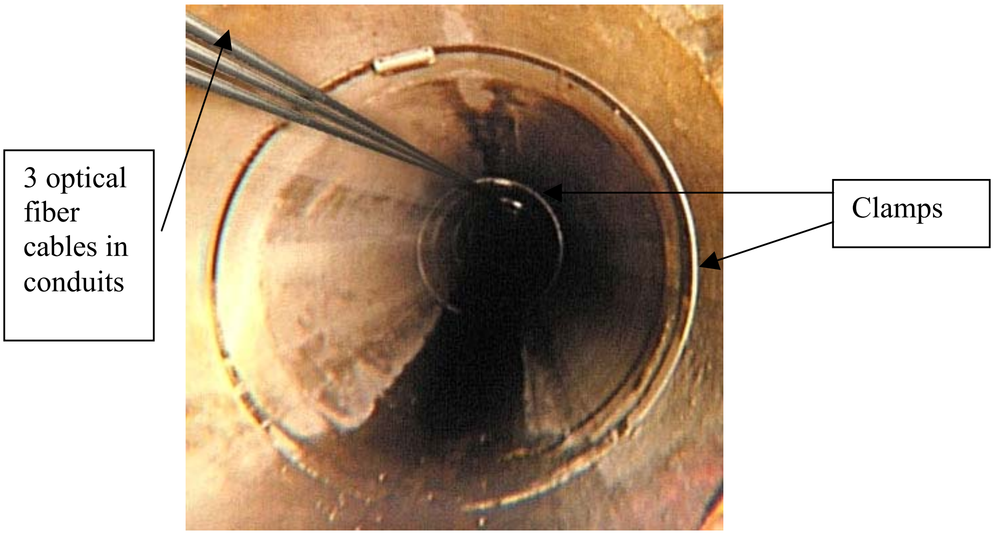


Figure 4.4: Optical Fiber Cables in a Sewer Using FAST

In order to install a clip ring, the spring box on the clip ring is unlocked, so that the ring is snugly pushed against the sewer pipe walls engaging the 4 springs. The cables are tightly fixed to the inside sewer wall without any drilling, cutting or screwing. Depending on the requirements of the communications network, clip rings for sewers with a diameter of 300mm and above can be equipped with up to 9 clips, so that up to 9 protective conduits or 9 optical fiber cables can be mounted. Sewers with a nominal diameter of 200 to 250 mm can be equipped with a maximum of 3 clips. The planning of the work commences with a CCTV inspection, mapping, and analysis of the sewer line. Any maintenance work needed is carried out at the onset before installing any cable conduits. In the next step, the clip rings are installed in the sewer by means of the robot. Each ring is fitted with 3 to 9 clips that are used to fasten the steel conduit that will house the single mode optical fiber cable. The rings are loaded into a magazine that is attached to the robot, which then travels through the sewer, using a laser guide to precisely place each ring in its prescribed location within the sewer – approximately every 1.5 m apart. Once all the rings are placed, this robot crawls back out of the sewer and is fitted with another head, which transports the conduit through the sewer. Once again using the laser guides, the Ka-te robot fastens the conduit to the clips, locking it securely in place. When this part of the process is completed, the conduit is ready to accept the optical fiber cable. Using a push-pull method, the cable is threaded through the conduit, and then terminated to a patch panel inside the building for use by carrier customers. Single mode fiber was selected because it offers the best mix of high bandwidth capability and wide range compatibility with carrier customer systems. Following installation, usually the optical fiber owner then routinely inspects the sewers and provides any necessary cleaning to preserve the integrity of the network and the function of the sewer. Furthermore, the existing sewer pipe structural integrity remains unscathed. Despite of all of this, Ka-te' system is slow, cumbersome, and most expensive and we do not see much potential for this technology to be used in Egypt or in any other country. Because the City of Hamburg is a partner in the FAST system, despite it's enormous cost, this city is the only one that uses FAST system for 50% of its route length of fiber networks built on the average 100 km per year as shown in Figure 4.5.

Figure 4.5: Fiber Network in Hamburg Sewers

4.2.4 Optical Fiber in Sewers

In summary, CableRunner uses a drill and dowel system in sewers of 250 to 700 mm in size. DTI-CableCat uses either a back-reamed anchor or an adhesive bed system in sewers of sizes 200 to 1200 mm, while Nippon-Hume and RCC use drill and dowel systems for the same sized sewers. Ka-te uses a clamp-conduit system in sizes smaller than 700 mm. In addition, there are liner systems vying to do some of this as part of routine sewer maintenance programs. There is a good chance that these liner companies will succeed if they are able to offer value-added relining systems for an attractive incremental fee to the city sewer agencies over the standard lining systems without cutting too much into the current functions of the sewers. Tokyo Metro Government (TMG), Corning Cable Systems MCS-Drain, and Ashimori Industries' offering to use tensioning devices to span the optical fiber cable manhole to manhole to anchor them on the walls of the manhole are quite similar and this is shown in Figure 4.6. It is also possible to replace an aging pipe carrying sewage, water, or gas with a new pipe and provide additional smaller sized conduits on the outside of the new pipe for the insertion of optical fiber cables and/or power distribution cables.

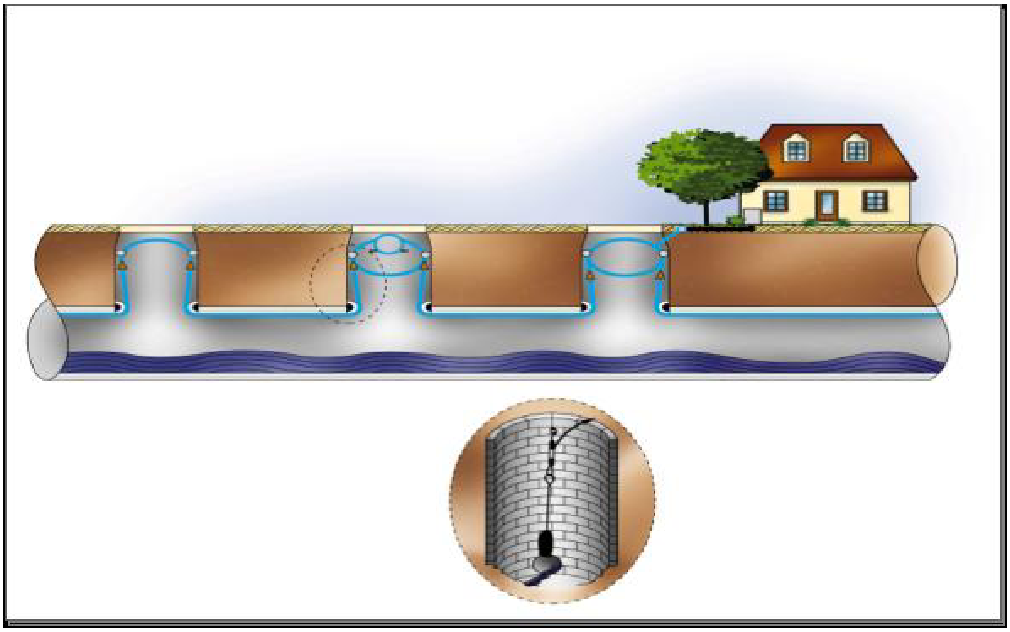


Figure 4.6: Corning Cable's MCS Drain System

If the sewer is larger than 700 mm in size, then many possible ways of using humans to attach the optical fiber cables to the walls of the sewer can be used at a relatively low cost of materials and labor and at high production rates. Brugg cables shown in Figure 4.7, have placed over 280 km of its sewer link at the bottom of sewers in the past 10 years.

Figure 4.7: Optical Fiber Cable Sewer Link by Brugg

An adhesive bed robot is being developed by DTI-Cable Cat as shown in Figure 4.8.

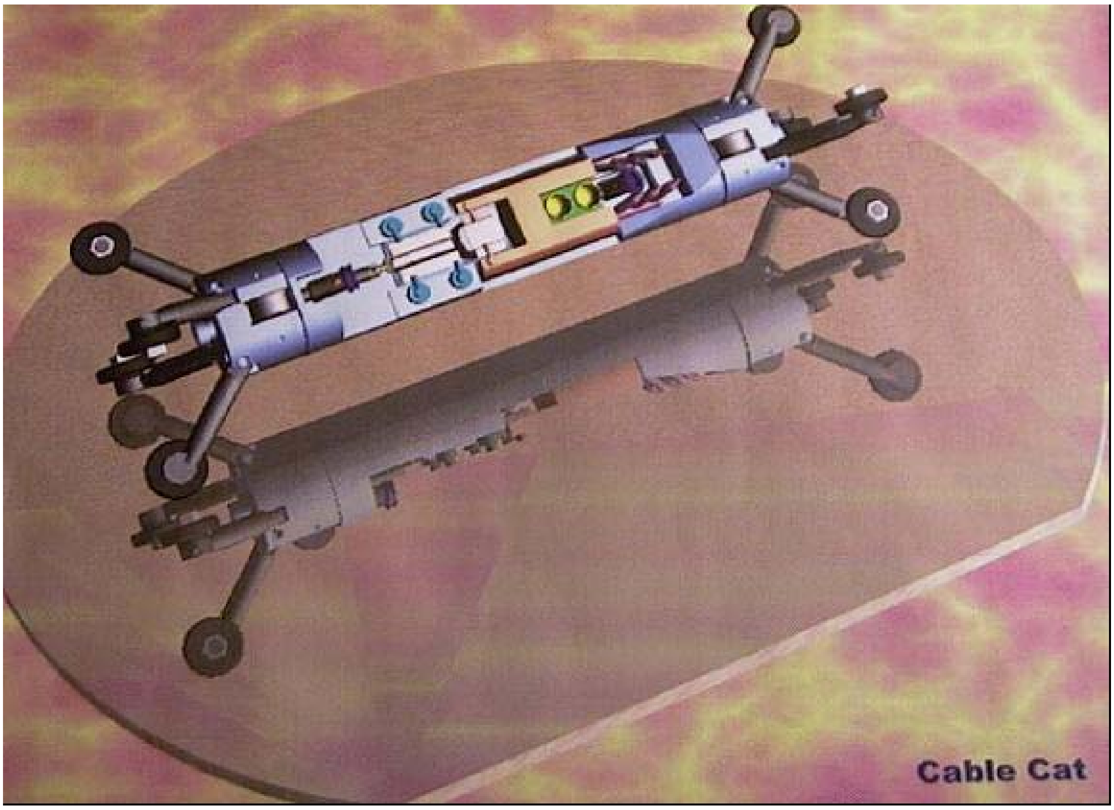
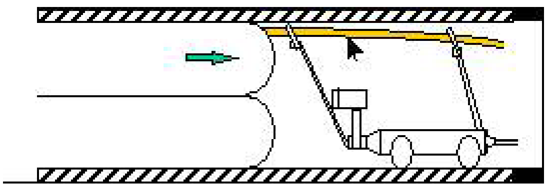


Figure 4.8: DTI-CableCat Adhesive Bed Robot Under Development

NHC's latest robot system is shown in Figure 4.9 Using lining methods to repair leaking sewers to include fiber cables in the last mile is another option and 2 of many such technologies as offered by Brand-Rex [7] and Topcote for example are shown in Figure 4.10 and 11. We are able to pick and choose among over 20 different ways to include additional ducts for either pulling or blowing optical fiber cables through as part of relining a leaking pipeline, and the best choice when it comes to speed of execution, ease of use, and overall cost is governed by the specific site conditions at hand in a project.



Robot Installing The Felt With Additional Ducts For Optical Fiber

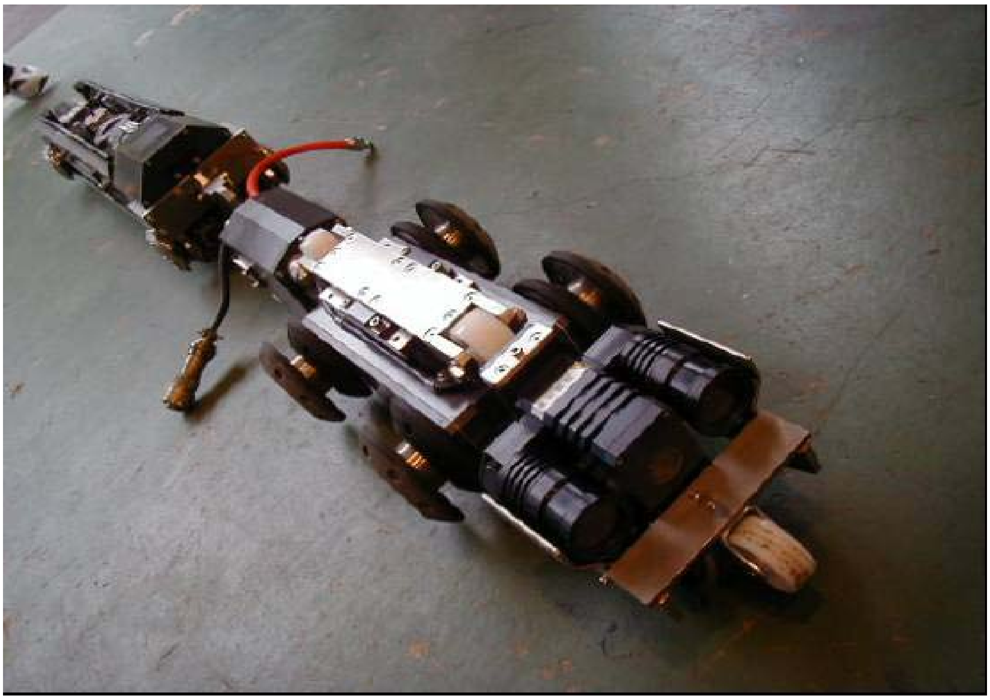


Figure 4.9: Nippon Hume's 3rd Generation Modular Robot

Figure 4.10: Bytes in Old Pipes Solution from Brand-Rex

Figure 4.11: Fiber Cable as Part of Relining Leaking Sewers

4.2.5 Important Manholes

The sewer manholes form an important part of this technology due to them serving as major access ports. Junction boxes and extra cable lengths are stored in telecommunication hand holes located in close proximity to the sewer manhole yet away from the main traffic thoroughfares. These hand holes also serve as customer connection points. The initial plan for fiber companies is to target buildings, which meet certain criteria such as minimum floor area, number of tenants, building owners' needs, type of tenants, existing communication services in the area, etc.

A ring topology is preferred to service the buildings to meet redundancy requirements, optimum bandwidth needs, the tree and branch geometry provided for in the sewer paths, future expansion needs, etc. The splice points on these mini-rings are located off the main traffic route to provide a safe zone for access for customer connections and for easy O&M. Connections from the street sewer optical fiber ring to the premises will be through pipes installed for carrying the fiber. These dry connections are sealed with mechanical means to ensure that a) there is no I/I into the sewer and b) no sewer gas escapes.

4.2.6 Optical Fiber In Natural Gas Pipes

Sempra Fiber Links [56], Alcatel [1,51], and Gastec [11] are three companies offering new technologies to install optical fiber cables in natural gas pipes. In Sempra's technology, special fittings are attached after tapping the gas main at two locations to form the entry and exit points for the optical fiber The gas mains could be even as small as 25 mm in size and the fiber conduit will take up to no more than 10% of gas flow area. In the event a particular gas line cannot handle even a 10% reduction in capacity, additional pipe capacity will be added. A small HDPE conduit is threaded through the entrance fitting until it reaches the exit fitting. A special tool is used to grab hold of the threaded conduit and pull it out through the exit fitting. Once this housing conduit is placed in the gas main, the optical fiber cable is pushed through this conduit from one fitting to the next. The fittings and seals are designed to meet all gas pipeline safety requirements of the U.S. DOT, CFR 49, section 192 and any local regulations such as California PUC General Order 112-E. Sempra reports that a crew of 5 to 7 workers can install up to 600 m per day.

In the Alcatel system, a balloon device shown in Figure 4.12 is used to pull a specially designed optical fiber cable through the Inlet port clear through the Outlet port shown in Figure 4.13 using a gas pressure differential. The cable itself has a special metallic barrier as shown in Figure 4.14, to prevent hydrogen gas migration to cause the optical fiber strands going blind. Again, the seals and the ports are designed to meet various safety regulations. A schematic of how this system works is given in Figure 4.15. More details could be found in Leppert et al. [51].

Figure 4.12: Special Balloon Used in Alcatel Gas Pipe Technology

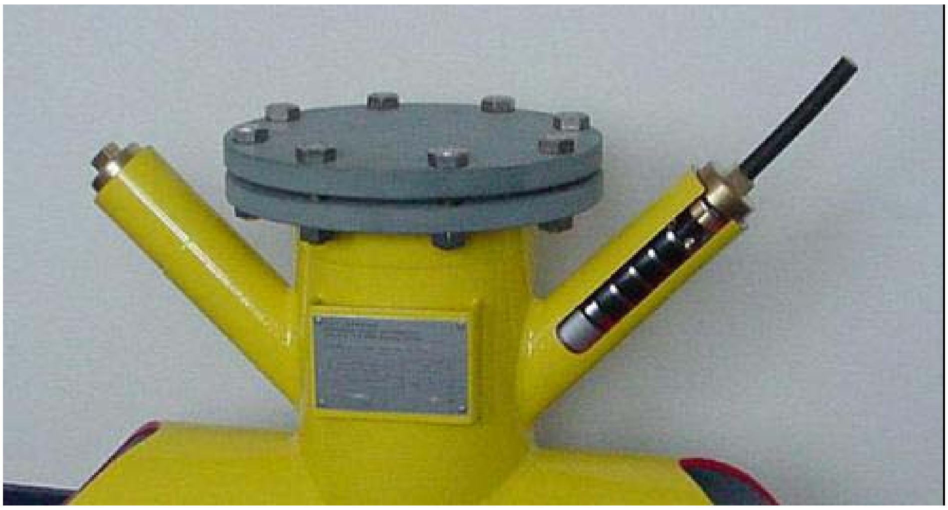
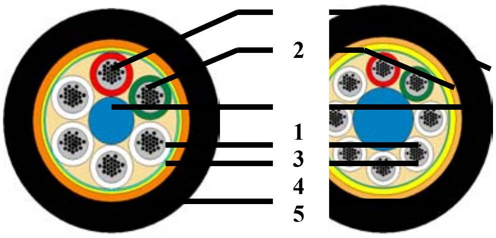


Figure 4.13: Fittings Used by Alcatel for Entrance and Exit Ports



1 = central element
2 = buffer tubes with fibers
3 = stress bearing element
4 = copolymer-coated alumium tap
5 = high density polyethylene sheath

Figure 4.14: Special Optical Fiber Cable From Alcatel for Natural Gas Pipes

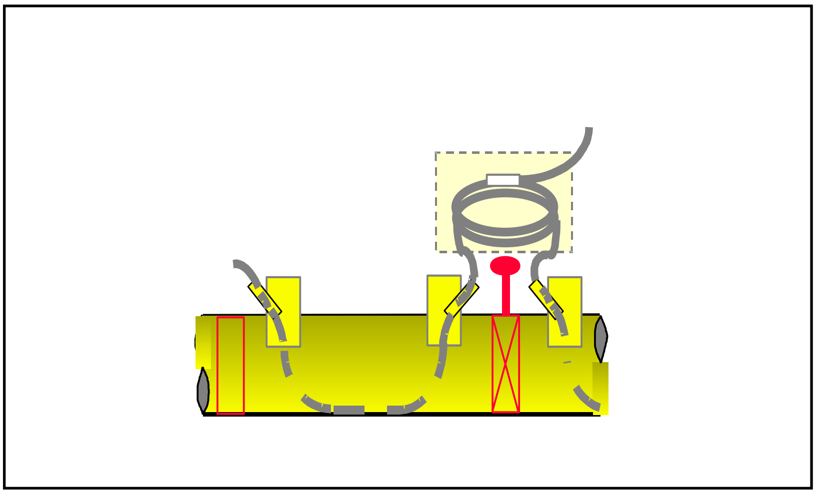


Figure 4.15: Schematic of Alcatel's Technology for Fiber in Natural Gas Pipes

Execution Steps for Figure 4.15

- Insertion of the balloon device connected to the optical fiber cable
- Insertion of special cable guiding rollers
- Closing of ports and release of gas flow
- Finishing the laying process by reducing gas pressure below 10 mbars
- Installation of cable protection/guiding tubes in I/O-ports
- Insertion of sealing packages
- Mounting of cable bending protection
- Performing corrosion protection
- Gas tightness testing and quality control of new corrosion cover

Gastec offers a solution where a specially designed shuttle shown in Figure 4.16 pulls a cord from an inlet attached to the gas main all the way to the exit port using a gas pressure differential. This is done by creating an overpressure of about 150 mbar at the inlet side while a negative pressure is created by flaring off gas through a venting safety valve at the outlet side as shown in Figure 4.17. If for some reason, shuttle gets stuck, the exact position will be known to the engineers from the transmitter signal built into the shuttle. The fitting shown in Figure 4.18 is typical of what Gastec uses for entry and exit ports.

An added benefit of fiber in gas deployment is that a few strands of the fiber could be used as a leak detection system by collecting spatial resolution data. When an engineer applies, Raman's law and Joule-Thompson's effects, the exact point along the pipe alignment where a leak appears can be detected with a short response time to take appropriate remedial actions. Tokyo Gas and Osaka Gas also has used similar deployment systems in their gas pipes but they have not these tools available to any third parties to date.

Figure 4.16: Shuttle Used by Gastec for Pulling Optical Fiber Conduit

Figure 4.17: Shuttle Inside a Clear Plastic Pipe for Launch

Figure 4.18: Fittings Used by Gastec for Entrance and Exit Ports

4.2.7 Optical Fiber in Potable Water Pipes

Drinking water pipelines also enter most buildings. All fiber cable materials must meet EPA regulations on drinking water. In typical metropolitan regions, numerous valves exist in the drinking water pipeline and are bypassed with the cable. Ideally, each of these bypasses forms a fiber POP. A cable entry point consists of a water pipe flange and a sealed cable inlet.

The flange is installed on the water conduit under normal operating conditions and the water flow is interrupted only for the actual cable insertion. The cable is installed by means of a suitable tape, which is fed into a flange and floated to the next flange. The cable is then attached to the tape and pulled manually into the pipe. In drinking water pipeline systems, cable-pulling sections are on the order of 250 meters in length, although some additional cable is stored in the small manhole above each valve to accommodate future fiber links as shown in Figure 4.19.

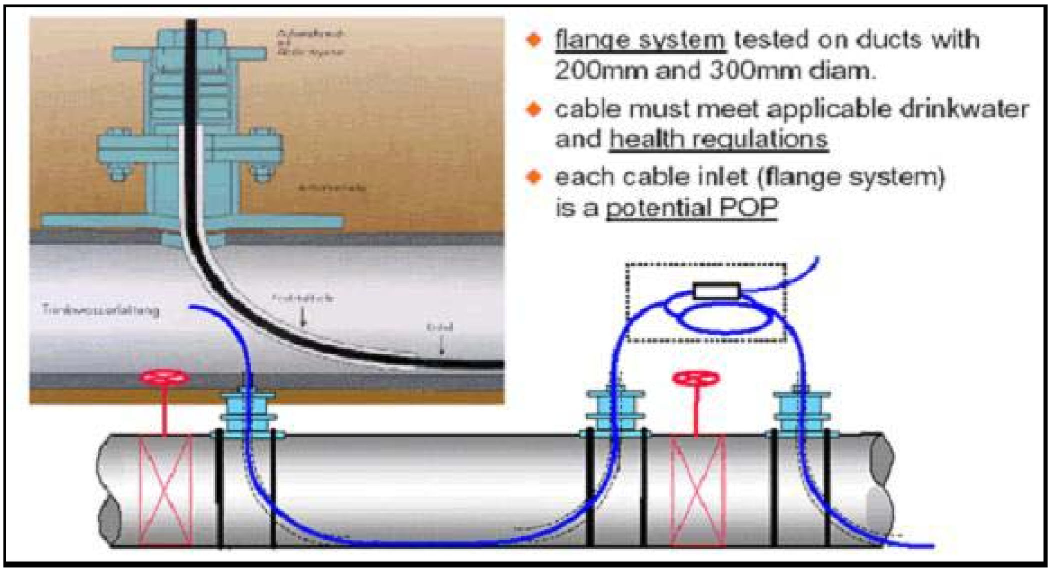


Figure 4.19: Optical Fiber Cable Through Potable Water Lines

Fiber in drinking water pipes is also inexpensive and every valve is a potential customer connection point. There have been installations of communication networks in drinking water pipes owned by the cities of Vancouver and Chicago going as far back as 1896. However, the fears of people drinking water of the same pipelines that carry optical cables need to be alleviated early on during an era when we have potable water contamination making either the front page of the local press or 6 O' clock news.

4.2.8 Optical Fiber in Micro-Trenches, Electrical Conduits, or Micro-Ducts

In addition, micro trenching in roads could be used to install the last mile fiber. There are several cities in France that have used this technique as shown in Figure 4.20. Because fiber is installed in a shallow groove formed by a special saw cut, security of the network is always a concern. When the optical cable is installed at such shallow depths, the impact of the traffic loads on the fiber needs to be taken into consideration. The void between electrical distribution cables in existing conduits or occupied ducts could also be used with micro-duct fiber blowing to finish the last mile construction as shown in Figure 4.21. Micro-cables also could be blown into place. Some of the names in this business are: Neptco, Nextgen, Sumitomo, Draka, Alcatel, Lancier, Arnco, Condux, Plummetaz, Hubbell, TVC, and others. A careful consideration of the strengths and weaknesses of these technologies is warranted before any one of these systems is used for building last mile fiber.

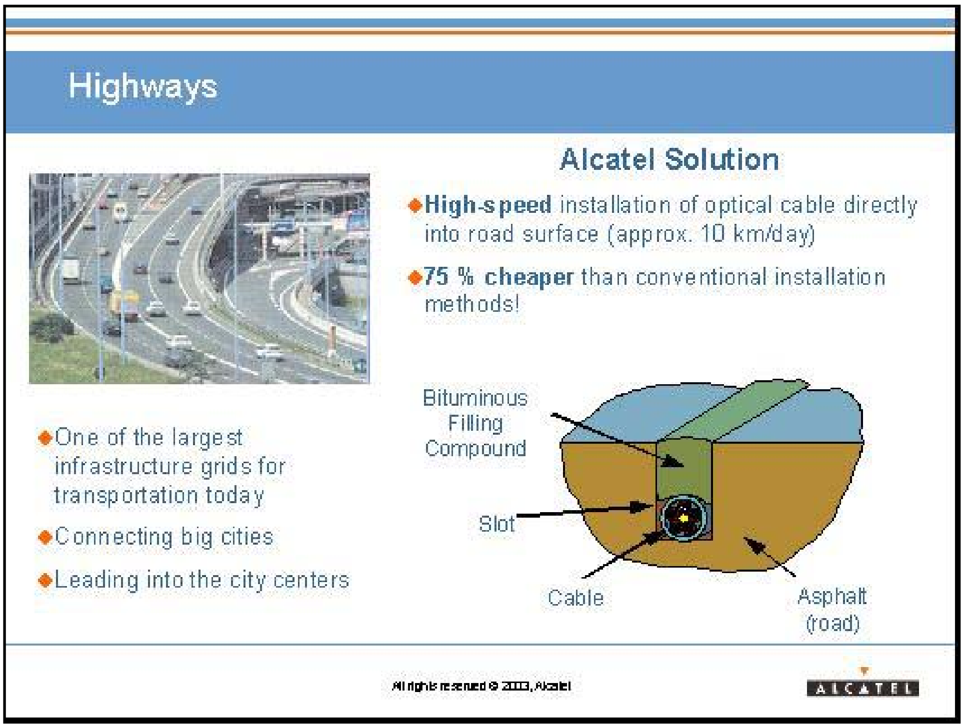


Figure 4.20: Optical Fiber Cable Through Micro-Trenches

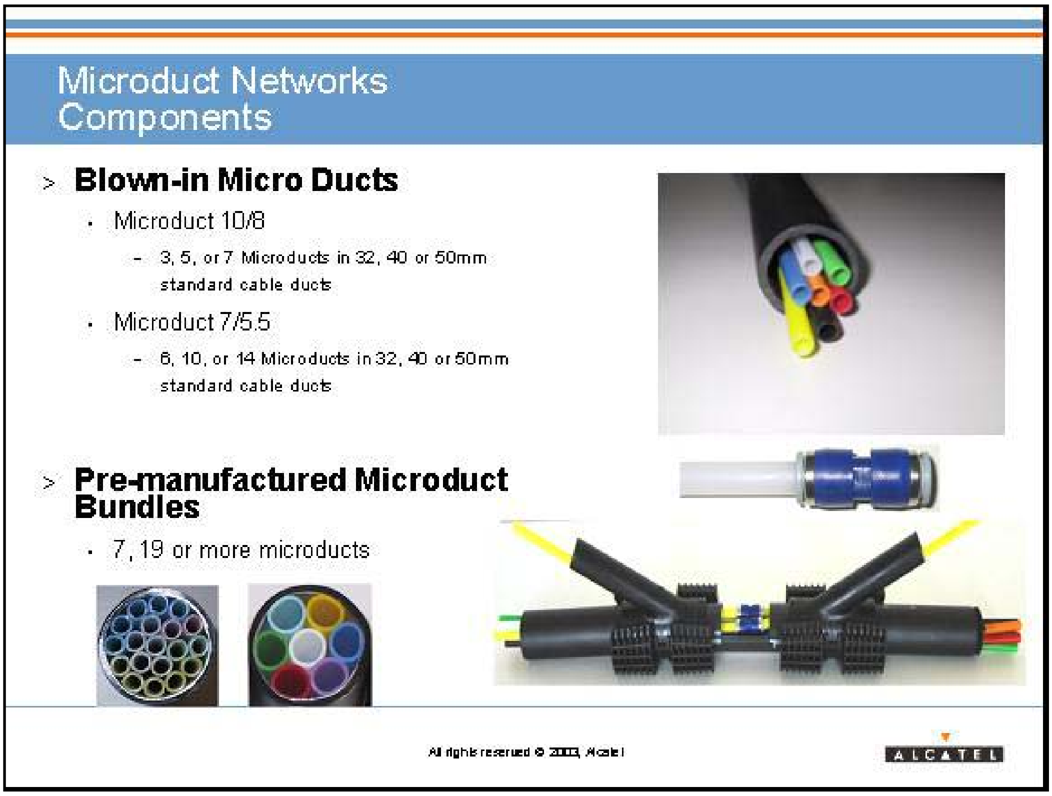


Figure 4.21: Optical Fiber Cable Through Occupied Ducts by Blowing

4.3 PIPE SELECTION CRITERIA

Operating an optical fiber network in the sewers poses its own challenges. Proper pipeline engineering input is essential for the selection of the suitable sewer system for deployment. The factors to consider in selecting the right sewer path are:

a. Access to the Sewer;
b. Hydraulics of the Sewer;
c. Structural Capacity of the Sewer;
d. Sewer Cleaning After Installation of Optical fiber Cable;
e. Sewer Inspection After Installation of Optical fiber Cable;
f. Sewer Maintenance After Installation of Optical fiber Cable;
g. Compatibility of the Sewer Wall;
h. Presence of Excessive Grease in the Sewer;
i. Presence of Excessive Chemical Reagents in the Sewage;
j. Presence of Excessive Calcium Deposits on the Sewer Walls;
k. Presence of Joint Separations/Offsets;
l. Presence of Excessive Root Intrusion: Condition of the Manholes;
m. Condition and Frequency of Lateral Connections.

More details on pipe selection criteria and the benefits of this approach to building optical cables in existing pipes could be found in Jeyapalan. In addition, the criteria that would set the winners from others are given in Jeyapalan.

The selection criteria to use for natural gas mains would differ from the above and are being writing into a series of ASTM standards at the present time.

4.4 STANDARDIZATION

Efforts are underway to develop consensus standards within ASTM International by bringing industry experts together. ASTM International provides a legal, administrative, and publication forum within which producers, users, ultimate consumers, and representatives of government and academia can meet on a common ground to develop standards that best meet the needs of all concerned. Over 300 stakeholders from 30 countries have joined together to form new ASTM Committee F36 on Technology and Underground Utilities. It is important that the Egyptian government appoints one of its senior engineers to this working group to follow the progress made in this field. The group is in the process of developing standards for the deployment of fiber-optic cables in underground utilities, FTTX, pipeline rehabilitation methods, and seismic risk assessment procedures. Participants in the new committee include municipal authorities, building owners, robot- manufacturers, pipe manufacturers, optical-fiber cable manufacturers, telcos, and construction, architectural and engineering consultants, to name just a few.

This committee usually meets in January and July. Although attendance of members is always preferred because of its value in networking, participation is still encouraged via web forums, teleconferences, emails, and regular correspondence. The first standard from this committee is already available from ASTM [3] and several more are about to be released. This working group F36 has already identified the following to guide this new industry:

1. Standard practice on sewer and gas pipe selection for fiber deployment.
2. Standard test methods on materials, components, longevity.
3. Standard specification on documentation.
4. Standard specification on network topology.
5. Standard specification on safety, access rights, and construction.
6. Standard guideline on decision analysis on economic factors.
7. Standard practice on design, operation, and maintenance.

Similar efforts are underway to develop engineering guidelines within ASCE for this 130,000-member organization of civil engineers to provide their input to the telecommunications industry in this new discipline. More than 25 authors have committed their time toward developing these guidelines for many months on this Task Committee on Installing and Operating Optical Fiber Networks in Existing Sewers.

There are a number of last mile and FTTH projects underway worldwide and additional communities have undertaken feasibility studies on FTTH deployments. Scotland has announced that it will use its sewers all over Scotland to complete the last mile. The cities of New Orleans, San Francisco, Los Angeles, Phoenix, Scottsdale, San Diego, St Paul, Dallas, Houston, Saint Antonio, Fort Worth, and Chicago in America also have announced that they will use their sewers to finish the last mile. Many of the techniques reported in this Chapter could be used to lower the overall cost of FTTH deployments while cutting the construction time by a substantial percentage. It should be borne in mind that the inclusion of additional conduits to carry optical fiber either inside or outside of utility pipes planned in new construction projects would add minimal cost to the overall design and construction of conduits in the ground. Therefore, consideration of such utility corridors is a must in every new construction project with provisions to serve multiple functions.

4.5 POSSIBLE BUSINESS PLANS

In the new paradigm to serve the people of Egypt best, we have to consider bridging the last mile as fast as possible with the lowest possible cost. Using the existing pipe networks, micro-trenches, or electrical ducts for deploying last mile fiber could be done in any one of the following business plans:

Plan 1: The fiber builder will either purchase or lease existing retired pipelines that are no longer used in active service in exchange for either an upfront payment or an annuity type payment to the owner of this strategic asset. Pacific Gas and Electric, Key Span Energy, Con Edison, Atlanta Gas, Peco Energy, are examples of this business model.

Plan 2: The fiber builder will make the pipe owner a business partner, where reserve capacity in the existing pipe network could be used by the fiber builder for installing last mile fiber in exchange for a negotiated percentage of the gross revenue. Cities of Albuquerque and Indianapolis are examples of this business model.

Plan 3: The owner of the existing pipeline network will take network providers, content providers, and vendors as partners to install fiber in their pipes and operate this network. Other than the few strands needed by the pipe owner for their needs, the rest would be leased to any number of the above partners for additional revenue to the pipe owner, where the cost of the fiber build out will be borne primarily by the pipe owner. City of Berlin is an example of this business model.

Plan 4: In this plan, some elements of the above 3 plans will be combined toward optimum results for all parties concerned. We are aware of several entities in the middle of active negotiations to reach many forms of business partnerships to deploy last mile fiber and the results will be reported at a later time.

Plan 5: In this plan, the pipe owner will build and own the fiber network. Cities of Tokyo, Hamburg, Vienna, Boston, Dublin, New York, and Los Angeles are examples of this business model.

Plan 6: In this plan, owner of local roads will build and own the fiber network. Some cities in France have followed this model, including Paris.

The people we serve always expect us to provide safe and cost-effective solutions with least damage to our environment. When acquiring rights of way to dig and bury various utilities and cables one by one is becoming increasingly impossible, we engineers and contractors have to learn to share the underground to avoid further conflicts and accidents. Society's problems needing the expertise of just one type of engineering have all been solved many decades ago. The remaining challenging problems require us working together on teams with experts of interdisciplinary skills in technology, business, public policy, and social sciences.

4.6 CONCLUDING REMARKS

1. Qwest, Level 3, 360 Networks, Broadwing, AT&T, NTT, France Telecom, and others have all offered to provide end-to-end optical network and true broadband to the masses. Offering in words is one thing, showing in actions is another. We have been waiting in America for true broadband at speeds higher than 100Mps, while these companies also have been waiting to light 99 % of their long haul, backbone, and metro fiber networks.

2. Removing the last mile bottleneck to generate the voice/video/data traffic needed to solve the fiber glut will involve creative business partnerships with existing utility pipe owners in Egypt, in America, in Iceland, and in any country in the world.
3. Egypt also will continue to upgrade its sewers, gas pipes, and waterlines in the coming years. It appears that a viable partnership could be arranged among telcos, pipe owners, service providers, and vendors, where each party has something to gain by cost sharing.
4. The installation of optical fiber cables either inside or outside of sewers, waterlines, and gas pipes is a major break through in sharing the underground pipes. However, communication companies need to address all the concerns, if any, associated with using existing pipes, before fiber deployment in the underground could proceed.
5. The factors which will continue to provide momentum for the market are:
   - Aging underground infrastructure
   - Doing more work with less funds
   - Protecting the environment
   - Increasing congestion in urban centers
   - Faster rate of knowledge transfer
   - Privatization of utility companies
6. The deployment of optical fiber cables in existing pipeline rights of way offer a win-win situation for all parties involved if proper standard of care is afforded.
7. If telecommunication did not follow proper engineering know-how, it would only be a matter of time before we will face major problems and the cost to return these sewers, waterlines, and gas lines to normal working order would be far greater than the benefits.
8. For telecom carriers and network service providers, it's a true, end-to-end last-mile optical fiber network, which they could control. For sewer, water, and gas pipe owners, it's a unique and powerful economic development tool, providing added revenue from an existing infrastructure, and of course protection from most damage to roads and disruptions to traffic.
9. Once the various parties involved in such creative partnerships are willing to make the commitment toward the idea of " let us meet our collective needs together," the solutions to the technical problems, if any in sharing the existing rights of ways of utilities will be found.
10. Then, we also have other construction methods for moving fiber cables underground such as ploughing ducts, horizontal directional drilling to install ducts, etc. that could be done at cheaper cost than open-cut construction.

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5 3G Mobile Communications and its Potential for Egypt

PREFACE

The purpose of this chapter is to present an overview of 3G technology and deployment status as of December 2003. In the discussion, a brief overview of the intermediate standard 2.5G is also given. It is shown how over the last few years the goals of 3G have changed to accommodate the needs of the customer base and market demand.

The chapter discusses 3G services and proposed applications and their respective quality of service requirements, indicating the need for much higher bandwidths than are currently supported by 2G cellular networks. The global deployment status of 3G is presented with a focus on several countries that have either deployed 3G or will do so in the next few months. The purpose is to present the issues associated with 3G deployment and highlight some of the hurdles that need to be overcome for a successful service offering.

In the chapter we address the status of cellular service in Egypt and the potential for introducing 3G technology is discussed. It is clear, that given the popular demand for 2G cellular service, and the increased access to the Internet across all segments of society, a move to 3G is a viable option. The success of any 3G deployment will depend largely on pricing, what the market is willing to bear, and the cost to enter the market. Currently voice service is the most popular if not the only service that cellular technology is used for. Internet access remains much more cost effective using the wireline infrastructure.

SUMMARY

The standard for Third Generation (3G) cellular technology was developed in the late 90's with a vision to provide a single unifying standard for mobile communications and services. That vision was not fully realized with the acceptance of three different 3G proposed standards. The most dominant of the three standards is the UMTS standard that was proposed by the European countries as a next step for the Second Generation (2G) GSM digital cellular network. Qualcomm presented its proposed upgrade to the IS-95 2G standard and China has put forward its own proposed standard, TD-SCDMA. Although all three standards use a CDMA air interface and will incorporate similar functionality in the Core Network (CN), they remain essentially different and will require added functionality to support full and transparent roaming between systems. The CN will be, in many cases, an evolution of today's core networks, re-using most of the existing 2G/2.5G components with a goal to move to an all IPv6 network that will provide mobility support at the transport layer and allow for unification of numbering plans, identification and authentication mechanisms, etc.

Most industry observers envisage a dual-track evolution for 3G systems, incorporating the refinement of 3G radio interface standards and a simultaneous move towards IP-based technology. For the initial years, 3G will have to rely on 2G for global coverage. The objective being to obtain a global coverage, so that in every place, the 3G services will be available, with high bit rates in 3G islands and with degraded quality under the coverage of 2G networks.

One of the major factors stalling the rapid deployment of 3G networks is the lack of 3G terminals and services that would make it attractive to the end user to switch from a less costly and familiar service. Since 2002 that has partially been solved with the market entry of new terminals that have longer battery life and provide the required interface to support 3G services and content. Other factors influencing the slow acceptance of 3G are mainly cost and lack of interest on the behalf of operators in deploying a technology that requires a major expenditure without an obvious market need.

It is in developing nations, where lack of wireline infrastructure is pushing the installation of wireless phone services, that one will see the most rapid deployment of 3G technology as it is used to fill a need in basic voice communication demand.

The potential for 3G deployment in Egypt is high because the demand for cellular services is very strong. But before moving in the 3G direction, it would be advisable to exploit 2.5G technology and EDGE, which do not require a major investment in infrastructure and that, can serve to satisfy the more immediate needs for high speed data services. Most of the current cell phone usage is focused on voice services, but it is envisioned that data services will take off if pricing of such service is made attractive. Internet access is popular in Egypt and with the Free Internet service the number of subscribers has grown in the last 5 years. It is expected that if pricing is made comparable to what it costs using wireline access, there will be a major shift to data services.

5.1 INTRODUCTION

The ultimate vision of Third Generation (3G) services is to support a variety of high speed reliable mobile communication and computing services through a unified standard and associated equipment satisfying that standard. The services envisioned include "global roaming" whereby mobile phones would be compatible with any local system in any country thereby opening up the possibility of delivering excellent communications services via a single "globally seamless network". Unfortunately, from the time of conception of this vision, there have been numerous 3G proposals put forward by different parties which complicated the process of unification. However, as a result of deliberation, scrutiny and negotiations, three of the proposals were accepted as 3G standards. These three proposed standards are grouped under the single name of IMT-2000 and they are:

- Universal Mobile Telecommunication Services (UMTS): the European Standard, evolving from the Second Generation (2G) Global System for Mobile communication (GSM) standard. (Note: UMTS is often referred to as the Wideband–Code Division Multiple Access (W-CDMA) standard.)
- CDMA2000: the Qualcomm standard evolving from their 2G IS 95 Code Division Multiple Access (CDMA) cellular system.
- TD-SCDMA – a Chinese variant of UMTS developed in conjunction with Siemens that uses Time Division Duplexing (TDD) and a Synchronous (S) CMDA air interface. This approach enables them to bypass any royalty payments for 3G technology.

UMTS, CDMA2000 and TD-SCDMA are true solutions to 3G, they offer all the required network support to handle the envisioned high bit rate services and promise efficient usage of spectrum. In Table 5.1 we show the development of 3G, how it evolved into a standard and its current status.

Table 5.1: The History of 3G Development

1998-1999	Radio Interface Development
2000	First 3G Wireless Networks demonstrations
May 2000	Approval of the IMT-2000 recommendations by the ITU Radio communication assembly
2000-2001	Auction of 3G licenses around Europe
Mid-2001	First 3G networks in countries such as Japan, based on first phase specifications of 3G
Start 2002	Basic 3G terminals available commercially, based on 2000 specifications of 3G
2002	3G services launched by some network operators
2002-2003	New 3G applications and terminals- focus on multimedia
End 2003	3G expands commercially to 11 countries

Due primarily to non-technical issues such as, cost, large installed 2G base of equipment, lack of availability of "3G savvy" end user terminals, the move towards 3G has not happened as soon as initially anticipated. An intermediate solution, referred to as 2.5G (and sometimes as 2G plus), was introduced in 1999 and is being widely deployed, in particular in markets where exorbitant 3G spectrum licenses caused many operators to scale back their 3G ambitions. The high cost associated with upgrading from current 2G systems to the new 3G system is a definite concern in particular since the applications and services that would make 3G highly desirable for end users are not yet that prevalent. In Figure 5.1 we show a chart that indicates how 3G technology today is still lagging behind both 2G and 2.5G in contract announcements.

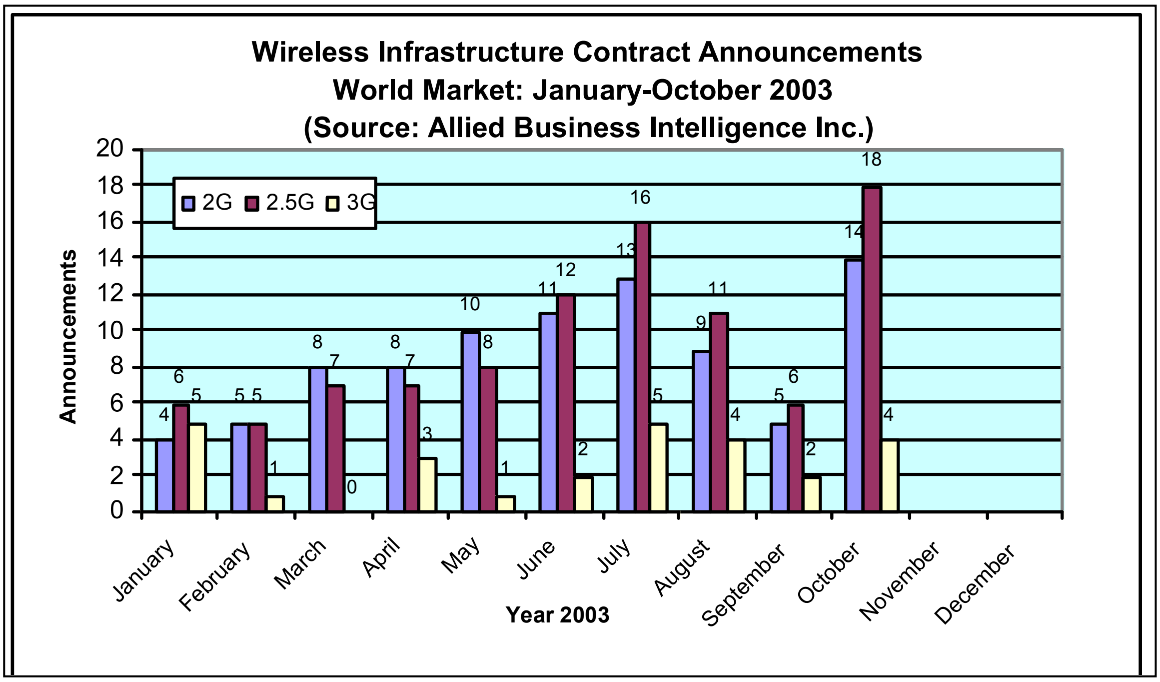

Figure 5.1: Chart of 2G/2.5G/3G Contract Announcements

The remainder of the Chapter is organized as follows: in Section 5.2 we discuss 3G deployment worldwide and give a brief overview of the status in Egypt and the potential for 3G deployment. Section 5.3 focuses on proposed 3G services and applications followed by a discussion of the intermediate standard - referred to as 2.5G - which has presented for many operators who are targeting to provide high bit rate services to their business customers, an easy and less costly solution than 3G in Section 4. In Section 5.5 we give a brief overview of 3G technology. We present our conclusions and recommendations in Section 5.6. For convenient reading, a list of abbreviations/acronyms is given at the end of the document. Appendix C provides a set of tables that summarize both 2.5G and 3G activities worldwide.

5.2 3G DEPLOYMENT

Although 3G implementation was planned and spectrum licenses auctioned in various countries a couple of years ago, the only commercial launches prior to 2003 occurred in Japan, South Korea, UK and USA. See Table 5.2. In 2003, 7 more countries had commercial 3G launches. Of the countries where 3G has been deployed to date, W-CDMA, which is the UMTS 3G standard, is the technology of choice except in USA, South Korea and Brazil, where CDMA2000 is the 3G technology used.

Table 5.2: 3G Commercial Launches
(Source Tomi T Ahonen 3G Strategy Consultants)

Country	Date	Operator (technical standard)
Japan	October 1, 2001	NTT DoCoMo (W-CDMA)
South Korea	January 25, 2002	SK Telecom (CDMA2000 EV-DO)
South Korea	May 1, 2002	KTF (CDMA2000 EV-DO)
Isle of Man (UK)	July 1, 2002	Manx (W-CDMA)
USA	October 29, 2002	Monet (CDMA2000 EV-DO)
Japan	December 20, 2002	J-Phone (W-CDMA)
UK	March 3, 2003	3 (Hutchison) (W-CDMA)
Italy	March 12, 2003	3 (Hutchison) (W-CDMA)
Brazil	March 24, 2003	Vesper (CDMA2000 EV-DO)
Australia	April 2, 2003	3 (Hutchison) (W-CDMA)
Austria	April 25, 2003	Mobilkom (W-CDMA)
Luxembourg	May 1, 2003	Tango (Tele2) (W-CDMA)
Sweden	May 5, 2003	Hi3G (Hutchison) (W-CDMA)
Denmark	October 20, 2003	3 (Hutchison) (W-CDMA)

The global GSM subscriber base is at nearly 900 million and projected to exceed the 1 billion mark in 2004, according to EMC Corp. By comparison, the total number of worldwide CDMA subscribers is at a modest 156 million. The massive global deployment of GSM technology across 70 countries is likely to result in continued industry support for the bulk of all research and development activity in the digital wireless communications realm.

While CDMA retains its traditional grip across the US and South Korean mobile markets, GSM is catching up in North America, the cradle of CDMA wireless communications. So much so, that 28% of new mobile connections sold in the US were GSM, a sharp rise from 17% in 2002.

GSM technologies dominate the world market, accounting for more than 62% of total contracts, a total value of US $2.3 billion in the second quarter of 2002 with Asia/Pacific and Western Europe being the largest contributing regions, according to Gartner Research Inc., September 2002.

Other countries with launch-ready 3G networks are listed in Table 5.3.

Table 5.3: Ready to Launch
(Source Tomi T Ahonen 3G Strategy Consultants)

Country	Mobile Penetration	Population	Operator (technical standard)
Croatia	80%	4 million	VIPnet (W-CDMA)
Finland	95%	5 million	Sonera (W-CDMA)
Germany	70%	80 million	Vodafone, O2 (W-CDMA)
Greece	65%	10 million	Teleset (W-CDMA)
Hong Kong	95%	6 million	Sunday (W-CDMA)
Ireland	85%	4 million	Vodafone (W-CDMA)
Malaysia	20%	19 million	Maxis & Telecom Malaysia (W-CDMA)
Monaco	N/a	N/a	Monaco Telecom/Vivendi (W-CDMA)
Norway	85%	5 million	Telenor (W-CDMA)
Singapore	85%	3 million	M1 (W-CDMA)
Spain	80%	40 million	Telefonica (W-CDMA)
Taiwan	105%	21 million	FarEastOne (W-CDMA)

5.2.1 3G in Japan

With the launch of 3G services by NTT DoCoMo, KDDI and J-Phone, Japan is now the most advanced mobile market in the world. The one difference with the deployment of 3G in Japan is that the 3G companies were not encumbered with fixed fees, or specific license durations or obligations.

Japan's DoCoMo is one of the world's first wireless players, launching its analogue service in 1979, while analogue service didn't begin in the United States until 1983. DoCoMo then launched a data service in 1993. By 2000 it had terminated its analogue service, and in 2001 it began rolling out its FOMA 3G network -- based on W-CDMA -- to begin replacing its 2G network.

But while Japan has shown a propensity to adopt new wireless technology early and quickly, NTT DoCoMo USA President and CEO, Nobuharu Ono said it didn't start that way with 3G. "Subscriptions where under expectations when launched in 2001, but the FOMA service took off since the beginning of 2003."

Ono ascribed the slow uptake to three key factors: poor coverage (FOMA only had about 22 percent coverage when launched), unsatisfactory battery-life, unattractive prices and original 3G handsets not being up to par with 2G equivalents at the time. But since then, DoCoMo has expanded its 3G coverage in Japan, reaching more than 90 percent of the population. Battery life has also improved, up to about 200 hours at present, and the company plans to launch a fuel-cell powered handset in the 2004 to 2005 timeframe. Perhaps most importantly, 3G service has allowed it to provide a higher-quality voice network combined with faster data at a lower cost. Voice costs 40 percent less on 3G than it does on 2G, and even video is comparable to the cost of just voice on a 2G network. The improvements have allowed the firm to boost its 3G subscriptions to 572,000 as of May 2003, although that is still a far shot from the total 38.3 million subscribers to its i-mode service.

Users in Japan have adopted data services in record numbers because of a number of factors. Firstly, like GPRS, the users are charged by packet transmission, rather than usage time. Attractive handsets are also part of the picture. But one of the most important factors is that the service utilizes IP and HTML, making it easy for content providers to convert their existing Web sites to be viewed on a handset. Users and content providers have grown on a symbiotic basis, and there are now 70,131 content sites available to users, of which only 3,572 are i-mode sites. The rest were created on a voluntary basis. See Figure 5.2

Ono also broke down usage, saying 50 percent of i-mode usage is for email, 23 percent is for i-mode menu sites, and 27 percent is for Web access to third-party sites. Delving further into the numbers, he said the vast majority of usage of its i-mode menus sites is for entertainment: 36 percent for ring tones and standby screens, 23 percent for music and movies information, and 17 percent for games and horoscopes. He said another 13 percent of usage is for information services. The remaining 10 percent applies more to enterprise usage, with 5 percent used for transactions and 5 percent for database access. See Figure 5.3.

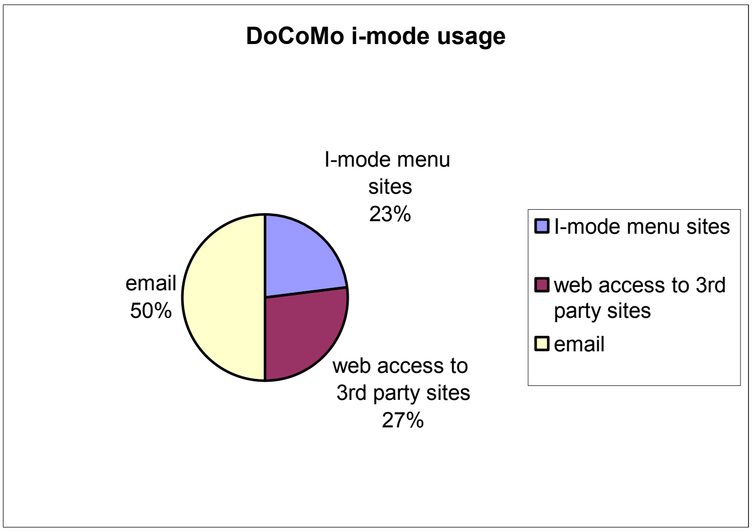

Figure 5.2: i-Mode Usage Compared to Other Services

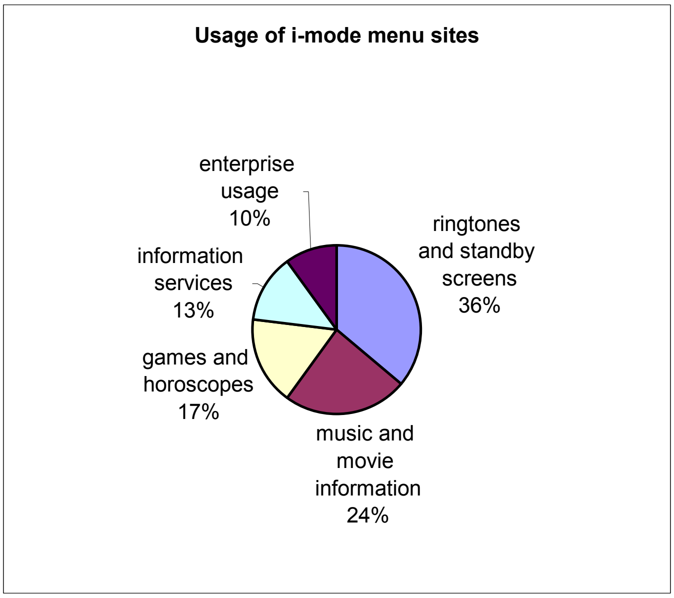

Figure 5.3: i-Mode Menu Sites

DoCoMo's present course has it fitting all sorts of new functionality into its handsets. It has recently debuted the SH505i, a phone equipped with a 1.3 megapixel digital camera. The phone actually swivels 180 degrees from the base, allowing it to look just like a camera as well. The company's i-shot service for photos was introduced a year ago, and already has 10 million users, Ono said. Users can send photos directly to other phones, or use the i-shot Center service that the company provides to email photos to PCs. Customers can also print out their pictures at 24 hour convenience stores.

DoCoMo is also getting ready to launch the F505i, which features fingerprint authentication to make mobile-commerce more secure, though it may have enterprise applications as well. Video is already here, and that is paving the way for new applications in which DoCoMo sees its phones providing "guide dog" services for the blind and email for the deaf (it is offering a 50 percent discount for disabled users), video monitoring capabilities that will allow parents to keep tabs on children at daycare or in kindergarten, location-based services for checking if a bus or subway is running on time, even remote control functionality.

The next step is "Mobile in All," in which mobile communications functionality is incorporated in all sorts of other devices. DoCoMo has already taken a step in that direction with the introduction of 500 c-mode Coca-Cola vending machines in Japan. Each machine incorporates a computer, full color display and printer, allowing users to make cashless purchases with their handsets. The company plans to have 3,000 vending machines deployed in Japan by March 2004. It doesn't plan to stop there. It sees all sorts of things incorporating mobile technology, including vehicles, robots, even pets.

In the meantime, Ono said the company is working to transfer its success in Japan by taking its experience in i-mode and FOMA to other countries. In the U.S. it is partnered with AT&T Wireless, which plans to launch its own W-CDMA network by the end of 2004.

5.2.2 3G in South Korea

Taken at face value, South Korea’s determined early-to-market 3G strategy is paying dividends. Since the launch of their “Enhanced Version – Data Only” or EV-DO 3G network, South Korea’s mobile leaders SK Telecom and KTF have boasted enviable statistics:

Within eight months of launch, SK Telecom acquired more than 1 million EV-DO users, equaling roughly 5.6% of total subscribers. KTF has nearly 0.7 million or 7% of total subscribers. This was in spite of having just four to five compatible $US500 handsets in a market where subsidies are banned.

The introduction of EV-DO 3G services has caused a spike in data spending. SK Telecom says the monthly ARPU from its EV-DO services is $US14 – nearly three times higher than revenues from the slower-speed CDMA1x. Similarly KTF’s monthly EV-DO ARPU is $US10.

Wireless video is popular with 3G users. EV-DO networks allows transmission speeds of up to 2.4Mbit/s, allowing streaming of video. The most popular services are movies (condensed into snapshot-sized 2.5 minute videos) and mobile broadcasting of news, traffic and sport. More than 90% of KTF’s EV-DO revenues come from video-on-demand and broadcasting. This is viewed as proof of pent-up demand for 3G services.

But this success has come at a price. Dig deeper and a story of aggressive marketing, cut-throat promotional pricing and heavy early acquisition costs emerge. Not surprising in a new network launch, but raising questions about just how long this growth can be sustained.

As South Korea's mobile market matures – EV-DO growth comes at a price - South Korea's overall mobile growth has stalled, and subscriber numbers have decreased for two consecutive months. Yes, wireless data revenues are rapidly increasing but still only comprise about 10% of total ARPU. This is still considerably lower than some western markets where SMS-fuelled data ARPU is as high as 14 to 17%. Voice revenue growth is slowing and competition increasing.

EV-DO is therefore the centerpiece to operators' strategy of increasing customer value. While EV-DO network technology is cheaper to deploy than the competing W-CDMA technology, other costs are high. In 2002 SK's overall marketing expenses escalated 80% to \$1.4 billion, against total revenues of \$7.5 billion. Marketing costs rose 37% between Q3 and Q4 alone – the period when EV-DO was re-launched as a commercial service. This contributed to a 19% drop in operating income. This, coupled with a 60% increase in network capital investment, lead to a powerful investor backlash against SK's 3G plans early in 2003.

At the same time, both SK Telecom and KTF offered heavy promotional discounts – all-you-can-eat flat rate packages of \$US20 per month until June 2003. While consumption of video and data was high (averaging 40,000 packets) during this period, it more than halved to 18,000 packets as soon as new higher tariffs were introduced. For all the range of sophisticated services on offer in South Korea, the vast majority of users still favor cheap and cheerful ringtones, screensavers, logos and messaging. It means video at a higher price tag is likely to prove a harder mass market sell.

Another cost is development of content. Both operators are now keeping a higher proportion of content revenues to cover much higher costs of rights management and licensing. SK Telecom is commissioning as well as creating its own 3G video content. It offers more than 6000 pieces of content, 30% of which are recently developed or custom made. This has lead to a change in business model – SK is directly investing in the production of films and video with content owners, which it is then repurposing for mobile at no extra cost. It's a strategy that would be prohibitively expensive of an undertaking for most mobile operators who lack the size and clout of SK.

The sustainability of EV-DO's success will depend on a number of factors. One is the price of handsets coming down – difficult in view of the ban on handset subsidies in South Korea. The other is cost of content. We expect EV-DO data revenues and usage to stabilize and possibly decline in the short term as users re-adjust to higher tariffs and operators recoup costs of content-rich services and move towards a more sustainable business model. But in the longer term, if EV-DO services are to translate into a popular mass market medium, then operators face a tricky balancing act between offering tariffs that encourage migration from the simple and popular services of today without underselling the product.

Yet for South Korean operators, the stakes are too high to risk losing momentum. They *need* EV-DO to work, in order to shore up the business case and familiarize users with 3G services. Otherwise they risk an investor backlash ahead of the launch of W-CDMA – an entirely new 3G network they are obliged to begin building this year under license requirements.

5.2.3 3G in India

The commercial launch of Reliance IndiaMobile's, third-generation (3G) CDMA2000 1x services, commenced on May 1, 2003. The Reliance IndiaMobile service marks the first CDMA2000 1x nationwide commercial launch in India, bringing advanced wireless data and voice services to 92 cities. Reliance Infocomm signed up over one million customers and achieved a record 30 million minutes of wireless usage per day. Reliance Infocomm is packaging its services as Reliance IndiaMobile, offering a host of applications, including messaging in Indian languages, e-mail, Internet surfing, access to real-time political, financial and sports-related news, games and streaming video at speeds of up to 144 kbps. Reliance's launch in India followed the launch of commercial 3G networks in countries across Asia Pacific, Australia, Eastern Europe and the Americas.

The 2G technology used in India was almost exclusively GSM so it will be interesting to monitor the progress of its implementation of 3G CDMA2000 1x technology.

5.2.4 3G in Germany & Austria

In Germany, the government auctioned spectrum licenses, at approx US $7 billion each, to six companies, with a conditional obligation that the company had to provide at least 25% coverage by 2003 and 50% coverage by 2005. Deployments of W-CDMA have been delayed as operators focus on short term cash flow. Two of the six firms, namely Quam and Mobilcom have since returned their licenses and are in legal processes hoping to bridge the losses incurred. Industry experts feel that the auctioning of the spectrum licenses has been a detriment to the German economy as it has made unavailable the large sums of money paid by industry for the purchase of these licenses resulting in the decreased cash flow for the advancement of the 3G industry.

Vodafone claims that deployment of its UMTS-Technology will definitely begin in 2004 after several postponements with a GSM customer base of 23.8 million. O2, the smallest German cellular service provider will commence offering UMTS service in March of 2004. The first offering is to be introduced at CeBIT, said an O2 representative, in Munich. It will take until the second half of 2004 before it hits the market. Before taxes, interests and write-offs, O2 in the first half of the fiscal year reported a profit of 155 million Euros compared to 1.7 million Euros in the same period last year. The customer base rose to 5.3 million. O2 has a market share of 8.4 percent and remains the smallest provider in Germany after market leader T-mobile, Vodafone and E-plus.

The Austrian mobile provider One was scheduled to commence regular UMTS-business for private customers on 30th December 2003. The company claims that the UMTS-network will serve more than 25% the population. In high population density areas such as Vienna, Graz, Klagenfurt and Innsbruck, the 3G network will be available at the end of December, and plans for further extension for 2004 are already underway. Initially, UMTS tariffs will include no monthly basic fee but will be charged by packet transmission. Transmission of data up to 5 megabytes to be priced at 2.5 Euros/megabyte, data up to ten megabytes at 2 Euros/megabyte, data up to 20 megabytes at1.5 Euros/megabyte and data over 20 megabytes at 1 Euro/megabyte. The first UMTS-telephone, the Nokia 7600, will be available to customers for 999 Euros.

5.2.5 3G In Egypt

Egypt with a population of approximately 72 million (UN, 2003) has the potential to become one of the largest cellular markets in Africa and the Middle East. Cellular technology has seen an unprecedented success since its introduction in the late nineties. The demand for cellular services in Egypt is high despite the relatively elevated cost of the service compared to average income. It is said that an average house hold in Egypt spends 20% of their income after taxes on cellular service.

The Egyptian consumer market is very demanding, the latest cell phone models are very popular as are second hand devices brought in from places such as Western Europe. Often the cell phone capabilities are not utilized to their full potential but are rather viewed as a status symbol. It is expected that multimedia services and Internet access will spur the success of 3G. In 2002 the International Telecommunication Union estimated that Egypt had some 1.5 million Internet users.

The Ministry of Communications and Information Technology (MCIT) is the overseeing body for the telecommunications industry and is responsible for guiding and influencing the development of the information-communications market in Egypt. The government has dismantled the monopolistic structure in the telecommunications industry, and today, Egypt is one of the most liberalized markets in Africa and the Middle East.

Egypt currently has 2 cellular providers that share the market equally. The technology deployed consists of 2G with some initial deployment of 2.5G. Of the approximately 2.7 million cellular subscribers, only 15,000 currently use GPRS. A representative from one of the cellular providers was of the opinion that the reason for the low subscriber volume was the cost of the GPRS handsets, currently priced at approximately 3000 LE. The most popular cellular applications are ringtones, music, news and games.

Telecom Egypt just recently bought a 25% stake in Vodafone Egypt and as part of the contract has agreed to stay out of the 2G market. Vodafone launched video streaming on 2.5G phones as of January 27, 2004

5.2.5.1 Key Drivers for Cellular Growth in Egypt

Some of the key drivers for cellular growth are:

- Competition and Regulation
- Technological Innovation – better handsets and higher quality voice services
- Rate/Tariff Adjustments and Reductions – The cellular market is very price sensitive and the cellular providers are currently experiencing a problem with pre paid cellular subscribers usage of cell phones as pagers resulting in both accounting problems as well as usage of the system at no cost to the subscriber. A solution to this problem is yet to be determined.
- Market Maturity – There is a lack of awareness among consumers of the capabilities of the services available to them. However, the cellular providers in Egypt have extensive coverage, services and handset capabilities available for the consumer.
- Wireless Internet access – the Internet has captured the imagination of the Egyptian population and if made available via cell phones at a comparable price to voice services, the market will see a growth in wireless access similar to what occurred in Japan with the launching of their i-mode services.

- Availability of 3G Services and Applications – with an increase in 3G deployment worldwide, we will witness an increase in media rich content that will require higher bit rate only available with 3G. That, plus the availability of higher quality and lower cost terminals, will convince potential subscribers holding out to make the switch from 2G to 3g.

5.2.5.2 3G's Future in Egypt

Egypt's cellular operators are fortunate in a sense that they did not have to go through a financially debilitating auction process as was the case in Western Europe. The 3G spectrum still remains to be auctioned and with the current climate, it is expected that the prices will not be exorbitant thereby enabling the operators to enter the 3G market with low overhead. The introduction of 3G technology in Egypt is expected to boost the development of applications and portals specifically designed for devices such as cell phones and PDAs. In Section 5.0 we describe all the possible applications that 3G will introduce and the benefits that they will bring to the different segments of the society.

5.3 3G SERVICES AND APPLICATIONS

UMTS services are envisioned to require data rates up to 2Mbps. Convergence of the wireless cellular world with IP will lead to the *Wireless Internet*, which together with the availability of high data rates will promise a multitude of services for the user. The diversity of services are considerably better compared to those of GSM primarily because of the ability to support bit rates that are commensurate with the needs of high end multi media services. Thus UMTS will expand the services that are currently provided by 2G systems. The *Wireless Internet* will in particular enable new services such as real-time video transmission and multimodal applications. Because of the higher bit rates, downloading data such as large images, which would take minutes in GSM, would take only seconds in UMTS. In order to increase competition between operators, only basic applications, referred to as bearer services, are being standardized by specifying the bit rate, BER and delay time for the application. An actual application from the users perspective can use a combination of bearer services. These basic applications are called Tele-services [7]. Only four UMTS Tele-services are standardized. These are Speech, FAX, SMS and emergency call. Other Tele-services can be created independently by network operators and service providers. Some examples of UMTS services [7] are listed below:

Information services

www-browsing, news, interactive shopping, on-line newspaper, on-line translation, location based broadcasting services, intelligent search- and filtering facilities

Entertainment

audio on demand, games, video clips, virtual sightseeing

Business services

IP telephony, B2B ordering and logistics, information exchange, personal information manager, dairy, scheduler, note pad, directory services, travel assistance, work group, FTP, instant voicemail, color fax

Finance services

virtual banking, on-line billing, universal SIM (USIM) card and credit card

Special services

tele-medicine, security monitoring services, instant help line, expertise on tap, personal administration

Community services

emergency call, administration services, democratic procedures

Communication services

video telephony, video conference, voice response and voice recognition, personal location

Telematics

road transport logistics, remote control, GPS

Education

virtual schools, on-line science lab, on-line library, on-line language labs, training

UMTS services are categorized into QoS classes based on their delay sensitivity. These classes are conversational, streaming, interactive, and background. The first two are representative of real-time, delay sensitive traffic. Conversational classes include typical speech over CS bearers, Voice over IP (VoIP) and video-telephony. These are real-time services with symmetric end-to-end delay thresholds below 399ms. Streaming implies continuous information transmission in streams. This technique facilitates Internet browsing. It has higher jitter tolerance and is useful in supporting large asymmetry in data transfer. Buffering helps smooth out traffic and it can support services such as video on demand as well as web broadcasting. Interactive services include ordinary web browsing, location services, passive information, games etc. The background class includes services such as email, SMS and database inquiry. Typically the broadcast services are delay tolerant to a great extent.

In addition to these classes there are several other attributes to the bearer services. These are [8] - maximum bit rate (kbps), guaranteed bit rate (kbps), delivery order (y/n), maximum Service Data Unit (SDU) size (octets), SDU format information (bits), SDU error ratio, residual bit error ratio, delivery of erroneous SDUs (y/n/-), transfer delay (ms), traffic handling priority, allocation/retention priority, source statistics descriptor (speech/unknown).

5.3.1 Family of UMTS Users

To identify potential UMTS users, the subscriber body can be divided into business, residential and mass market. Within these individual subgroups, light and heavy users can be identified and an array of possible services that the users within these three subgroups care about can be roughly portrayed [9].

Business Subscribers - This category can be associated with the enterprises that the subscribers belong to. The volume of traffic generated by these users has some correlation with the size of the enterprise they belong to, such as, big, medium, and small. A different type of classification relies on the nature of the business itself. These could include information technologists who are involved in transfer of all types of modern information such as communications, software etc. Financial people, traders and distributors are another type of users involved in marketing, trading, sales, banking etc.

Residential Subscribers – This category is usually divided based on the life style of the subscribers. This would reflect the type of traffic they would generate. Broadly people who are classified as communicators within this category tend to be involved in social activities and communicate at all times. Other classifications include always prepared users who try to keep up with the trends and have access to all means of modern communications and well to do users who usually form the wealthy segment of society.

Mass Market Subscribers – This includes people who do not belong to the top two categories, such as, people in academia, people between 5-22 years (largely dependents), and government bodies.

5.3.2 Goals, Scope and Typical 3G Services

One of the goals of 3G services [10] is the deliverance of advanced interactive, high speed (broadband), mobile capable services and applications. The 3G vision encompasses a wide variety of mobile devices to access content, and provide ubiquitous seamless mobile access. The successful creation of a mobile data mass market includes provision of access to all types of information in a format appropriate to each type of terminal and the right diversity of products (including terminals) to accommodate all types of users and usage. To provide the above vision a wide variety of participants would have to participate in the implementation to of a wide variety of services and applications for customers, operators and manufacturers.

User Expectations – 3G capabilities such as QoS, bandwidth-on-demand, security and privacy have to be exploited properly to develop applications that satisfy user expectations in the long term. Transparency/visibility of service charges is necessary to allow users to control costs. 3G services and applications need to account for users' communication habits and handle situations where ubiquitous access may not be available initially.

Typical Applications - A typical application would be commerce, which will be a leading driver for 3G systems and will influence the relationships between existing and emerging players. 3G provide the enormous increase in capacity (bandwidth), which can be used for fast delivery of multimedia messages that can be displayed on 3G terminals. VoIP is another enabler of convergence for services in fixed and mobile networks (2.5G/3G). 3G can be a key enabler for new forms of education on a global basis.

Issues faced while moving towards Mobile IP - Certain issues need to be addressed when moving towards the convergence of the cellular worlds with the Mobile IP world. Foremost is that the addressing schemes need to be mutually compatible. Backward compatibility for terminals that have not implemented Mobile IP is essential. The rapid wide-scale introduction of IPv6 should be the basis for overcoming problems relating to numbering, addressing, naming and QoS for real-time applications and services.

A summary of specific applications and services with the potential advantages and time to adoption is given below in Table 5.4 [11].

Table 5.4: Summary of Different 3G Applications and Services

Service	**Time to adoption (yrs)**	**Reason for use & Advantages**
VoIP Wireless WAN	2-3	Use of VoIP wireless WAN offers huge capacity gains. Advantages are lower communication service costs, increased network availability, enhanced quality and more features.
Wireless Audio/Video Streaming	5-10	Low demand, no immediate profitability foreseen. Advantages are provision of videoconferencing and real-time communications.
Multichannel Gateways:	2-5	Can repurpose consumer- and enterprise- oriented content across disparate networks to multiple devices. In addition to mobile requirements, vendors must meet network and device divergence requirements. Advantages are improved productivity and real-time collaboration.
Session Initiation Protocol-Based Push to Talk	2-5	Huge challenges remain for SIP-based PTT, including network capacity, network latency, device integration and interoperability. Early attempts will fall into the category of voice messaging, rather than true PTT functionality. Advantages are improved productivity and real-time collaboration.
Wireless Instant Messaging	<2	In North America, SMS is just beginning to achieve a wide spread acceptance, wireless IM will follow. However, interoperability remains an issue. Advantages are collaboration and real-time enterprise services.
Wireless Metropolitan-Area Networking	<2	Wireless metropolitan-area networking uses point-to-point technologies to compete with or replace wired data networking systems. Advantages are reduced network costs, open options for backup systems and provide network connectivity where none was before.
Wireless Number Portability .	<2	Wireless number portability refers to the ability to port a cellular telephone number from one provider to the next. Advantage is keeping a familiar phone number without restrictions to specific operators or service.
Java 2 Micro Edition	<2	J2ME has been slow to find support on mobile devices, but it has a good chance of eclipsing competitors through its breadth of network support and company backing. Advantages include standardized application interfaces for wireless devices.
Binary Runtime Environment for Wireless	2-5	Commercial applications have already been launched for BREW. BREW is based on a proven system, but there's a strong possibility that it will be eclipsed by J2ME in the medium to short term.

		Advantages include standardized application interfaces for wireless devices.
Smartphones	<2	Smartphone is a mobile terminal that is capable of sending and receiving voice and data calls. Although a smartphone is voice-centric, it can run data applications without a network connection. Early smartphone products were costly and haven't been widely adopted. More devices are coming soon. Advantages are anytime, anywhere computing.
Multimedia Messaging Service	2-5	Multimedia Messaging Service (MMS) is a new mobile messaging standard that offers multimedia services for phone-to-phone transmission. There is little early market awareness of MMS. Advantages are improved productivity and real-time collaboration.
Location-Aware Services	2-5	Location-aware services use cellular network technology to provide services that are relevant to a specific user location. Services include safety, information and tracking. Location-aware service integration into applications began in 2002; a critical mass of network and device support will occur through 2008. Privacy is a significant remaining hurdle. Advantages are improved productivity and real-time collaboration.
Wireless E-Mail	<2	Mainstream vendors such as Microsoft, Dell Computer and IBM now deliver mature products as part of a wireless e-mail solution. Advantages are improved collaboration and enablement of the real-time enterprise.
Short Message Service	<2	Although adoption & use varies regionally, SMS is a mature technology that handles billions of messages per month. Advantages are improved multimodal communications options, collaboration and real-time communications.

5.4 ON THE PATH TO 3G: THE INTERMEDIATE STANDARD – 2.5G

Several intermediate standards, referred to as 2.5G standards, have emerged over the past 4 years to accommodate the need for higher bit rates necessary to support data services. The 2.5G standard uses the same air interface, spectrum and underlying Core Network (CN) as the 2G network. The main feature that differentiates 2.5G from 2G is that the former provides a packet-switched overlay network in the CN to support the needs of data services.

General Packet Radio Service (GPRS), an intermediate packet-switched based technology for the 2G GSM networks, has been widely deployed, in particular in such markets as Western Europe and the US, with numerous planned deployments worldwide (see Table C-2 in Appendix C). GPRS, because of its use of the installed 2G base of equipment, is proving to be a very successful solution, meeting the current needs of the end user at very little cost to the operators. The upgraded 2G cellular network with GPRS service (GSM/GPRS) is the most popular 2.5G standard worldwide, primarily due to the wide deployment base of 2G GSM cellular systems.

GPRS moved wireless data transmission technology from circuit-switched mode (ISDN supported data services) to packet-switched mode with the anticipation that over an IP-based network, higher speeds and a more efficient service can be achieved. The peak data rate for GPRS is 115Kbps. The 2.5G upgrade of CDMAone (IS-95A) is CDMAone (IS-95B), which offers a maximum data rate of 115Kbps similar to GPRS. In Figure 5.4 we show the overall architecture of a GSM/GPRS network.

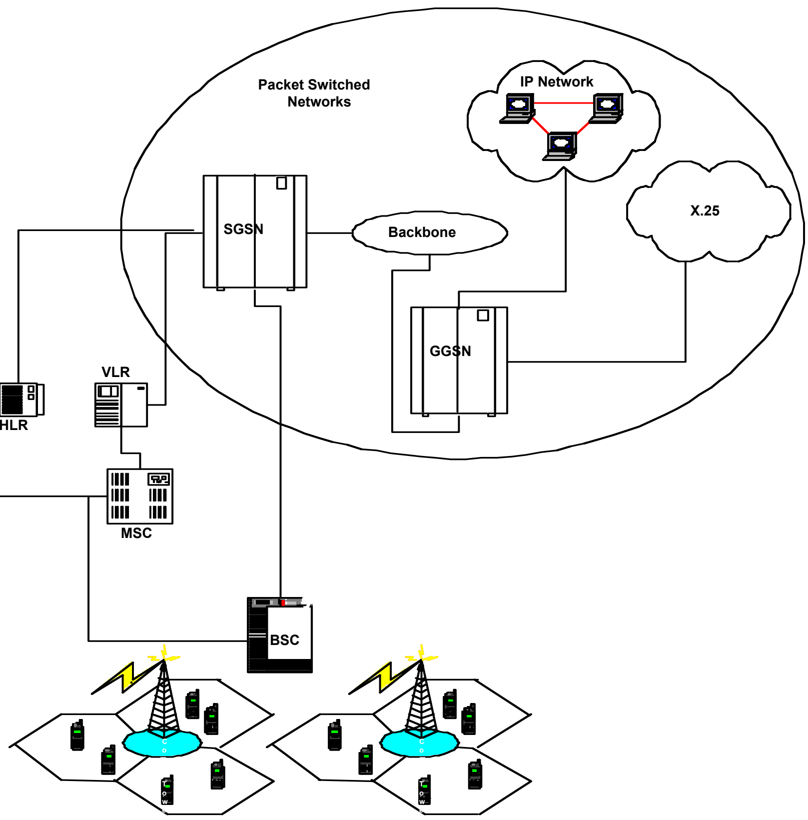

Figure 5.4: GSM/GPRS Architecture

5.4.1 EDGE

EDGE (Enhanced Data for Global Evolution), is another upgrade for 2G GSM cellular systems [1]. EDGE, initially considered to be a 2.5G standard, was designed to provide high rate bit rate 3G type services (lower end) for the Time Division Multiple Access (TDMA) based 2G GSM network. EDGE supports data services at a peak rate of 384kbps over the same air interface using the Quadrature Phase Shift Keying (QPSK) modulation technique - compared to the Gaussian Minimum Shift Keying (GMSK) modulation scheme that is used by GSM - that enables an increase in the symbol transmission rate over the same bandwidth channel. EDGE therefore has only a moderate implementation complexity as compared to a true 3G system. Since it basically uses the same GSM radio technology and is able to achieve 3G bit rates, it may become yet another acceptable intermediate solution for operators seeking to avoid a move towards 3G deployment yet needing to provide high bit rate asymmetric data services. However to realize a peak bit rate of up to 384Kbps, EDGE requires a better signal quality than what is used in 2G systems, hence more base stations and added infrastructure are necessary for migration to EDGE.

5.4.2 A Revision of Goals

In November 1999, the ITU accepted both W-CDMA and CDMA2000 3xRTT as 3G technologies. When the 3G technology was standardized, technologies such as CDMA2000 1xRTT (IS-95C or CDMAOne Rev C) and EDGE were considered to be 2.5G. The ITU in the past year lowered the peak bit rate requirement of 3G networks to 144Kbps primarily as an acceptance of the fact that true 3G is still several years away from becoming the dominant cellular technology. As a result, technologies such as CDMA2000 1xRTT and EDGE, that offer 144-384 Kbps bit rates for data services, were upgraded to 3G status.

5.4.3 Migration from 2G/2.5G to 3G

The migration path from 2G/2.5G to 3G is different for each of the 3G standards. For the W-CDMA standard, the entire radio transmission network must be replaced. This is not the case for CDMA2000 networks, where a consolidation of frequency bands will be all that is needed to provide a 3G radio transmission system. The transmission mode over the air interface in 3G uses packet-switched technology for higher multiplexing capabilities and thus a more efficient use of spectrum.

The long term goal is for 3G networks to have a common transport infrastructure with the Internet. As such, we see a trend in 3G networks to move, from the current combined CS/PS core, to an all IP based CN using IPv6, the preferred choice for GPRS cores. This migration to all IP will allow for the easy integration of the cellular world with the global Internet, an absolute necessity given the success of the latter and the need for end users to be able to access the WWW “anytime, anywhere, anyway”.

5.5 A BRIEF OVERVIEW OF 3G TECHNOLOGY

The majority of existing cellular telephones are of the 2G era, which constituted the first digital standard in the cellular environment. In contrast, the 1G standard supported analog mobile phones. In the 2G standard, the European market is supported by GSM, which uses TDMA as its RTT (Radio Transmission Technology). GSM was and still is a huge success. It is the unifying standard in Europe and has captured well over 70% of the global cellular market. In contrast to the unified 2G GSM standard of Europe, in North America the 2G market is divided between GSM, TDMA based IS-136 and Qualcomm’s CDMAone (IS-95A). Up to 9.6Kbps data rate is supported by 2G technology. In Table 5.5 we compare all the cellular standards highlighting the air interface used, the access technology, the transmission mode and bit rates supported.

Table 5.5: Summary of 2G, 2.5G and 3G Technologies

Cellular Family	Standard		Peak data rate (Kbps)	Typical data rate (Kbps)	Connection Type	Modulation
GSM	GSM(normal)	2G	9.6/14/4	9.6	Circuit	GMSK
	HSCSD		28.8/43.2	28.8	Circuit	GMSK
	GPRS	2.5G	115/171	50	Packet	GMSK
	EDGE	3G	384/513	115	Packet	8-PSK
UMTS	FDD	3G	384/2000	144	Packet	QPSK
	TDD		384/2000	144	Packet	QPSK
CDMAone	IS-95A	2G	14.4	14.4	Circuit	QPSK
	IS-95B	2.5G	64/115	56	Packet	QPSK
CDMA2000	1X	3G	144/307	130	Packet	QPSK
	1X-EV		2000	TBA	Packet	QPSK
	1X-EVDO		2400	TBA	Packet	QPSK

5.5.1 The 3G Standards

As was mentioned in the Introduction, three proposals were accepted as 3G standards. The air interfaces of all of the 3G standards are based on CDMA access technology. Below we describe in a few lines the three different standards. We then devote the rest of the discussion in Section 3 to a description of the UMTS based 3G standard because of the very large GSM cellular base deployed worldwide.

5.5.1.1 The UMTS (or W-CDMA) standard

The 3G standard adopted in Europe and Japan is UMTS, which is the logical upgrade for 2G and 2.5G GSM networks and is based on W-CDMA technology. The non satellite portion of UMTS, called UTRA (UMTS Terrestrial Radio Access), supports both Frequency Division Duplexing (FDD) (synonymous with W-CDMA) and Time Division Duplexing (TDD) (referred to as the TD-CDMA standard) (see Section 0 for more details). W-CDMA envisions supporting a peak data rate of 2Mbps for low mobility environments. Recent experiments with UMTS services include UK based Hutchison's 3G and Japan based NTT DoCoMo's FOMA (Freedom Of Mobile multimedia Access). The standardization for UMTS is carried out by the 3GPP forum.

5.5.1.2 CDMA2000

The American supported standard for 3G is Qualcomm's CDMA2000 and constitutes a natural upgrade from the 2G CMDA based IS 95 standard. The standardization of CDMA2000 is carried out by the 3GPP2 forum. CDMA2000 is deployed in two bit rate formats–1xRTT which provides 144Kbps peak data rates and 3xRTT which provides 2Mbps peak data rates. South Korea's launch of the world's first 3G system in October 2000, can be regarded as an experiment in CDMA2000. Operational CDMA2000 systems have appeared in major East and West coast markets in the USA. Sprint's PCS Vision is one such service. It should be noted that markets that adopted IS-95 based service for 2G have advantages in moving towards CDMA2000. The upgrade is a less costly solution than UMTS because the air interface has remained essentially the same.

5.5.1.3 TD-SCDMA

While W-CDMA FDD requires paired spectrum, TD-CDMA, developed primarily by Siemens, does not have that requirement. However, because of the strict timing requirements associated with TD-CDMA, it cannot be deployed in wide coverage areas (see Section 5.5.3). TD-SCDMA is a synchronous version of TD-CDMA jointly developed by the Chinese Academy of Telecommunications Technology (CATT) and Siemens. It is designed specifically to overcome the TD-CDMA short coming so that it can handle both local and wide area communications. By developing its own standard, the Chinese avoid the payment of royalties for 3G technology.

Figure 5.5 gives an overview of the 3G roadmap. It highlights the different 2G technologies and their migratory paths to 3G using (or in the case of IS-136 by-passing) 2.5G technology.

Table 5.6 compares the different 3G standards, showing the access technology used, the bit rates supported, the carrier spacing and the modulation scheme.

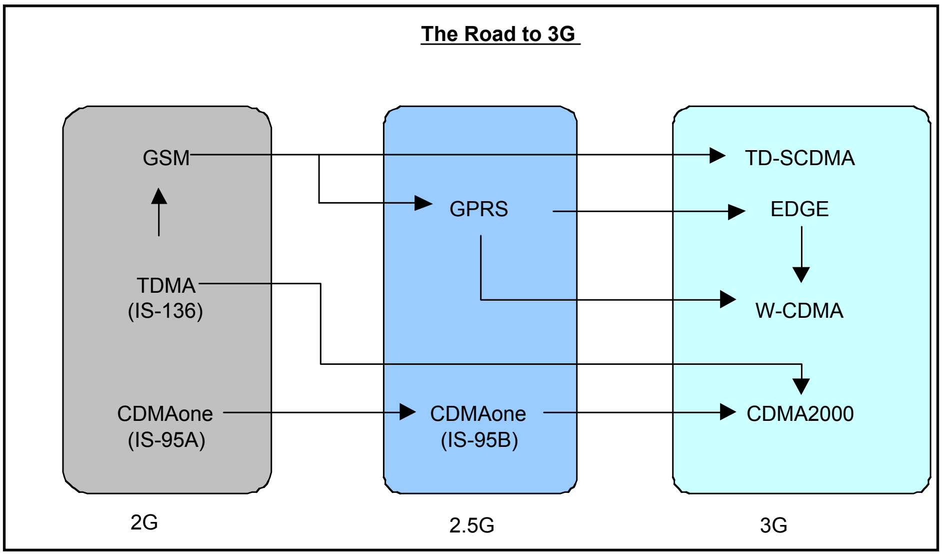

Figure 5.5: Envisioned Evolution from 2G to 3G Networks

Table 5.6: Comparison of the Most Common 3G Technologies

Feature	CDMA2000 (1XRTT)	CDMA2000 (3XRTT)	EDGE	UMTS
Carrier spacing	1.25MHz	3.75MHz	200KHz	5MHz
Access technique	CDMA	CDMA	TDMA	CDMA
Data rates supported	144Kbps	384Kbps	384Kbps	384kbps
Modulation type	QPSK/BPSK	QPSK/BPSK	GMSK 8-PSK	QPSK

5.5.2 Spectrum Allocation

The services envisioned for 3G include a wide variety of multimedia and high data rate applications. To accommodate this vision, a tremendous increase in existing bandwidth is necessary. A predicted 500 fold increase in bandwidth compared to the current 2G communication systems is essential for realization of 3G services. The amount of bandwidth necessary for a peak data rate of 2Mbps is around 15-20MHz. Radio spectrum is usually organized as *paired spectrum* to operate FDD (Note: *unpaired spectrum* suffices for TDD where a frame of slots are used for the downlink followed by a frame of slots for the uplink). Figure 5.6 gives a global overview of the spectrum allotment for 3G [2].

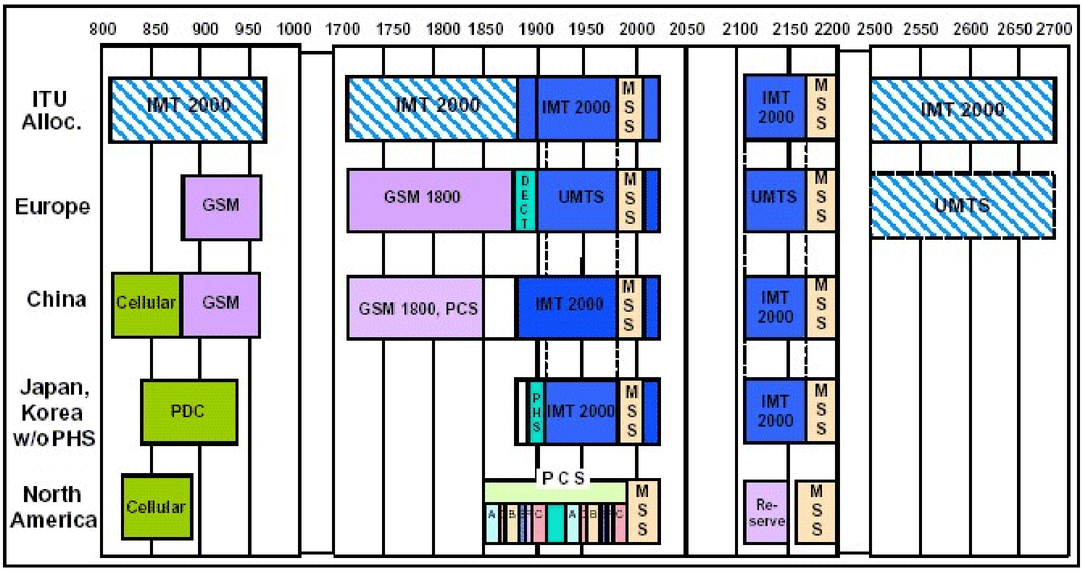

Figure 5.6: Global Spectrum Allocation

In Europe, the total spectrum allocated for terrestrial UMTS is 155 MHz. This is divided into the following bands – 1900-1980MHz, 2010-2025MHz, and 2110-2170MHz. The uplink from the mobile to the base station (BS) for FDD occupies 1920-1980Mhz. The downlink from BS to mobile in FDD occupies 2110-2170Mhz. TDD occupies 1900-1920MHz and 2010-2025MHz bands (both unpaired). The Mobile Satellite Services (MSS) portion of the spectrum allocations are around 2Ghz - 1980-2010MHz (uplink) and 2170-2200MHz (downlink). Thus the satellite components occupy 60MHz in all. A number of licenses have been issued by respective European governments through auctions to companies to operate 3G networks in these bands.

There have been several studies directed towards analyzing the growth of 3G traffic over the next decade. The studies recommended allocating extension bands to accommodate the foreseen increase in data traffic as end user devices that support video streaming and Internet access become more prevalent. The candidate bands are seen to be 470-862MHz, 2290-2300MHz, 2520-2670MHz and 2700-2900MHz. Some of the bands are in use currently but it is expected that the services using those bands will be phased out in the future, for example, phasing out of analog broadcasting in the 470-862Mhz band and replacing it with efficient digital broadcasting. Moreover spectrum currently used by current GSM standards could be used for future UMTS use. Spectrum sharing between terrestrial UMTS and MSS could be possible in the future too. All the above spectrum projections were made keeping in mind the capabilities of existing access technology, modulation and coding techniques, and interference management. A technical improvement factor of up to 1.35 in spectrum usage is possible compared to present day technology for the year 2010. Moreover the capabilities of multi-antenna technology should help in alleviating the spectrum problem for the future.

5.5.3 Hierarchical Cell Structure

One of the visions of UMTS is to provide global seamless radio coverage. For this purpose the radio access network (RAN) will be built hierarchically in layers with varying coverage. The higher the layer is in the hierarchy, the larger the coverage area will be. Global coverage via satellites is envisioned at the highest layer. The lower layers form the UMTS Terrestrial Radio Access Network or UTRAN. The smaller cells are divided hierarchically downward as macrocells, microcells and picocells. See Figure 5.7.

Naturally the picocells have the smallest coverage area. However picocells potentially could cover areas with the highest user density. Hence macrocells could be used as a generic wide area coverage with additional microcells installed to take care of areas with higher population density. Picocells usually refer to coverage inside buildings and special high density areas such as stations, airports, shopping malls, etc.

The data rate for each layer also varies. At the macrocell layer a rate of 144Kbps at hundreds of miles per hour user speed can be provided. At the microcell level a data rate of 384Kbps with tens of miles per hour user speed is to be supported. At the picocell level, where user speed is usually at the pedestrian traffic level, a data rate of 2Mbps is envisioned.

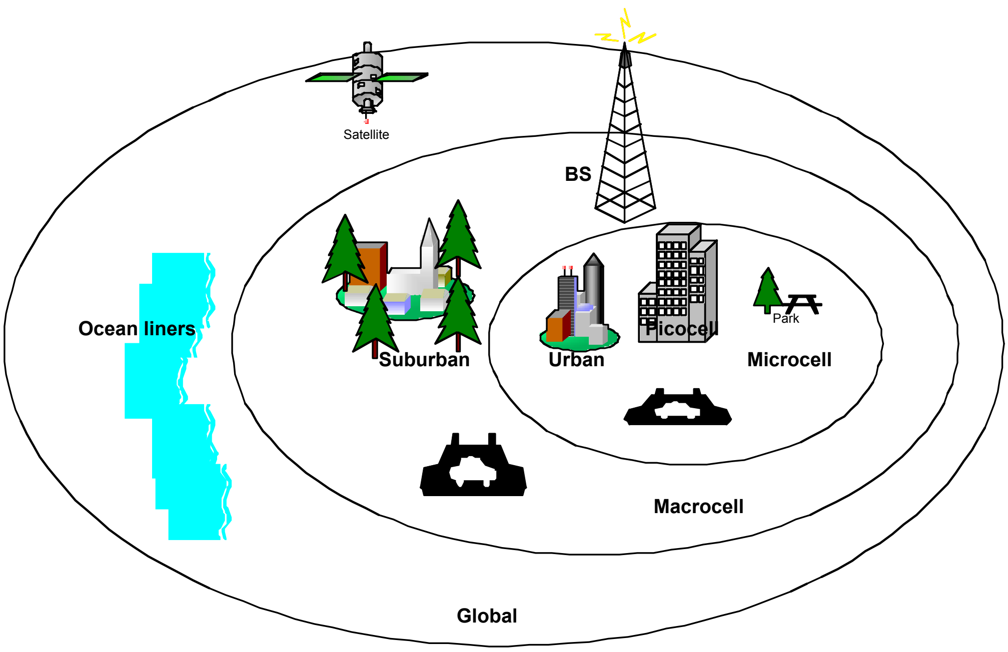

Figure 5.7: Cell Hierarchy

5.5.4 UMTS Architecture

The UMTS architecture is similar in structure to that of the 2G GSM system. In the UMTS architecture, the network elements are functionally grouped into the UTRAN and the Core Network (CN). The UTRAN includes a radio interface for supporting data rates up to 2Mbps and handles all radio related functionality. The CN is responsible for all call and data switching related functions and routing. The User Equipment (UE), that serves as the interface between the end user and the radio interface is also defined. An overview of the architecture is provided in Figure 5.8.

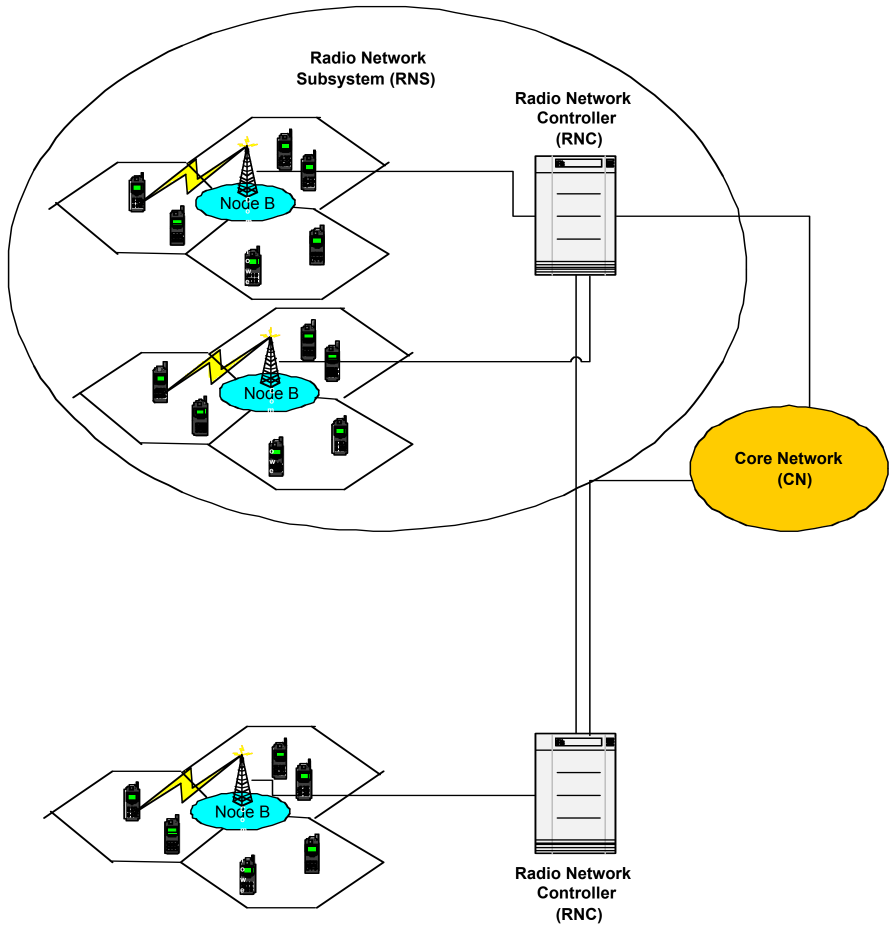

Figure 5.8: UMTS Architecture – Main Elements (UTRAN and CN)

5.5.4.1 UMTS Terrestrial RAN (UTRAN)

The UTRAN consists of Radio Network Controllers (RNC) and base stations referred to as Node Bs. A Radio Network Subsystem (RNS) is formed by one RNC connected to several Node Bs as shown in Figure 5.8. The CN controls several RNCs, providing the necessary interconnectivity between the different RNSs. In the UMTS standard, every interface between the various network devices is specified.

a) *Radio Network Controller (RNC)*

The RNC controls the radio resources of a UTRAN. As such it supervises the resource allocation of the Node Bs. The RNC facilitates load and congestion control of its own cells and also executes admission control and code allocation for new radio links. The RNC is thus responsible for the centralized Operation and Maintenance (O&M) of a whole RNS. In the case where a mobile-UTRAN connection utilizes more than one RNS, then the involved RNCs are named Serving RNC (SRNC) and Drift RNC (DRNC) depending on their logical roles in the connection. There is only one SRNC connected to the (source) UE. In contrast the number of DRNCs that are connected to the (sink) UE may be zero (wireline telephone), one or more than one (multicast).

b) The Base Station - Node B

A Node B may service the mobiles in one or more cells. It can support both FDD and TDD modes. Node B communicates with the UE via the radio interface and with the RNC via a land line. Node B converts data to and from the air interface and performs functions that include Forward Error Control (FEC), rate adaptation, W-CDMA spreading/dispreading and QPSK modulation. It performs link quality updates by measuring the FER (Frame Error Rate), the quality and strength of a connection, and reports this information to the RNC to facilitate handover and macro diversity combining. Node B also takes part in power control. All this information is used by the RNC to manage the radio resources in its RNS.

c) User Equipment (UE)

In addition to the RNCs and Node Bs, the UE also forms a part of the UTRAN. The UE acts as a counterpart to each of the network elements - Node B, RNC and CN - and therefore participates in many of the control functions and procedures. As a Node B counterpart it participates in FEC, functions such as encoding and interleaving, power and quality control, spreading & de-spreading and modulation & demodulation. As an RNC counterpart it participates in the Radio Resource Control (RRC) function, handovers (see Section 5.5.6.2) and cell-selection. As a CN counterpart it takes part in mobility management functions such as location registration and authentication and bearer negotiation and service request.

5.5.4.2 The Core Network (CN)

In the 2.5G GSM network, the CN has both a packet-switched (PS) and a circuit-switched (CS) domain. Initially, the CN in UMTS had both domains specified. In recent years the focus has been to go to an all IP CN and the CS portion has been dropped. The CN consists of location registers, an authentication center, an equipment identity register and a Short Message Service (SMS) server. Unlike the 2G and 2.5G GSM CN, which has a CS domain that contains the Mobile-Services Switching Center (MSC), the Gateway-MSC and the InterWorking Function (IWF) to handle voice call traffic, the CN of UMTS being packet-switched based, will have all of these entities fall under the PS domain. The PS domain in 3G evolved from the 2.5G GSM/GPRS CN. The GPRS PS domain contains the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). SGSN takes care of authentication and mobility management, protocol conversion between the IP backbone and the protocols used in the RNS and UE, collection of traffic statistics and routing data between GGSN and the external network. GGSN on the other hand, acts as a router to a sub-network. It simply checks if the address to which data is to be forwarded is active; if it is, then GGSN forwards the data to the SGSN serving the mobile.

a) An All-IP Core and other differences from GSM/GPRS

Although in the short term it is envisioned that CS and PS domain services will coexist, the long term goal is to move towards a pure PS based network. Considering the widespread usage of IP and its ability to communicate across different networks, the long term vision for the PS based CN is to have IP as the convergence layer. Introducing GPRS into the GSM cellular system required the introduction of new equipment such as SGSN and GGSN into the CN. Any evolution to 3G will use most of the 2G/2.5G CN components. The GPRS based CN uses IPV6 and it is expected that the all IP CN of UMTS will too.

The benefits of an all IP CN include an efficient solution for integrating voice and data services, direct support of Internet applications, and cost reduction through PS networking due to multiplexing capabilities.

A special note should be mentioned regarding the packet headers of CS services such as voice. Usually the voice packet payload is small hence compression of the header is necessary to maintain network efficiency. However compression increases vulnerability of the header to errors and hence might require stronger error protection than is currently provided for data traffic.

In the UMTS CN, besides the move to IP, a new architecture was defined. In principle it consists of separating the control layer (call control) from the transport layer (data transmission). To support real-time services such as interactive video, voice calls, etc. DIFFSERV in combination with MPLS is a recommended strategy to guarantee quality of service (QoS) for the IP based UMTS CN. Figure 5.9 gives the overall picture of the UMTS network architecture detailing the CN.

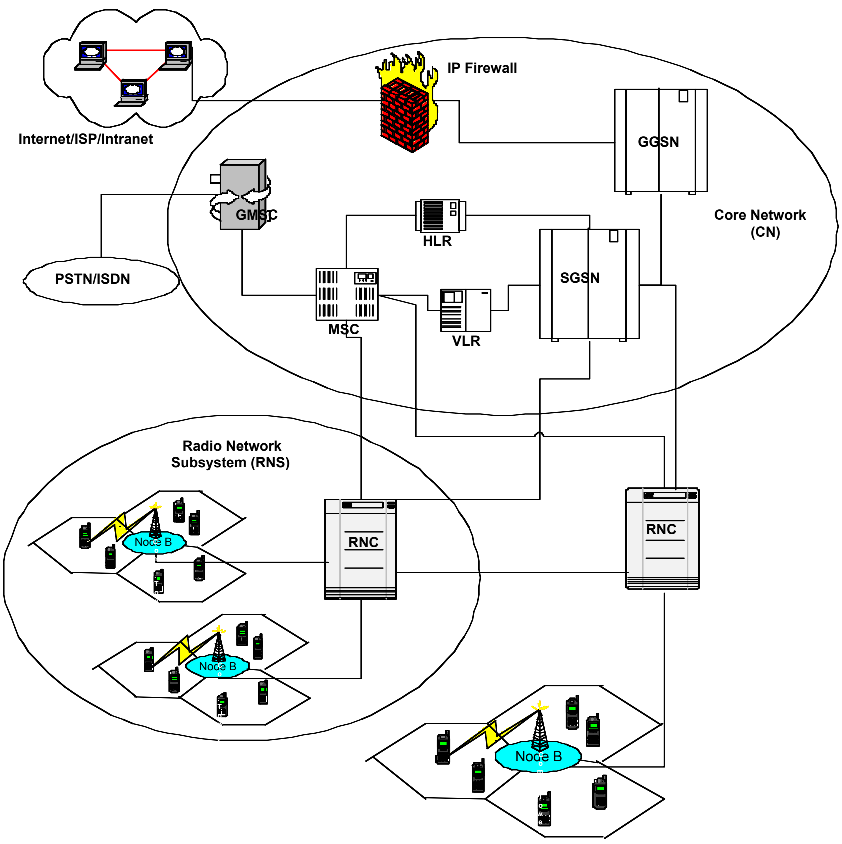

Figure 5.9: UMTS Architecture Detailing CN Components

5.5.5 UMTS Protocol Architecture

Logically the UMTS protocol architecture is divided into a control plane and a user plane that handle the signaling/control and data transmission respectively in both the radio layer and the network transport layer. The data transfer is done within the user plane. The control plane takes care of link control and all signaling functions for connections. Figure 5.10 highlights the main functions of the protocol architecture.

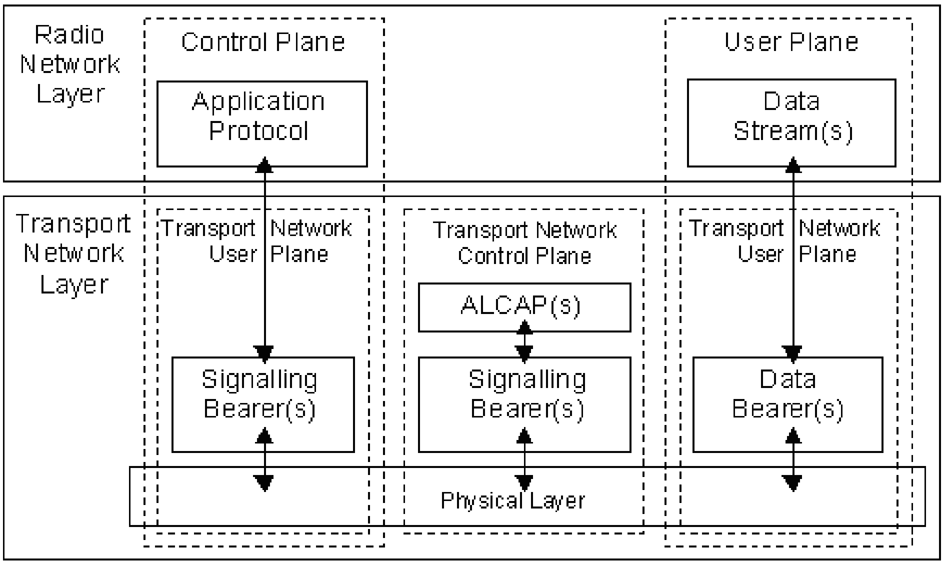

Figure 5.10: UMTS 3G Protocol Architecture

The five major blocks in the above figure consist of the Signaling Bearers, the Data Bearers, the Application Protocols, the Data Streams and the Access Link Control Application Part (ALCAP). Signaling Bearers transmit signals and control information between layers. The Data Bearers are responsible for framing the data for transmission over the link and they are set up by the ALCAP in the Transport Network Layer control plane. The ALCAP reacts to the radio network layer’s demands to set up, maintain and release data bearers.

In the user plane of the Transport Network Layer, a GPRS Tunneling Protocol (GTP-U) is used to provide the data conduits. The transport layer below GTP is the UDP/IP protocol.

5.5.6 UMTS Air Interface

The physical layer of UMTS, which is responsible for the actual data transmission, specifies both a FDD and a TDD solution. This is discussed in detail in Section 5.5.6.1

The data link layer has four sublayers – Medium Access Control (MAC), Radio Link Control (RLC) and two more Layer-2 protocols used only in the user plane called Packet Data Convergence Protocol (PDCP) and Broadcast/Multicast Control (BMC). Usually logical channels are defined to transmit specific information types. The MAC layer is responsible for converting these logical channels to physical ones. It also handles priority management of UEs, ciphering of data, traffic monitoring, and multiplexing among other tasks. Some tasks of the RLC include the establishment of RLC connections, transparent data transfer, QoS settings and Acknowledged/Unacknowledged data transfer. Each radio bearer has one RLC connection.

Several network layer protocols such as IPv4 and IPv6 have to be supported across the air interface. PDCP supports transparent transmission of network protocols. It also is responsible for header compression over the air link for more efficient bandwidth usage. BMC offers broadcast and multicast services over the air interface.

5.5.6.1 Physical Layer Transmission Technology

Several functions are incorporated into the physical layer. They include diversity combining, FEC, time synchronization and frequency synchronization, modulation/demodulation, spreading/dispreading,` transport channel multiplexing, radio channel measurements, rate matching, and inner-loop power control. The UMTS physical layer supports two multiple access schemes – W-CDMA used in FDD mode and TD-CDMA utilized in TDD mode.

FDD and TDD modes:

The crucial difference between 2G and 3G technology is the adoption of CDMA as a multiple access technology. As mentioned in earlier sections, the FDD mode uses W-CDMA and requires paired spectrum to accommodate the uplink and the downlink transmissions, whilst the TDD mode combines TDMA and CDMA in unpaired spectrum and as such can accommodate asymmetric links. However, the stringent timing requirements of TD-CDMA make it suitable primarily for picocells only. The move towards CDMA requires a significant demand in computational resources as the technology is computationally complex to implement.

A detailed description of the FDD and TDD modes can be found in [3,4]. In Table 5.7 we summarize the key features of FDD and TDD [5].

Table 5.7: Comparing FDD and TDD in UMTS

	UTRA FDD	**UTRA TDD**
Multiple access	CDMA	TDMA/CDMA
Frequency Band	1920-1980MHz (UL) 2110-2170MHz (DL)	1900-1920MHz 2010-2025MHz
Channel BW	2X5MHz	5MHz/1.6MHz with 1.28Mcps
Frequency Reuse	1	1
Channel Coding	Convolutional/Turbo	
Duplexer	Needed	Not needed
Asymmetric connection	Supported	
Modulation	QPSK	
Time Slot Structure	15slots/frame	15slots/TDMA frame
Chip Rate	4.096/8.192/16.384 Mc/s	3.84Mcps or 1.28Mcps
Power control	Closed loop (1500Hz)	800Hz (DL-Closed Loop) 100/200Hz(UL-Open Loop)
Receiver	Rake	Joint Detection (mobile:Rake)
Frame Length	10ms	
Handover	Soft, Softer (interfrequency:Hard)	Hard
Power Control Step Size	0.5,1,1.5,2dB(Variable)	1,2,3dB (variable)
Mobile Peak Power	class 1: +33dBm(+1/-3)=2W class 2: +27 dBm class 3: +24 dBm class 4: +21 dBm	
Number of base station codes	512/frequency	
Chips/slot	2560	
Multirate method	Multicode, multislot, OVSF	Multicode, OVSF
Spread factor	4-512	1-16

5.5.6.2 Handovers

Handovers in cellular systems provide the mechanism by which a mobile terminal can sustain a connection whilst roaming between different cells, radio networks and cellular systems. For a detailed discussion on UMTS handovers refer to [[6]]. In UMTS three types of handovers are defined:

- A hard handover – one that requires a change in frequency band
- A soft handover – one that allows a mobile to maintain several active links to different Node Bs
- A softer handover – one that allows a mobile to maintain several active links to the same Node B

Hard Handover- Hard handover means that all the old radio links in the UE are removed before the new radio links are established. Hard handover can be seamless or non-seamless.

Seamless hard handover means that the handover is not perceptible to the user. In practice a handover that requires a change of carrier frequency (inter-frequency handover) is always performed as a hard handover.

Soft Handover - Soft handover means that radio links are added and removed from a mobile's receiver in such a way that the mobile always maintains at least one radio link to a UTRAN. Soft handover is performed by means of macro diversity, which refers to the condition that several radio links are active at the same time. Normally soft handover is used when cells operate on the same frequency.

Softer Handover - Softer handover is a special case of soft handover where the radio links that are added and removed belong to the same Node B (i.e. the site of co-located base stations from which several sector-cells are served). In softer handover, macro diversity with maximum ratio combining can be performed in the Node B, whereas generally in soft handover on the downlink, macro diversity with selection combining is applied. In summary, a soft handover is an inter cell handover, whereas a softer handover is an intra cell handover.

For UMTS the following types of handovers are specified:

- Handover 3G – 3G (i.e. between UMTS and other 3G systems)
- FDD soft/softer handover
- FDD inter-frequency hard handover
- FDD/TDD handover (change of cell)
- TDD/FDD handover (change of cell)
- TDD/TDD handover
- Handover 3G - 2G (e.g. handover to GSM)
- Handover 2G - 3G (e.g. handover from GSM)

A mix of both soft, softer and hard handovers will be required to enable global roaming with transparent cellular service to the end user.

5.6 POINTS OF VIEW AND CONCLUSIONS

The path to 3G has not been an easy one, fraught with high expenditures and little to offer the end customers beside high speed data rates. The initial pricing of the services is key to attracting a loyal customer base that is willing to move from a proven, easy to use 2G service to one that has yet to prove itself and whose pricing structure has far from stabilized. It is obvious that in the long term, 3G is the solution needed to provide better communication services for a larger customer base that is more and more Internet savvy and interested in accessing the vast array of services and content that is available on the WWW. Multimedia services such as real-time video streaming, video-telephony, etc., combined with high bit rate data transfers of web information will without doubt be the main reasons for customers to switch to 3G. With the ability to support a larger population base using the same bandwidth as 2G, 3G should be able to price its basic services at a lower cost than what is currently being charged.

However, because of high deployment costs, Forrester calculates that even with operators' unrealistic penetration assumptions they will need to triple 3G user ARPU (Average Revenue Per Unit) to break even in year five. More sensible penetration rates and a realistic, flat ARPU over the full license period will push average break-even out to 2014 for most countries. Developing countries have a different problem, one of lack of sufficient wireline infrastructure to support a population demanding communication capabilities. This problem is being solved with the deployment of wireless phone services. This high demand for a communication service provides a very strong basis for the deployment of next generation wireless services that can over time be fully expanded to support services well beyond just basic the voice/telephony service.

The discussion presented below and ensuing conclusions are taken from a presentation entitled “Do Developing Countries Need An Alternative Route To 3G?” by M. Suwarso, Asia Pacific Telecommunity, IMT 2000 Forum 4, Vice-Chairman. It nicely summarizes the current view of 3G.

By and large the route to 3G implementation has been established. The point of departure is usually the existing 2G network. The next intermediary step is then the enhancement of the network with 2.5G technologies. Finally, IMT 2000 systems would overlap it, and would proceed gradually to replace the pre-IMT 2000 network. This strategy on 3G deployments has been adopted or planned to be adopted by most operators in developed countries and few, if any, in developing countries.

Developing countries are characterized by the tremendous low teledensity of its fixed (PSTN) service. This has been driven by – besides scarcity of capital – the very high up-front investment needed for rolling out new copper-based subscriber networks. Furthermore, to install physical lines to individual customer premises is often very cumbersome. Even though IMT-2000 technology is conceived primarily for mobile communications, it also is capable for providing an economical and effective alternative to wired local loops. Used as FWA (Fixed Wireless Access) it can substantially reduce the up-front investment necessary for PSTN new lines and speed-up the expansion of the PSTN service.

Actually, FWA (Fixed Wireless Access)or also known as wireless local loop (WLL) has been used in a number of environments for some time. Some countries have started to install FWA, utilizing IMT 2000 derived technology. For example, the incumbent fixed-line operator in Indonesia is deploying over a million FWA lines using CDMA 2000 1x technology, which is an IMT-2000 technology. Moreover, 3G-based FWA is expected to account for most new subscriber additions in the coming years. This course of action is being taken mainly to shorten the long waiting time for and to accelerate the expansion of coverage of the fixed telephone service. But there are grounds for speculating that the strategy could be construed as the initial step toward the deployment of full-scale IMT-2000. The strategy enables not only the early introduction of 3G technologies with less initial investment; it also permits the generation of cash flow practically from day one. This is because the details of would-be customers have been registered or recorded in the lengthy waiting list, so that as soon as the access were made available, it would be virtually effortless to acquire new subscription. Furthermore, the deployment of such FWA facilitates scalability that can cost-effectively grow as needed.

It would be not unrealistic to suppose that the evolution of 3G-based FWAs towards full scale IMT 2000 would proceed with less complexity, as there are high degrees of commonalities between both applications. Nevertheless, to ensure the viability of such progression, a number of issues need to be dealt with. These include:

1. The transition of FWA that utilizes 3G-derived radio access technologies and initially being used as alternative to wire-line local loop of the PSTN, toward full-scale IMT-2000 mobile network has to proceed smoothly and seamlessly without disrupting normal operation.
2. To increase the practicability of the progression, it has to be examined the possibility of allocating to such FWAs the same frequency block, which has been designated for IMT 2000 by the WRC 92/2000.
3. The specifications of interfaces of FWAs that utilize IMT-2000 radio technologies with existing fixed public networks have to be closely aligned with the corresponding standards of IMT 2000 as developed by ITU, 3GPP or 3GPP2.
4. Further market liberation will drive the increasing demand on more spectrums for 3G-based FWAs. To meet this demand efficiently and effectively, there is a need to explore whether spectrum-efficient IMT 2000 radio access technologies, such as IMT 2000 CDMA TDD (Time Division Duplex), are suitable to be used as basis for FWAs.
5. Technically, IMT-2000-based FWAs have the capability to offer limited outdoor mobility service, even though the limit may possibly extent to an area covering a single area code. Existing operators of mobile systems might challenge regulation that allows fixed service operators to offer mobility service features. As consequence, the definition of market for fixed telephone service in the existing regulatory framework may likely need to be amended.

The above described issues are not only about the deployment of IMT 2000 *per se*, but it also gets to the bottom of lessening the deficiency in fixed line teledensity, a common concern of most, if not all, developing countries.

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5.8 GLOSSARY

3GPP	3rd Generation Partnership Project
ALCAP	Access Link Control Application Part
AMR	Adaptive MultiRate
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
BMC	Broadcast/Multicast Control
BS	Base Station
CDMA	Code Division Multiple Access
CN	Core Network
CS	Circuit Switched
DECT	Digital Enhanced Cordless Technologies
DIFFSERV	Differentiated Services
DL	Down Link
DRNC	Drift RNC
EDGE	Enhanced Data for Global Evolution
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FER	Frame Error rate
FOMA	Freedom Of Mobile multimedia Access
FWA	Fixed Wireless Access
GGSN	Gateway GPRS support node
GMSC	Gateway-MSC
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GTP	GPRS Tunneling Protocol
HLR	Home Location Register
IEC	International Engineering Consortium
IP	Internet Protocol
ISDN	Integrated Services Digital Network
IWF	InterWorking Function
LAN	Local Area Network
LLC	Logical Link Protocol
MAC	Medium Access Control
MPLS	MultiProtocol Label Switching
MS	Mobile Station
MSC	Mobile-Services Switching Center
NBAP	Node B Application Part
NGN	Next Generation Network
Node B	UMTS 3G base station
NSS	Network SubSystem

OVSF	Orthogonal Variable Spreading Factor
PDCP	Packet Data Convergence Protocol
PDU	Protocol Data Unit
PS	Packet Switched
PSTN	Public Switched Telephone Network
PTT	Push to Talk
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAB	Radio Access Bearer
RANAP	Radio Access Network Application Part
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RNSAP	Radio Network Sublayer Application Part
RRC	Radio Resource Control
RTT	Radio Transmission Technology
SCCP	Signaling Connection Control Part
SDU	Service Data Unit
SGSN	Serving GPRS Support Node
SMS	Short Message Service
SNDCP	SubNetwork Dependent Convergence Protocol
SRNC	Serving RNC
TD-CDMA	Time Division CDMA
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous CDMA
UE	User Equipment
UL	Up Link
UMTS	Universal Mobile Telecommunications Systems
UTRAN	Terrestrial Radio Access Network
VLR	Visitor Location Register
VoIP	Voice over IP
WAN	Wide Area Network
W-CDMA	Wideband CDMA

APPENDIX C

C.1 GPRS Contracts

Table C-1: GPRS Worldwide Contracts

Country	Network	Activation Status	Infrastructure Suppliers
Argentina	Telecom Personal	Live	Ericsson
Australia	Optus	Test	Nokia & Nortel
Australia	Telstra	Test 9/00	Nortel & Ericsson
Australia	Vodafone	Live	Ericsson
Austria	T-Mobile	Live 4/01	Siemens
Austria	Mobikom	Under construction	Nokia & Motorola
Austria	ONE	Live 2/01	Nokia
Austria	Tele-ring	Live	Alcatel
Bahrain	Batelco	Under construction	Ericsson
Belgium	Base(KPN Orange)	Under construction	Ericsson
Belgium	Mobistar	Live 6/01	Nokia
Belgium	Proximus	Live 1/01	Motorola & Nokia
Bolivia	Entel	Under construction	Ericsson
Bolivia	Nuevatel PCS de Bolivia	Under construction	Nokia
Brazil	Oi	Live 6/02	Alcatel & Nokia
Brazil	TIM	Live	
Bulgaria	GloBul	Under construction	Motorola
Bulgaria	Mtel	Live	Siemens
Canada	Microcell	Live 6/01	
Canada	Roger AT&T	Live	Ericsson
Chile	Entel Telfonia	Live 10/01	
China	China Mobile	Test	Alcatel, Motorola, Nokia & Ericsson
China	China Unicom	Test	Nortel, Motorola & Siemens
Costa Rica	Instuto Costaricense de Electricidad	Under construction	
Croatia	Hrvatski Telekom	Live 7/01	Siemens
Croatia	Vip Net	Live 6/01	Ericsson
Cyprus	CYTA (South)	Under construction	Ericsson
Czech	EuroTel Praha	Live	Nokia
Czech	Oskar Mobile	Live 2/02	Ericsson & Siemens
Czech	T-Mobile	Live 1/02	Siemens & Motorola
Denmark	Orange	Live	Nokia
Denmark	Sonofon	Live	Nokia
Denmark	TDC Mobil	Live 7/01	Nokia
Denmark	Telia	Live	Ericsson
Egypt	Mobinil	Test 1/01	Nokia
Egypt	Vodafone	Live 4/03	
El Salvador	Personal	Under construction	Alcatel
Estonia	EMT	Live 7/01	Ericsson
Estonia	Radiolinja	Under construction	Nokia
Finland	Alands Mobile	Under construction	Ericsson
Finland	Sonera	Live 12/00	Ericsson & Nokia
Finland	Suomen 2G	Under construction	Ericsson

Table C-1: GPRS Worldwide Contracts (continued)

Country	Network	Activation Status	Infrastructure Suppliers
Finland	Telia	Live 10/01	Nokia
France	Bouyges Telecom	Under construction	Ericsson & Cisco
France	Orange France	Under construction	Alcatel
France	SFR	Live 7/01	Alcatel & Nokia
Georgia	Geocell	Test 7/01	Motorola
Germany	Vodafone D2	Live 2/01	Siemens
Germany	E-Plus	Live 12/00	Nokia
Germany	T-Mobil	Live 6/01	Ericsson & Motorola
Germany	O2 (Viag)	Live 3/01	Nokia
Greece	Cosmote	Live 3/01	Nokia
Greece	Tele Stet	Live 7/01	
Greece	Vodafone	Live 3/01	Ericsson
Hong Kong	CSL	Live 11/00	Nokia
Hong Kong	New World	Live 10/00	Nokia
Hong Kong	Peoples Phone	Under construction	Ericsson
Hong Kong	Smartone	Live 7/00	Ericsson
Hong Kong	Sunday	Under construction	Nortel
Hungary	Pannon	Live 6/01	Ericsson
Hungary	Vodafone	Under construction	Nokia
Hungary	Westel	Live 8/01	Motorola &Ericsson
Iceland	Siminn	Under construction	Ericsson
Iceland	OG Vodafone	Live 2/01	Nortel
India	Airtel World	Live 2/03	
India	Idea Cellular (Birla Tata AT&T)	Under construction	Nokia
India	BPL Mobile	Live 1/02	
India	Escotel Mobile	Under construction	Lucent
Indonesia	Satelindo	Under construction	Siemens
Indonesia	Telkomsel	Under construction	Siemens
Ireland	Vodafone	Live 1/02	Ericsson
Ireland	O2	Live 2/02	Nortel
Israel	Orange	Live 6/01	Ericsson
Italy	Omnitel Vodafone	Live	Nokia
Italy	TIM	Live 5/01	Siemens
Italy	Wind	Live	Siemens
Jordan	FastLink	Live 1/02	
Jordan	Mobilecom	Live 5/02	
Latvia	LMT	Live 6/02	
Lebanon	Cellis	Live 4/01	Ericsson
Liechtenstein	Mobilkom	Live	
Liechtenstein	Orange FL	Under construction	Nokia
Lithuania	Bite	Under construction	Ericsson
Lithuania	Omnitel	Live	Motorola
Luxembourg	LuxGSM	Live 2/01	Siemens
Luxenbourg	Tango	Live 1/01	Ericsson
Malaysia	Celcom	Test 10/00	Siemens & Lucent
Malaysia	Digi	Under construction	Ericsson

Table C-1: GPRS Worldwide Contracts (continued)

Country	Network	Activation Status	Infrastructure Suppliers
Malaysia	Maxis	Test 8/00	Motorola
Malaysia	Telekom Cellular	Under construction	Alcatel
Malta	Go Mobile	Test 8/01	Nortel
Malta	Vodafone	Live 8/01	Siemens
Mexico	Telcel	Under construction	Ericsson
Morocco	Maroc Telecom	Under construction	Siemens
Netherlands	T-Mobile (Ben)	Live 12/01	Nokia
Netherlands	Orange	Under construction	Nokia
Netherlands	KPN Mobile	Live 12/00	Nokia
Netherlands	Telfort	Live	Ericsson
Netherlands	Vodafone	Live 9/01	Ericsson
New Zealand	Vodafone	Live 8/00	Nokia
Nicaragua	Enitel	Under construction	Ericsson
Norway	Netcom	Live 1/01	Siemens
Norway	Telenor	Live 1/01	Nokia
Pakistan	Ufone	Under construction	Nortel
Panama	TelCA	Under construction	Motorola
Philippines	Globe Handyphone	Under construction	Ericsson & Nokia
Philippines	Smart	Under construction	Nokia
Poland	CenterTel/Idea	Live	Nokia
Poland	ERA	Live 11/00	Siemens & Alcatel
Poland	Plua GSM	Live	Nokia
Portugal	Optimus	Live	Nokia
Portugal	TMN	Live 11/00	Siemens & Alcatel
Qatar	Q-Tel	Under construction	Alcatel
Romania	Connex	Live 10/01	
Romania	Orange	Live 7/01	Siemens
Russia	Beeline	Live	Nokia
Russia	Mobile Telesystems (MTS)	Live 9/00	Motorola & Siemens
Singapore	MobilOne	Live 11/00	Nokia
Singapore	SingTel	Live 11/00	Ericsson
Singapore	StarHub	Live 10/00	Nokia
Slovenia	Mobitel	Live 6/01	
South Africa	MTN	Under trial	Motorola
Spain	Amena	Live	
Spain	Telefonica	Live 6/01	Siemens, Nokia, Motorola & Ericsson
Spain	Vodafone	Under construction	Siemens & Ericsson
Sweden	Comviq	Under construction	Siemens
Sweden	Vodafone	Live 9/01	Nokia
Sweden	Telia Mobitel	Live 9/01	Nokia & Ericsson
Switzerland	Orange	Live	Nokia
Switzerland	Sunrise	Live	Nokia
Switzerland	Swisscom	Live 1/02	Ericsson
Taiwan	Chunghwa Teleocm	Under construction	Nortel & Nokia
Taiwan	FarEasTone	Live 6/02	Ericsson
Taiwan	KG Telecom	Live 8/01	Nokia

Table C-1: GPRS Worldwide Contracts (continued)

Country	Network	Activation Status	Infrastructure Suppliers
Taiwan	Mobitai	Live 1/02	Siemens
Taiwan	TransAsia	Under construction	Ericsson
Thailand	AIS	Under construction	Siemens
Thailand	CP Orange	Under construction	Alcatel
Thailand	DTAC	Live	Nokia
Tunisia	Tunisie Telecom	Under construction	Alcatel & Ericsson
Turkey	Aria	Live 3/02	
Turkey	Telsim	Live 8/00	Siemens & Motorola
Turkey	Turkcell	Live 3/01	Ericsson
UAE	Etisalat	Live 1/02	Alcatel & Motorola
UK	O2	Live 7/00	Motorola
UK	Orange	Live	Ericsson
UK	T-Mobile	Under construction	Nortel & Ericsson
UK	Vodafone	Live 7/01	Ericsson
Ukraine	Kyivstar	Live 1/03	Ericsson
Ukraine	UMC	Under construction	Siemens
USA	AT&T Wireless	Live 7/01	Nortel & Ericsson
USA	Cingular	Live 01	Ericsson, Nokia & Siemens
USA	T-Mobile	Live 11/01	Siemens & Ericsson
USA	MBO Wireless	Live	AirNet
Yugoslavia	Mobtel	Under construction	Ericsson

C.2 3G Infrastructure Contracts Worldwide

Table C-2: 3G Worldwide Contracts

Country	Cellular Network	Month	Vendor
Hong Kong	Sunday	Dec-03	Huawei Technologies
Taiwan	FarEasTone Telecommunications	Dec-03	Ericsson
Singapore	M1	Dec-03	Nokia
Singapore	StarHub	Oct-03	Nokia
Netherlands	KPN Mobile	Oct-03	Lucent Technologies
Greece	Cosmote	Jun-03	Ericsson
Germany	E-Plus	Jun-03	Lucent
France	Orange	Feb-03	Ericsson
France	Orange	Feb-03	Alcatel
Luxembourg	P&T Luxembourg	Dec-02	Siemens
Germany	O2	Oct-02	Marconi
Japan	J-Phone	Oct-02	Ericsson
Japan	J-Phone	Oct-02	Nokia
Italy	H3G	Jul-02	Alcatel
Finland	Radiolinja	Jun-02	NOKIA
Austria	Hutchison 3G	Apr-02	Nokia
Austria	Hutchison 3G	Apr-02	Siemens
Pan-Europe	MmO2	Apr-02	Nortel Networks
Pan-Europe	T-Mobile	Apr-02	Nortel Networks
Norway	Tele2	Mar-02	Siemens
Sweden	Svenska UMTS Nat	Mar-02	Ceragon Networks
Sweden	Orange Sverige	Mar-02	Teracom
Germany	Telefonica Moviles	Mar-02	Nortel Networks
Spain	Telefonica Moviles	Mar-02	Nortel Netwoks
Switzerland	Sunrise	Feb-02	Ericsson
Portugal	TMN	Feb-02	Alcatel
Belgium	Proximus Belgacom Mobile	Feb-02	Siemens
Belgium	Proximus Belgacom Mobile	Jan-02	Nokia
Sweden	3GIS	Oct-01	Nokia
Hong Kong	CSL	Sep-01	Nokia
HongKong	SmarTone	Sep-01	Ericsson
Finland	Telia Mobile	Sep-01	Nokia
Sweden	Vodafone	Aug-01	Nokia
Sweden	Vodafone	Aug-01	Nokia
Japan	J-Phone	Aug-01	Nokia
UK	Orange	Aug-01	Nokia
France	Cegetel SFR	Jul-01	Nokia
France	Cegetel SFR	Jul-01	NEC & Siemens
Portugal	Vodafone	Jul-01	Nortel Networks
Italy	Omnitel Vodafone	Jul-01	Nokia
Russia	Moscow Cellular Communications	Jul-01	Lucent Technologies
Germany	VIAG Interkom	Jul-01	Nokia
Australia	Hutchison 3G	Jul-01	Motorola
Austria	Hutchison 3G	Jul-01	Motorola

Table C-2: 3G Worldwide Contracts (continued)

Country	Cellular Network	Month	Vendor
Italy	Hutchison 3G	Jul-01	Motorola
UK	Hutchison 3G	Jul-01	Motorola
Sweden	Hutchison 3G	Jul-01	Motorola
Sweden	Hi3G	Jun-01	Ericsson
Portugal	ONI WAY	Jun-01	Nortel Networks
Australia	Hutchison 3G	Jun-01	Ericsson
Sweden	Svenska UMTS Nat	Jun-01	Ericsson
Norway	Telia Mobile	Jun-01	Siemens
Finland	Telia Mobile	Jun-01	Siemens
Netherlands	Telia Mobile	Jun-01	Siemens
Italy	Omnitel Vodafone	May-01	Nortel Networks
Finland	Radiolinja	Apr-01	Nokia
Switzerland	Orange	Apr-01	Nokia
Italy	Wind	Apr-01	Nokia
UK	Orange	Apr-01	Nokia
France	Orange	Apr-01	Nokia
Germany	Mobilcom	Apr-01	Nokia
UK	Hutchison 3G	Apr-01	Nokia
Australia	Optus	Apr-01	Nokia
Netherlands	KPN Mobile	Apr-01	Ericsson
Germany	Eplus	Apr-01	Ericsson
Belgium	Base	Apr-01	Ericsson
Netherlands	Vodafone	Apr-01	Ericsson
Finland	Radiolinja	Apr-01	Siemens
Finland	Telia Mobile	Mar-01	Nokia
Norway	NetCom	Mar-01	Nokia
Norway	Telenor Mobil	Mar-01	Nokia
France	Cegetel SFR	Mar-01	Nokia
Austria	Mobilkom Austria	Mar-01	Ericsson
Norway	Telenor Mobil	Mar-01	Ericsson
Spain	Amena	Mar-01	Ericsson
Austria	One	Mar-01	Ericsson
France	Orange	Mar-01	Alcatel
Spain	Amena	Mar-01	Siemens
France	Cegetel SFR	Mar-01	Siemens
USA	Verizon Wireless	Mar-01	Lucent Technologies
Monaco	Monaco Telecom	Feb-01	NEC & Siemens
Portugal	Optimus	Feb-01	Ericsson
Portugal	TMN	Feb-01	Ericsson
France	Cegetel SFR	Feb-01	Alcatel
Portugal	OniWay	Feb-01	Siemens
France	Cegetel SFR	Feb-01	Nortel Networks
Canada	Roger AT&T	Jan-01	Ericsson
Portugal	TMN	Jan-01	Alcatel
Portugal	TMN	Jan-01	Siemens
Germany	T-Mobile	Dec-00	Nokia

Table C-2: 3G Worldwide Contracts (continued)

Country	Cellular Network	Month	Vendor
Finland	Sonera	Dec-00	Nokia
Finland	Sonera	Dec-00	Ericsson
Norway	Telenor Mobil	Dec-00	Ericsson
Switzerland	Swisscom	Dec-00	Ericsson
Germany	T-Mobile	Dec-00	Siemens
Germany	T-Mobile	Dec-00	Nortel Networks
Germany	Group 3G	Dec-00	Lucent Technologies
Spain	Telefonica Moviles	Nov-00	Nokia
Netherlands	Telfort	Nov-00	Ericsson
Spain	Telefonica Moviles	Nov-00	Ericsson
Germany	D2 Vodafone	Nov-00	Ericsson
Germany	D2 Vodafone	Nov-00	Siemens
USA	AT&T Wireless	Nov-00	Nortel Networks
France	Orange	Oct-00	Nokia
Italy	Wind	Oct-00	Nokia
Japan	J-Phone	Oct-00	Nokia
Spain	Xfera Moviles	Oct-00	Ericsson
Germany	MobilCom	Oct-00	Ericsson
Slovenia	Mobitel	Oct-00	Ericsson
Italy	Wind	Oct-00	Ericsson
Italy	Andala Hutchison	Oct-00	Ericsson
Italy	TIM	Oct-00	Ericsson
Japan	J-Phone	Oct-00	Ericsson
Italy	Wind	Oct-00	Siemens
Spain	Xfera Moviles	Oct-00	Nortel Networks
Spain	Vodafone	Sep-00	Nortel Networks
Mexico	Telcel	Aug-00	Ericsson
Singapore	MobileOne	Jun-00	Nokia
Sweden	Tele1 Europe	Jun-00	Ericsson
Norway	Tele1 Europe	Jun-00	Ericsson
Singapore	StarHub	May-00	Nokia
UK	Vodafone	May-00	Ericsson
UK	MmO2	May-00	Nortel Networks
Germany	VIAG EuroPlattform	Apr-00	Nokia
Hong Kong	New World Mobility	Apr-00	Nokia
Japan	J-Phone	Mar-00	Nokia
Finland	Alands Mobiltelefon	Mar-00	Ericsson
Japan	J-Phone	Mar-00	Ericsson
Finland	Suomen 2G	Feb-00	Nokia
Finland	2G Ltd	Feb-00	Ericsson

C.3 3G Deployment

Table C-3: A Sample of 3G Deployment

Country	South Korea	Singapore	Israel	Japan
Date Awarded	Dec-00	Apr-01	Dec-01	12-Jun-00
Award Method	Beauty Contest	Beauty Contest	Auction	No contest
Frequency Bands MHz	1920-1980	1900-1920,1920-1980, 2110-2170	1710-1785 & 1805-1880 & 1920-1980 & 2110-2170 & (1900-1920 or 2010-2025)	1920-1980 & 2110-2170
Spectrum per license	LG Telecom (1920-1940) SK Telecom (1940-1960) KT ICOM (1960-1980)	1 of 2x15MHz + 5MHz and 3 of 2x14.8 MHz + 5 MHz	2x10Mhz + 2x5Mhz + 5Mhz (not the entire spectrum will be available until 2004)	DoCoMo - 1920-1940 MHz uplink 2110-2130 MHz downlink J-Phone - 1940-1960 MHz uplink 2130-2150 MHz downlink KDDI - 1960-1980 MHz uplink 2150-2170 MHz downlink
License Duration	?	20 years	?	not formally awarded
Coverage Obligations	none	nationwide by end 2004	?	none
Adult Population (>15 years)	37,131,000	3,395,000	4,313,588	107,868,000
Cost/head of adult population	US $ 89	US $44	US $ 36	US $ 0
Fixed Fee	US $ 1.1 billion	US $50 million	US $52.02 million	US $ 0
Regulator Web Site	Ministry of Information & Communications	IDA	Ministry of Communications	Ministry of Posts and Telecommunications
Bidders/Winners	LG Tel pd US$1.1billion, start Q1 03 SK Tel pd US$1.1billion, start Q3 03 KT ICOM pd US$1.1billion, start late 02	MobileOne, pd US$50 million SingTel, pdUS$ 50 million StarHub, pd US$50 million	Partner/Orange,pd US$52.02 million start 2003 Pelephone, pd US$53.2 million TBA Cellcom pd US $52.02 million late 2002	DoCoMo, pd US$ 0 live, Oct 2001 Japan Telecom, pd US $0 Q4 2002 KDDI Corp, pd US$ 0 live April 2002
Infrastructure contracts : vendor, date, type, cell network	Lucent Tecnologies, 7/02 CDMA2000 1x, KTF	Nokia, 12/03, 3G, M1	Nortel Networks, 4/02 CDMA, Pelephone Nokia, 7/01, GSM, Cellcom	Ericsson, 10/02, 3G, J-Phone Nokia, 10/02, 3G, J-Phone Nokia, 8/01, 3G, J-Phone