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9. ABSTRACT

A presentation of the results of a cost-benefit study of the usefulness of certain advanced communications technologies for the less developed countries. The specific technologies examined concern non-voice, non-video electronic communication of text and data via telex, facsimile, computer polling systems, computer time-sharing networks, packet switched computer networks, satellites, or multiple-access satellite systems. To examine the needs and costs of such communication systems, the authors focused on the telecommunications needs of the International Agricultural Research Centers located in less developed countries. Their communications needs are acute. The authors conclude that an estimated $150,000 per year would cover the communication and equipment costs of a telephone-based computer polling system for all IARCs, and would enable each to send and receive about 75 typewriter pages a day at a cost of a quarter to a half-dollar a page. The general conclusion of the study is that high-technology systems of data communication are manageable in and appropriate to the needs of the less developed countries. The use of such technologies can markedly reduce costs for some important services, and give the LDCs access to the best and most advanced technical information bases. The result of such participation by the LDCs will be their quicker achievement of independence.

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LOW COST DATA AND TEXT COMMUNICATION FOR THE LESS DEVELOPED COUNTRIES

A Study With Special Reference to
The Needs of
The International Agricultural Research Centers

by

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One of a series of reports on
low cost international data communication
done by the

Research Program on Communications Policy
in the
Center for Policy Alternatives
Center for International Studies
Center for Advanced Engineering Study
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FORMAT

The body of this report is printed double space. Backup material is inserted in the body of the text single spaced. The casual reader can read through the double spaced material, turning to the rest only as he is curious.

CHAPTER 1

SUMMARY AND CONCLUSIONS

The world's food crisis has drawn attention to the possible value of international computerized information retrieval systems to aid technical development in the less developed countries.

Recently Secretary of State Henry Kissinger offerred the services of the Smithsonian Institutions Science Information Exchange to facilitate agricultural development. The US has proposed similar co-operation in the UN, a proposal that was supported by the General Assembly.

In order to draw on international computerized data bases, however, the user must have telecommunications facilities for data transmission. How can the advanced communications technologies needed for such information systems be provided in the LDCs?

That is the subject of this study. It is a study of the usefulness of certain advanced communications technologies for the less developed countries (LDCs). It is therefore a cost benefit study. It asks both how valuable those technologies might be for poor countries, and what various designs of those technologies might cost.

NEW TECHNOLOGIES FOR COMMUNICATION:

The specific technologies that we shall examine concern non-voice,

non-video electronic communication, i.e. the transmission of text or data. From an engineering perspective, text and data are identical, so the usual technical name for what we are describing is "data communication." When a teletype, or computer network, or other electronic channel transmits a numeral of data or a character of text it does so in a six to eight bit code. The important point is that six or eight bits is a very small amount. A single satellite voice channel has enough bandwidth to transmit six to eight thousand such characters in one second. (1)

If one translates that to about two printed pages per second, one realizes at once why data communication can be much more economical than voice communication. By voice someone talking may get about a word and a half across in a second. (2)

For developing countries whose telephone cables, microwave links and satellite circuits are now few in number and are expensive to construct, a mode of communication that can pack large amounts of information into limited facilities, carries very important implications.

The technologies that have been developed in advanced countries for data communication and which might meet needs of the LDCs are:

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(1) Even a fairly low grade telephone line (2400 bps) will carry about 300 such characters in a second, or about 45 words.

(2) Voice communication is more economical, in turn, than video. One can get 500 to 1000 voice channels into the bandwidth of one video transmission.

SUMMARY AND CONCLUSIONS

1. Telex
2. Facsimile
3. Computer Polling Systems
4. Computer time sharing networks
5. Packet switched computer networks
6. Satellites
7. Multiple access satellite systems

In Chapter II we shall review what each of those technologies can do. The bottom line, however, is that each, in its way, can contribute to making low cost data and text communication internationally available.

THE REQUIREMENTS OF THE LDC'S AND THE AGRICULTURAL RESEARCH CENTERS:

The communication requirements of any society are manifold. The government requires facilities to mobilize its population; the population in turn must have the means to express itself. Business needs communications for management and marketing. Security forces depend upon communcations and so do educators, railroads and airlines.

In part, as we evaluate advanced telecommunications technologies for the LDCs we shall try to do it with reference to their total communications needs. We shall consider to what extent LDCs require such gadgetry. However, a total evaluation of that sort is beyond

the scope of this study. LDCs, like other countries, have a myriad of different communication needs. We cannot begin to consider them all in any detail.

We shall proceed instead by a case study - an examination of the telecommunications needs of the International Agricultural Research Centers (IARC's).

The needs of the IARC's are far from typical for the LDCs. Like airlines or banks, they are institutions with extremely advanced communication needs that put a strain on the capabilities found in poor countries. A study of how to meet the telecommunications needs of the IARC's is thus a test of what is possible in an LDC and how progress in telecommunications can be initiated within them. It is not a study of a statistical sample of users of telecommunications in LDCs.

To meet the communications needs of the IARC's is nonetheless of considerable importance to the LDCs. Churchill's remarks on the Battle of Britain could with minor modification be applied to the war against hunger: Never have so many been dependent upon so few. The prospect of avoiding famine in the world rests critically on the research that the IARC's are doing. Any money spent to assure their success will be returned a thousand fold.

But those considerations alone do not necessarily justify a large investment in communication technologies. It is not self-evident that better communications will solve the problems of the IARC's.

SUMMARY AND CONCLUSIONS

That is a matter for evaluation.

In fact it turns out that there are fairly clear indications that the communications needs of the IARC's are acute and that the character of their communications facilities do affect the conduct of their business.

One reason for the problem is the location of the IARC's. Each research center is an island of high technology activity in a remote location. By the very nature of IARC activities they are located in underdeveloped countries, frequently some distance from the capital, in rural locations. As we shall see below their main communications problem is often covering the 30 or 50 miles from their rural site to the nearest capital or major city.

The research centers have libraries which have to keep up with current literature. They have sophisticated equipment which has to be maintained with parts and advice from remote locations. They engage in co-operative experiments with researchers at other institutions, sometimes located half way around the globe and sometimes located in places even harder to reach than the IARC headquarters. There is need for up-to-the-minute weather information and current reports on crop yields.

There is a special requirement for rapid information on genetic strains and on experimental results. Plants and animals grow on nature's schedule. When the time has come for fertilization, or breeding or modifying an experiment, the scientist has to learn

promptly what genetic strains are available and from where, and he has to get them.

The research stations have remote sites where experiments on their special crop are being done in a different environment, sometimes in another continent. The centers also conduct outreach and educational programs.

Last but not least, the fact that up to several dozen sophisticated foreign scientists might be living away from their homelands at the isolated research station creates a communication need. It will be much easier to attract able researchers and keep them there and happy if they have quick and easy communication with children at boarding schools, with elderly parents, and with professional colleagues.

Clearly then, the IARC's have acute communication needs, over and above their most obvious need: the need of their administrators to report to sponsors and monitors in foundations and governments, to order supplies, and to make travel arrangements. Those needs can also be met better by better telecommunications equipment. We shall below consider how all these needs can be better served.

As previously noted, the investigation of the communications requirements of IARC's may produce pilot models of what can be done in the LDCs. There is, however, a caveat which should be noted, namely, the problem of scale. It may be possible to put one computer from a remote rural location on-line onto a global

network. Given the scarcity of capital and of technical and maintenance personnel, it may not be possible to do that 100 times or 10,000 times in an underdeveloped country. A successful pilot project in telecommunications for the IARC's may prove what can be done, given enough priority and enough allocation of scarce technical resources. It does not demonstrate what would be required to give the LDC the full benefit of the experimental technology.

Nonetheless a pilot project permits the measurement of costs, difficulties and maintenance requirements. It provides the data needed to estimate how and at what expense a system could be expanded to meet other needs. Thus a telecommunications pilot project for the IARC's even if not directly expansible into a national system, would be useful, not only for its contribution to the IARC's but also as a basis for cost/benefit analysis of more extensive uses of the system tested.

Actually, however, our conclusions are more optimistic than that. Minicomputers used as store-and-forward switching devices seem particularly well adapted to meeting some communications needs of the LDC's. They permit messages to be transmitted automatically over telephone lines whenever the connection is made. The messages can be stored until the computer gets through to its number, perhaps late at night when traffic is low. And where reliable phone circuits are not available the computer can receive or send the messages at low data rates on telegraph lines or even radio. The switching computer can be at a central location in the capital

or near the satellite earth station where sophisticated service facilities exist. The nodes at the end of the system can have terminals appropriate to their location.

Technically such a system is possible. The major problems are those of an administrative and regulatory nature which involve the agreement of governments and telecommunications administrations to the establishment of such novel facilities which in some instances violate their normal way of doing things.

In most instances developing countries simply copy the technologies used by advanced industrialized countries, but with a lag. Data communication with store and foreward minicomputers is an example of a direction of technical development that is particularly appropriate to LDC's. They have the opportunity to innovate, establishing a system that meets their special needs, and is somewhat different from the one they will acquire if they simply follow the established practices of Europe and America.

CONCLUSIONS AND RECOMMENDATIONS

The action-related conclusions and recommendations of this report mostly bear upon the particular case that we studied, the International Agricultural Research Centers. There is also one general conclusion:

High technology systems of data communication including

facsimile, computer polling systems, packet switching, and multiple access satellite systems are managable in, and appropriate to the needs of the less developed countries.

Use of such technologies can 1) markedly reduce costs for some important services, 2) locate activities in those centers where adequate maintenance and technical personnel exists, and 3) give the LDC's access to the best and most advanced technical information bases. A result of participation in such international systems will be quickly increased independence by the LDCs, not greater dependence. LDC's and aid agencies should, therefore, give high priority to the development of advanced data and text communication systems.

With regard to the International Agricultural Research Centers, a survey led to some findings about their present use of communications facilities.

International telecommunications are used by the IARC's mostly for administrative business including travel arrangements, employment, purchase orders, and budgetary explanations and proposals. Scientific information is generally transmitted by mail or conveyed by travel.

For the short messages carried in the administrative traffic the present costs of telecommunication are quite low relative to the large sums that the messages discuss. Because communication is a small item on the budget, little attention

is paid to doing it efficiently; substantial improvements could be made. For scientific communication on the other hand the present costs of telecommunications are far too high. A sharp reduction in costs, making telecommunications competitive with airmail would lead to a big increase in usage by scientists, though they are not now thinking much about that possibility.

Most of the communications by the IARC's is with the United States. CGIAR, AID, and the IIE are the main sources and destinations of messages. Also there is substantial traffic with universities with which the centers have contracts and with the Ford and Rockefeller Foundations. There is also substantial communication with Europe.

There is only a modest amount of communication between centers except in those instances when an outreach or experimental post is colocated at another center. Most of the long distance communication of the IARC's within the developing world is to outreach posts and to national research centers with which they are engaged in co-operative research. Communication within the developing world is much harder than communication to Europe and the United States. The most difficult communication problems are often about the last few miles of rural communication to the IARC or to some co-operating rural site.

SUMMARY AND CONCLUSIONS

We have three recommendations for action by AID, CGIAR, and the centers. Of these, two are almost banal in their simplicity and are already being done by some centers.

1. To speed up the delivery of scientific publications, the US purchasing agent for each center should subscribe to journals and other series in the US, collect them and send them by air pouch periodically. Some money would be saved by avoiding overseas rates on subscriptions, but more important, the journals would come much more rapidly.

2. All centers should acquire telex and make more use of it instead of telegrams. It is more economical, more reliable and faster. The main problem is that telex messages can only be sent to recipients who have telex machines. All the main locations with which the great bulk of the communications take place should be urged to have them. Furthermore, AID or CGIAR should publish a directory in many copies listing the telex numbers of all the active participants in the international agricultural research community. It turns out that one of the main reasons for not using telex is that people are not fully informed as to who has it and are unable to quickly find their numbers. International telex directories have not been widely disseminated. A specialized mimeographed directory, relating to the needs of the IARC's could be distributed to every major office in each center therby facilitating their use of telex.

3. The establishment of an international computer polling network

should be carefully considered. The switching computer would be in the Washington or New York area and a node would be at every center and at all places with which the centers do much communicating. A phone call to each node once a day would probably be adequate. It seems likely that at present all the message traffic could be moved within the limits of a minimum-cost three minute call. It seems possible that a system of this kind could deliver messages to most nodes for a quarter to a half dollar a page. The report outlines ways in which various operational problems could be overcome, particularly for locations to which there is no international direct distance dialing. The next step toward establishing a polling system would be a detailed on-site engineering study at each of the centers.

We estimate that about $150,000 a year would cover the communication and equipment costs of a telephone based computer polling system for all Centers, and would enable each to send and receive about 75 typewriter pages a day.

CHAPTER 2

WHAT IS TECHNICALLY POSSIBLE?

In this chapter we shall describe several technologies which could be used to put the IARC's into direct rapid contact with each other, with off-site outreach posts, with their sponsoring organizations in the USA and Europe, with library and information centers, and with co-operating scientists all over the world. This Chapter consists of two parts. The first part surveys a variety of technologies for low cost international communication, some of which are already in use, but still not commercially available. In this section we will lay out the technical alternatives for establishing telecommunications internationally among the LDCs.

The second part of the chapter applies those alternatives to the particular service of the IARC's. It considers seven alternative system designs for an IARC network.

In both parts we start with alternatives that are already available off the shelf and move on to ones that may become regularly available during the next decade or two. The most revolutionary alternatives are described in order to permit a look into the future. However AID and the IARC's are not going to create whole new communications systems to meet their limited needs; they will use facilities when they become generally

available. In our recommendations for the IARCs therefore, we stick to the already commercialized alternatives.

Technologies for International Communication

1. Telex:

Telex is already widely used throughout the LDCs. Table 2.1 and Figure 2.1a-f show that it is in operation virtually everywhere. It has not, however, penetrated any more rapidly than telephone; across the board it has not been a substitute although there are some places where telex is used instead of the telephone because long distance phone service is expensive or inadequate. Telex can operate on ordinary telegraph grade lines. Indigenous PTT personnel, however limited their skill or equipment, are accustomed to doing maintenance on those and on phone lines; sophisticated skills are not required. Airlines, banks, and traders all over the world therefore posess telex terminals.

In Europe telex is used more than in this country. Telex rates in Europe are lower than here and long distance phone rates higher. Also given the many languages in Europe it is convenient to have written text to check rather than trying to understand the extemporaneous spoken word.

The same considerations apply in the LDCs. Also important is the fact that the transmission of international telex messages is not inhibited by time zone differences in the way that phone calls are.

Diffusion of Telephone & Telex - Selected Developing Countries
(1971 Figures)

Country	Pop. (Millions)	Telephones	Telex Subscribers	GNP Per Capita	Phones per 100 pop.	Telex per 10,000 pop.	Rate of Increase of Telex 1970-71
Phillipines *	37.9	351,000	1707	240	0.9	0.43	16%
Venezuela	10.6	444,000	1748	1060	4.2	1.63	66%
Uruguay	2.9	235,000	387	750	8.0	1.32	5%
Peru*	14.0	243,000	721	480	1.7	0.51	4%
Columbia*	22.3	856,000	1921	370	3.9	0.88	4%
Brazil	95.4	2,145,000	3190	460	2.4	0.33	2%
Argentina	23.5	1,828,000	2188	1230	7.7	0.89	10%
Cuba	8.5	275,000	800	510	3.2	1.94	14%
Lebanon*	2.8	300,000	655	660	10.2	2.28	6%
Egypt	34.0	----	217	220	---	.06	25%
Ethiopia	25.2	51,000	194	80	0.2	.08	12%
Gabon	0.494	----	112	700	---	2.24	5%
Ghana	8.856	19,000	141	250	0.6	.15	26%
Kenya*	11.6	85,000	185	160	0.7	.16	6%
Liberia	1.6	3,000	74	210	0.2	.47	23%
Zaire	19.3	41,000	384	90	0.2	.17	12%
Nigeria*	56.5	87,000	265	140	0.1	.05	8%
India*	551.0	1,293,000	5838	110	0.2	0.1	21%
Israel*	3.0	584,000	1466	2190	18.8	4.96	16%
R. China *	15.0	300,000	739	430	20.0	.52	56%
S. Korea	14.3	755,000	800	310	2.3	.25	0
Malaysia	11.2	15,000	176	400	1.8	.16	17%
Pakistan	62.7	220,000	198	130	0.2	.05	22%
Indonesia	120.0	230,000	720	80	0.234	.058	7%
Mexico*		1,700,000	3231	---	3.4	0.6	19%
Thailand	37.3	202,000	232	210	0.6	0.6	41%
Chile	10.0	393,000	662	760	4.0	.66	27%
Algeria	14.4	199,000	564	360	1.3	.39	27%
Morocco	15.3	171,000	1026	260	1.1	.64	15%
Ivory Coast	5.2	34,000	405	330	0.7	.92	32%
Niger	4.1	4,000	52	100	0.1	.13	24%
Uganda	10.1	34,000	91	130	0.3	.09	32%

*Locations of International Agricultural Research Centers

Table 2.1

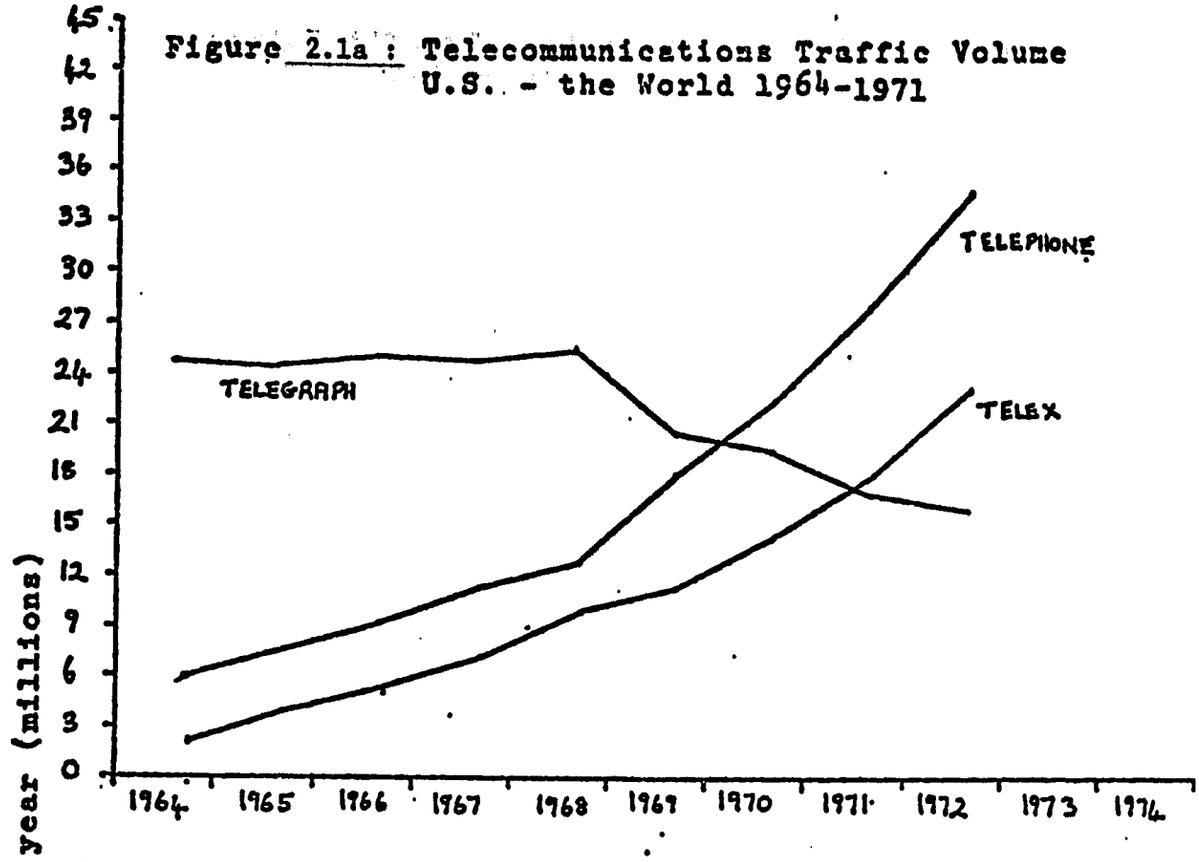

Figure 2.1a : Telecommunications Traffic Volume U.S. - the World 1964-1971

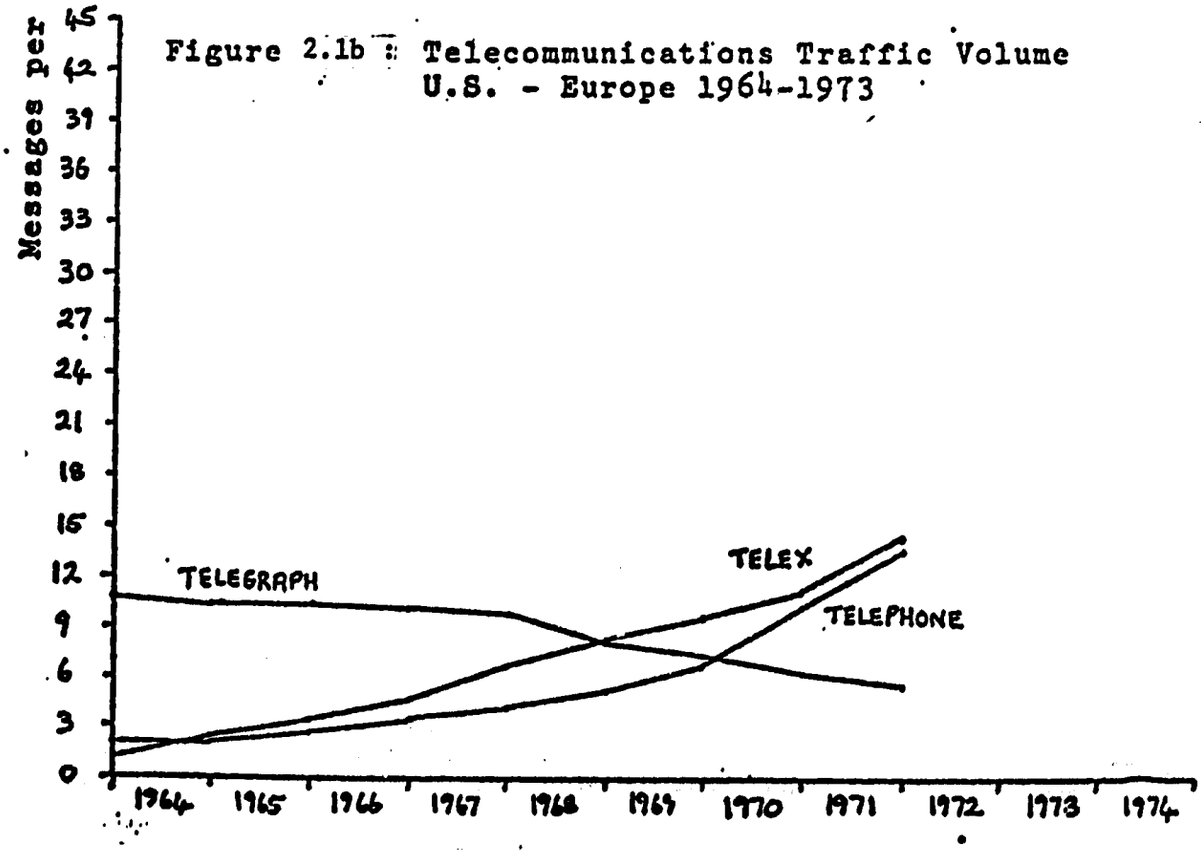

Figure 2.1b : Telecommunications Traffic Volume U.S. - Europe 1964-1973

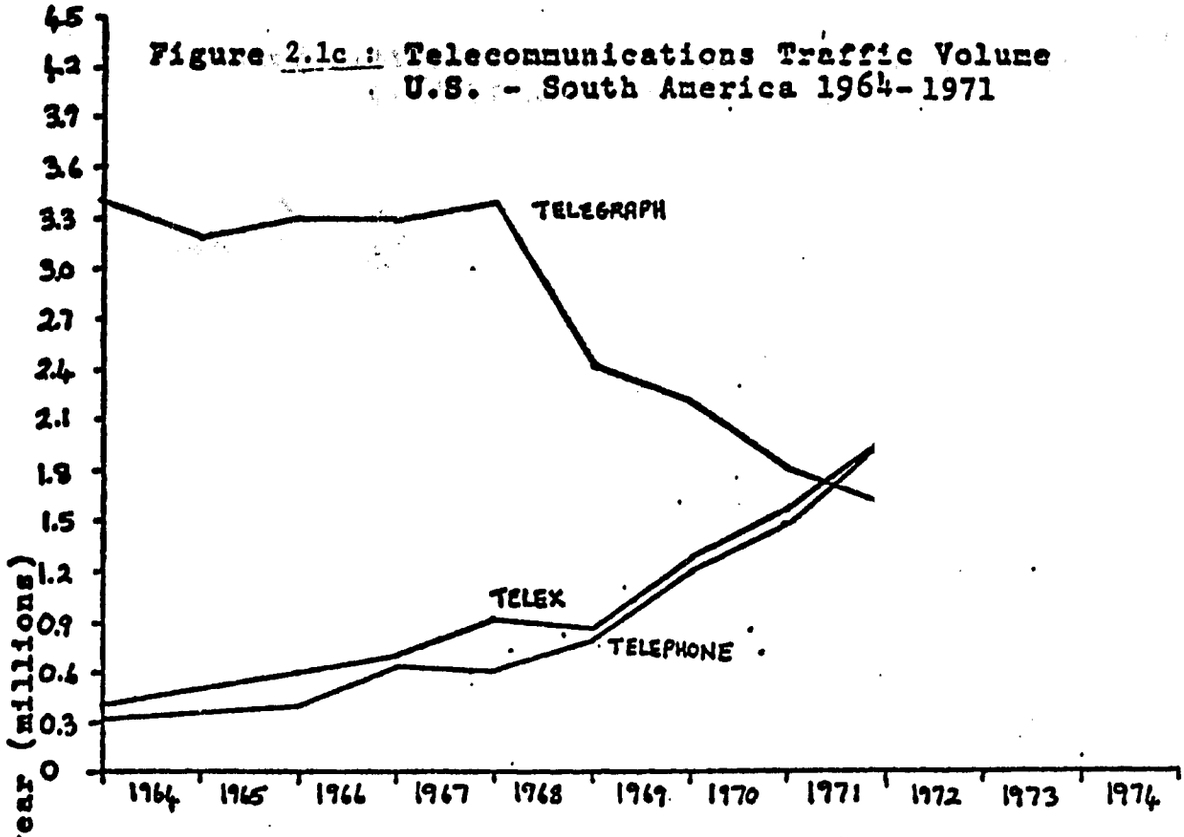

Figure 2.1c : Telecommunications Traffic Volume U.S. - South America 1964-1971

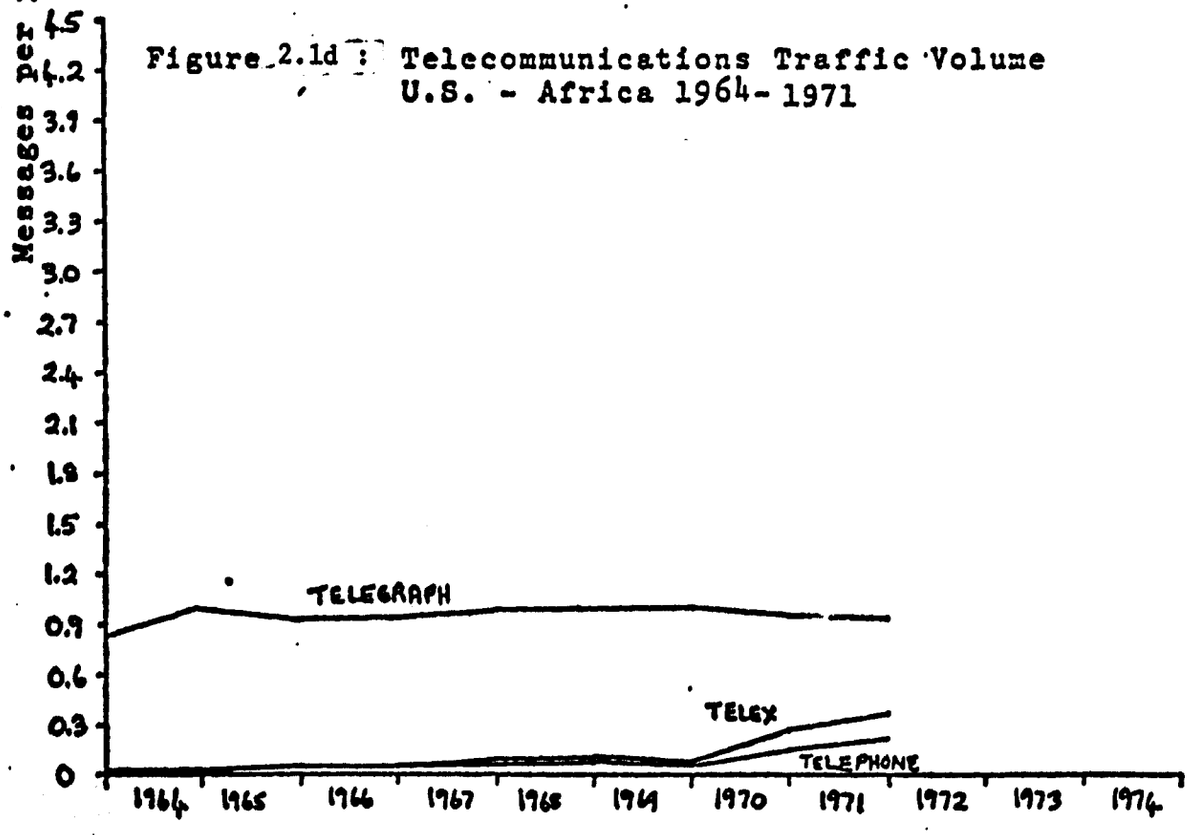

Figure 2.1d : Telecommunications Traffic Volume U.S. - Africa 1964-1971

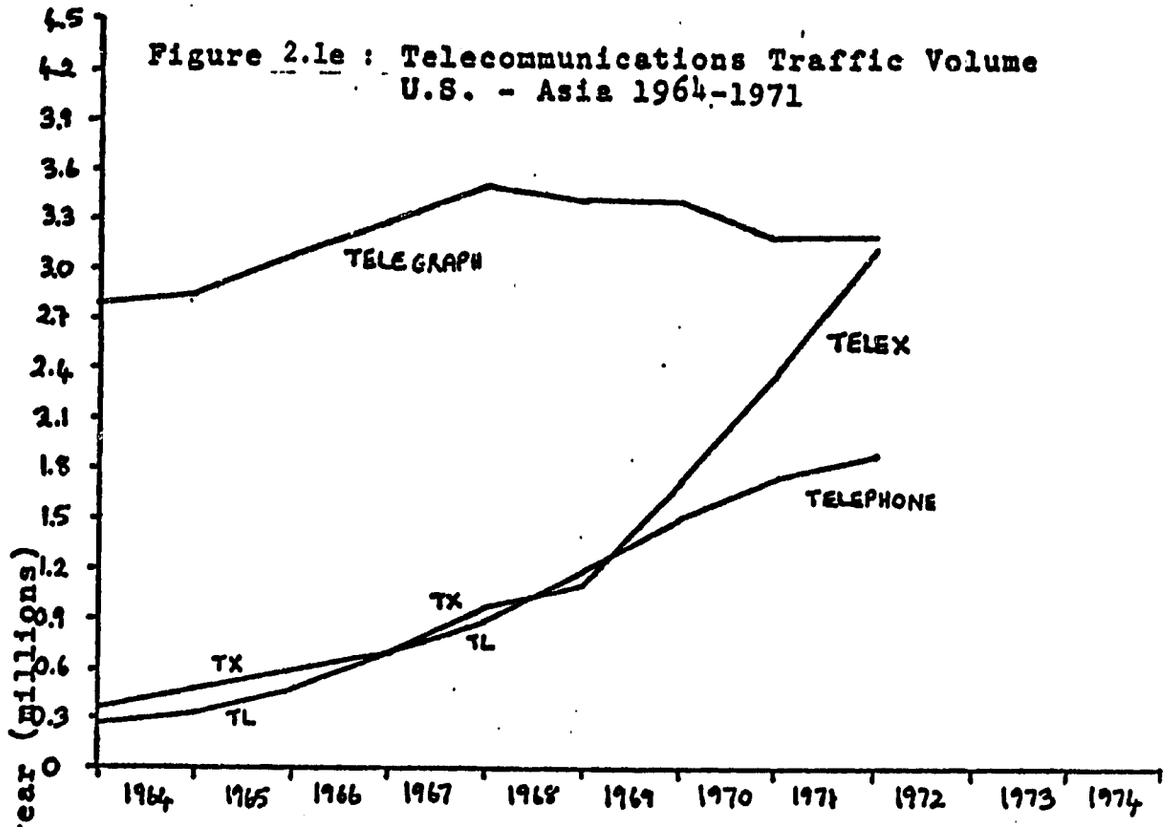

Figure 2.1e : Telecommunications Traffic Volume U.S. - Asia 1964-1971

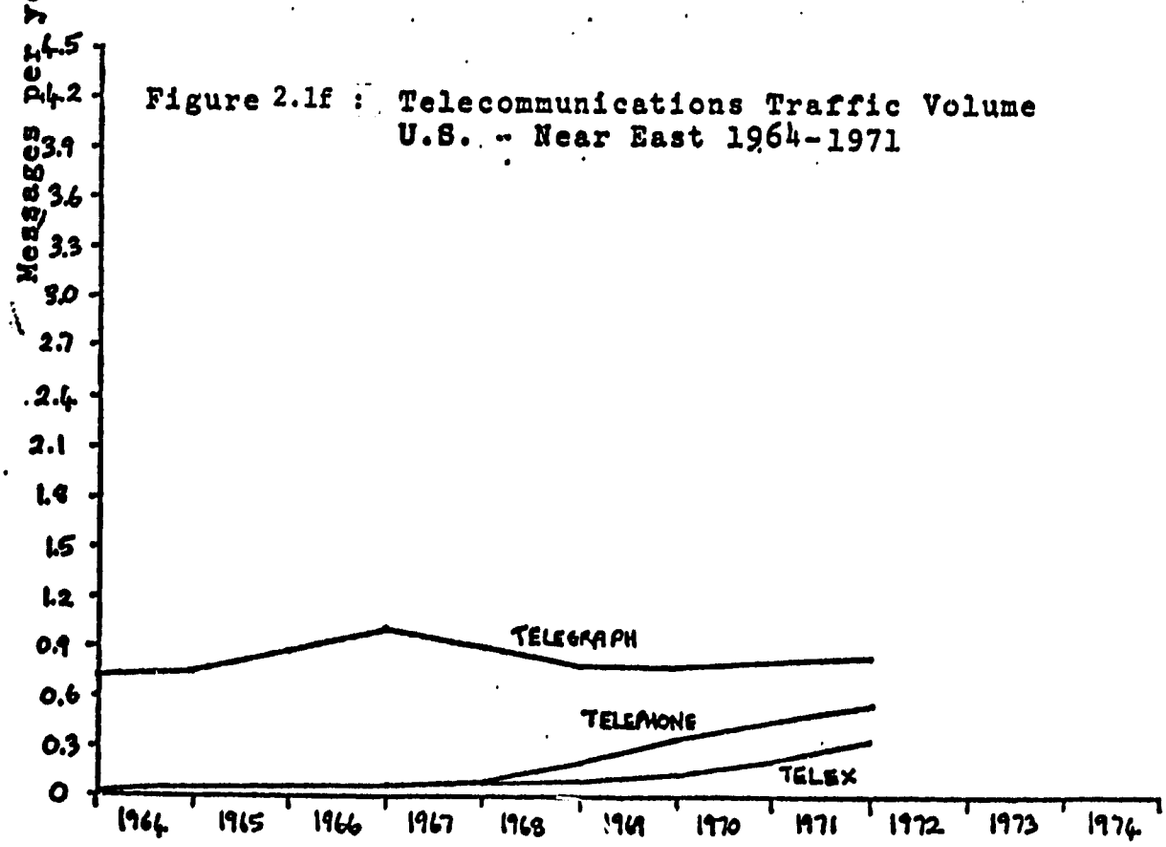

Figure 2.1f : Telecommunications Traffic Volume U.S. - Near East 1964-1971

WHAT IS TECHNICALLY POSSIBLE?

Much of the international traffic to and from the LDCs is to Europe and America. A telephone call from the US to Nigeria, given the six hour time zone difference, must be made before 11:00 AM EST to reach an office in Nigeria before 5:00 PM local time. Since during peak hours, there is normally a two hour time delay in getting a call through, it may become impossible to connect at all. To the Far East the situation is worse. A call from the US East Coast to Taiwan must be made between 8:00 PM and 4:00 AM local time in order to be received in Asia between 9:00 AM and 5:00 PM local time. A telex message, on the other hand, will usually be on the recipients desk the next morning when he gets in.

In most of the world telex has been pushing out ordinary telegraph traffic. The reliance of telegrams on human delivery at the far end is often a source of delay or even loss. Our interview respondents repeatedly talked about problems with telegram delivery; to some countries a telegram will sometimes arrive at the same time as the confirmatory letter.

Telex is the most conventional and widely used text communication technology. It is, however, expensive and of low capacity. A full speed telex line operates at 66 words per minute. (Half speed and quarter speed lines are also sometimes available) International Telex rates are less than telegraph rates, and usually lower than phone rates, but not by much.

US to	20 word telegram	20 word† letter telegram	1 minute telex (66 words)	3 minute phone call station to station
Mexico	varies	varies	$1.67*	$2.25-3.85
Peru	$6.20	$3.10	3.00	8.00
Columbia	6.20	3.10	3.00	9.00
Nigeria	5.60	2.80	3.00	15.00
Kenya	5.60	2.80	3.00	8.10
India	5.60	2.80	3.00*	12.00
Taiwan	6.80	3.40	3.00	9.00
Philippines	6.80	3.40	3.00	9.00

*3 minutes minimum †The minimum is usually 22 words.

Table 2.2
Comparison of International Rates

The basic reason for the high cost of telex, compared to newer transmission systems aside from marketing and regulatory policy, is that it is inefficient to use transmission plant at the low data rate of telegraphy. The point can be illustrated by comparing transatlantic rates for private lines at different speeds.

WHAT IS TECHNICALLY POSSIBLE?

Type Facility	Speed	Cost per Unit of Purchase	Cost/Mbit	Cost/hour
Telex	50 bps	$2.55/minute (1)	$868	$153
Datel	1200 bps	$4.00/minute (2)	$ 55	$240
Leased Telegraph	50 bps	$3600/month	$ 14 (3)	$ 5.00 (3)
	75 bps	$4070/month	$ 9.50 (3)	$ 5.50 (3)
Leased Voice/Data	4800 bps (4)	$10,500/month	$ 0.38 (3)	$13.69 (3)
Tymnet	300 bps	$9.00/hour plus $0.35/1000 characters	$ 43.30 (5)	$17.82 (6)

(1) One minute minimum
(2) Three minute minimuim
(3) Cost/Mbit and Cost/hour computed on a 24 hour a day, 7 day week utilization basis. For 5 day 40 hour week basis multiply by 4.2
(4) Some voice/data circuits are operated at speeds as high as 9600 bps but 4800 is the more common practice.
(5) Cost includes connect time at 300 bps and per character charge
(6) Cost/hour computed on basis of average transmission speed of 7 characters/second

Table 2.3 Comparative Costs of International Data Communication Facilities: U.S. - Western Europe

2. Facsimile:

The facsimile systems that we describe here are those which use ordinary telephone lines and therefore take advantage of the economy of the higher bandwidths available on them than on telegraph circuits.

In the long run facsimile will probably prove to be a less efficient way of transmitting text than digital transmission of characters, since facsimile scans and transmits the contents of the entire page, blank spaces and all, rather than merely sending a brief code for each character. However, at the present time facsimile has two great advantages.

(1) It does not require transmission facilities beyond those which the Centers already have and use. It operates over existing telephone lines and so is usually cheaper than most telex messages at present rates except for short messages.

(2) Facsimile can reproduce the format and graphics of a document in addition to its text. It is, therefore, used extensively for sending engineering drawings, hand written forms, or copies of legal documents.

An acoustically coupled, portable facsimile device that rents for $29 per month can transmit a black and white page in four minutes from a phone in the US to the same device on the other side of the

world. Thus, where there is direct distance dialing the cost would be a maximum of $12 to send a page at daytime rates to the most remote location. There are various ways to reduce that cost.

A facsimile machine which transmits an 8 1/2" by 11" sheet of black on white material in 4 minutes, requires six minutes for half tones. More sophisticated models can do it in two minutes by coding schemes which compress the bandwidth needed for faster transmission; this sophistication can be be expected to become cheaper in the future.

A single spaced typewritten page contains about 500 words which, at the $2.55/minute telex rate applicable to most European countries, will cost $18.95 to transmit or $3.79 per hundred words. Facsmile, using telephone circuits at $2.25/minute will cost $9.00 or $1.80 per hundred words. The use of small type or the photocopying of two sheets on one 8 1/2" by 11" page as is possible with some Xerox machines can reduce these costs still further. Eliminating the need for keyboarding the information into the telex and possible retyping at the other end, and the ability to transmit graphical material are other advantages.

Until now FCC approved tariffs would have been violated by such international use of phone lines. A certain amount of such transmission occurred nonetheless, because the rules were difficult to enforce; as long as they existed, full development of the potential of facsimile for international traffic did not occur. In January 1976 the FCC announced that it was removing the ban on international transmission of data by telephone.

3. Computer Polling Systems:

Within the US, leased telegraph networks are in many cases being replaced by computerized message switching systems which poll and switch messages among nodes on the network via WATS lines. These systems consist of a central computer and associated dialing

equipment which switches the messages and polls the network and nodes which are equipped with a printing terminal microprocessor and an inexpensive storage device (e.g. cassette or floppy disk) on which outgoing messages are stored to await polling. A large company can install such a device as an in-house communication system. The central equipment leases for $1000/month, and the node terminals for $200/month. Alternatively, the service is provided centrally for as low as $0.15 a poll.

These systems are relatively new. One manufacturer of turnkey systems has installed over 60, and many more have probably been built up within major organizations. The quoted prices are likely to come down in the future.

The topography of such a system is as shown below:

```
                 dial up                                dial up
 ___________                 ____________________                 ___________
|Terminal   |--- Telephone--|Switching Computer  |--Telephone--|Terminal   |
|  U.S.     |               |   U.S. or Abroad   |             |  Paris    |
|___________|               |____________________|             |___________|
```

Periodically the switching computer telephones each terminal to receive whatever outgoing traffic it may have. It then phones each terminal to deliver this traffic.

The capacity of these systems is much greater than that of the networks they replaced and the marginal cost of communication is very low. Vendor's salesmen report that their clients now use them

for many communications formerly sent by mail. An additional advantage is that messages may be interfaced with another computer for, say, order processing with less trouble than with a leased telex network.

Such systems are capable of being used internationally. As an example of the cost advantage of such a system against a leased telex line, we can consider a user linking New York and Paris via even a 1/4 speed line costing $1661.60/month. (For LDC locations quarter speed lines are often not available and leased line rates are higher.) Assuming that both offices are keeping normal business hours, the five hour time difference leaves only a three hour overlap between both offices working hours. If a maximum delivery delay during office time of one hour is acceptable (only banks and a few businesses need faster service), four exchanges between the two offices will suffice to clear all traffic within this requirement. The traffic handling capacity of those four calls operating at 1200 bps is well in excess of that of the quarter speed line in the four hour period. (See below).

Monthly Costs

20 days X 4 calls/day U.S. Switching computer-Paris terminal at $6.75 per call	$540
20 days X 8 calls/day U.S. Switching computer-U.S. terminal at $0.50/call	$ 80
20 days X 12 polls a day by the switching computer at $.15/poll	$ 36
Rental of two terminals at $200/month	$400
Rental of two 1200 bps modems at $30/month	$ 60
	$1116

This represents a 30% decrease from the $1660 monthly cost for a quarter speed line. (1)

These costs are computed assuming that the switching computer is located in the US where a three minute minimum on overseas calls is in effect. In Europe, where metering is by short time intervals (one second in the UK), the international calls could be shortened to the time necessary to clear the traffic. As very short calls are unlikely to be permitted by administrations (as ATT has shown

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(1) Recomputing the costs utilizing Datel service (which is allowed) from the IRCs at $4.00 a minute still yields a slightly lower total cost of $1536/month. For a foreign terminal in the UK where there is a special direct dial rate to the US of $3.60 for the first three minutes, the total monthly costs over dataphones would drop to $854.

by requiring a one minute minimum on WATS calls) recalculating with a one minute minimum (as the shortest likely minimum) gives monthly costs of $766/month to France and $672 to the UK.

Additional advantages of the computer system are greater capacity and the accomodation of much higher volumes of traffic on the computer system than on a 1/4 speed line. The 1/4 speed circuit can transmit a total of 23,760 words in a 24 hour day, while the computer system can transmit 14,400 in just the 12 minutes needed to ensure four polls a day. Furthermore, the computer system is better suited to interfacing with other in house computers, and the system reportedly reduces labor costs of operating the leased network.

Clearly, a message switching system using dial-up telephone is now economically competitive with a low speed leased circuit and could be very much cheaper if terminal equipment costs per minute diminish and one minute minimum charges are instituted internationally. While all are likely to a varying degree, the reduction in terminal equipment is almost certain.

Our cost-benefit analysis employed the lowest price leased circuit. Comparison with any other speed teletype circuit will show the computer system to be far cheaper. We have also considered a point to point system. For a network consisting of several points within the USA and abroad in the USA the advantages are greater. For a global system there one might link more than one switch in a single

system, forwarding traffic to the regional switch which could transmit it in turn to the node by whatever local facilities were available and cheapest. For example, an American organization building such a network might locate a switching computer in the UK to take advantage of the low IDDD rates and forward traffic to other European countries by telex (which averages $.30/minute inside Europe) or alternatively by phone calls to terminals, depending on traffic volume and service standards.

Time Sharing Networks:

There are now a number of computer time sharing networks that operate internationally. The largest, General Electric's Mark III, is represented in Figure 2.2; its main computers are in Ohio. One reason why it is economic for a time sharing service to operate internationally is that time zone differences even out peak loads; the computer will be kept busy at different times from different places. The economy of load levelling outweighs the telecommunications costs.

Most time sharing systems possess a so-called "mailbox" facility. A user of the system can address a message to another user. It is transmitted to the addressee's files and can be read by him the next time he logs into the system. The main purpose of the mailbox facility is to facilitate co-operation in computer use. A customer can use it to complain that an aspect of the system worked incorrectly or the user of some data can leave an instruction with

his programmer about what analyses to run. Those would be uses related to computation. But there is no effective way to prevent the messages from containing anything from a Christmas greeting to a purchase order, though postal regulations almost everywhere prohibit such use of a time sharing system as a message carrier.

The point we wish to make here is not about the legalities, but rather the fact that time sharing systems demonstrate how efficient and cheap a computer based mailbox system can be.

A. Vezza of Project MAC has made an estimate of mailbox costs on the ARPAnet. He describes "one message system developed for a PDP-10 computer known as the Dynamic Modeling System (DMS) at the Massachusetts Institute of Technology's Project MAC that goes beyond the basic services and, in addition, provides a means for computer programs to create and receive messages and for filing and retrieving using of originator, recipient, keyword, file folder name, date, etc. The experimental DMS message system is used by some 30 staff and student researchers for intra-office message communication and for communication with researchers who are registered users of other ARPAnet hosts.

Table 2.4 indicates the cost and price of using the major services of the DMS message system for handling a typical 2000-character message. Cost was computed by amortizing the equipment over a 25-month period and adding operating expense. Price was determined by sampling the computation price of a number of commercial time-sharing companies with similar equipment. The range for CPU usage was small; therefore, an average is stated in the table. The price range for on-line disk storage was larger, and therefore the range is indicated. A trillion-bit memory with a relational data management system is not yet a commercial service, but the price range indicated is a projected one. The first number in each column opposite "COMPOSING" is for composing a single typical 2000-character message. The second number is for composing additional messages, the difference being the overhead to activate the composer. Note that the composition charge is the same regardless of the number of addressees. Thus, multiple addressee messages cost less to compose on a per-message transmitted basis. The transmission cost is the estimated ARPAnet transmission cost for such a message. Compared to the computational charges, the transmission charges are insignificant. The present price charged by commercial time-sharing systems, indicated in the table, is in the several dollar range and therefore not very attractive. Furthermore, the DMS message system is a laboratory prototype and

it was not implemented with computational efficiency in mind, but rather put together using, wherever possible, existing program modules. It is not unreasonable to expect that a commercial version could obtain a factor of ten improvement in computational efficiency. In addition, the DMS main-frame hardware is circa 1965 vintage, and main-frames with 6 to 10 times the computational power exist. One can expect that a commercial service similar to the DMS message system could today be offered for a price in the range of 25 to 50 cents per 2000-character message. Within 5 years, the price could well be lower than the price of sending a first-class letter.

GENERAL ELECTRIC'S MARK III INFORMATION SERVICES NETWORK

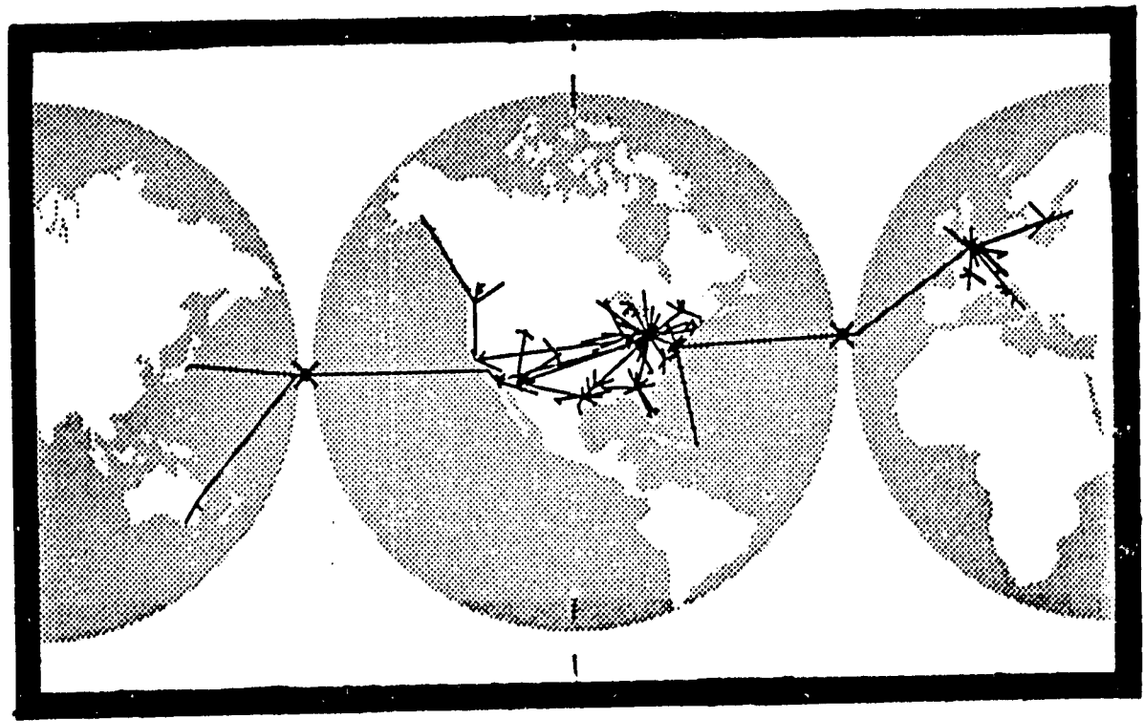

Figure 2.2

WHAT IS TECHNICALLY POSSIBLE?

	CPU-SEC	COST $	PRICE-$
COMPOSING	14/8.9	.10/.07	1.57/1.04
SENDING	8.8	.07	1.02
RECEIVING	10.4	.08	1.22
ARCHIVING	4.2	.04	.49
TOTAL	38/32	.29/.26	4.30/3.77
TRANSMISSION		.0006	.012

ONLINE STORAGE

	COST $./MONTH	PRICE $/MONTH
DISK	.04	.18-2.50
TERABIT MEMORY	.002	.01- .02

Table 2.4. CPU and Storage Costs and Prices in dollars for a 2000 character message. Storage overhead for indices is 25%. Cost is determined on 25-month payout.

5. Packet Switching:

There is one relatively new technique for linking computers in a network that is particularly efficient for message traffic. It is known as packet switching. The basic idea is that an interface computer sits between each computer on the network and the network itself; those interface computers collect the messages, and put them out to their addressees in standard form over circuits shared by the users. The standard form is a "packet" of uniform size e.g. 128 characters. A longer message is sent in several packets reassembled by the computer at the other end.

Under most, but not all circumstances, there are substantial gains in efficiency from switching the packet from node to node, rather than using a system that ties up a circuit for a single sender and receiver whenever they wish to communicate.

Packet networks are rapidly developing. The prototype was the Defense Department's ARPAnet. There is now a commercial packet network, Telenet. Several European companies are developing them. The basic expectation is that they will be so cheap that companies will use them instead of private lines.

Telecommunications networks have hitherto employed two switching schemes, circuit switching (sometimes called line switching) and message switching. Circuit switching requires the establishment of a physical circuit between the user terminals involved, as in the telephone network. The circuit is maintained until the exchange of information ceases. Transmission is virtually instantaneous. Message switching (also called store and forward) is used for telegrams and many other data communication systems. Messages are relayed from their point of origination to the next switching center in the direction of the addressee, where they are copied. This process is repeated until the destination is reached.

Transmission time varies considerably with network design and traffic load.

Circuit switching is inefficient for interactive use, since frequently less than 10% of the circuit's capacity is used; thus, a user is paying mostly for idle time. Data base publishing services, among others, generally involve short messages from originating terminals and longer responses from the computer. There is often no traffic on the circuit for considerable periods while the operator digests the computer output and decides what to do next. Message switching makes more effective use of transmission circuit capacity since one circuit can be used for many messages. Long messages, however, can tie up the circuit for some time forcing other messages to queue until the circuit is free. This frequently leads to unacceptable delays when a network handles both short and very long messages.

Packet switching combines the efficient line utilization of message switching with the reliable speed of circuit switching. It is a variant of store and forward techniques, deriving its name from the division of messages into small sections called packets, each of which is transmitted individually to the destination where the message is reconstructed.

A message originating from a user's terminal goes to a small computer acting as a switching center where it is divided into packets about 128 characters long, each with address, message identification, error checking and sequence commands. The packets are then transmitted independently to the next switching center in the direction of the destination. Alternate routing as well as priority designation is available. The transmitting switching center stores each packet until correct reception is acknowledged, using the idle interval for other traffic. This process is repeated until the packets reach the switching center serving the addressee's terminal. Here the original message is reconstructed and sent to the addressee.

End-to-end transmission times are very short, typically 100 milliseconds for distances up to several thousand miles. Packet interleaving, the dispersion of short messages between the packets of long messages, allows the handling of asymmetrically distributed traffic without adversely affecting the transit time of short messages. Subdivision of large data streams into a series of messages each containing a maximum number of packets provides insertion capability. In the case of a large file transfer, short messages arriving during its transmission can be strung into the long series of packets forming the file, rather than placed after its entirety to suffer long delays.

TECHNICAL AND ECONOMIC ADVANTAGES

The continuous and rapid decrease in the cost of computer hardware at the rate of 40% per year has made possible the use of minicomputers at the nodes of the teleprocessing network. Priority schemes in the switching of messages designed to favour shorter items lower the mean service time. Placing a ceiling on the number of packets per message reduces the buffer requirements. The freed storage area can be used to allocate communication bandwidth dynamically rather than on a preassigned basis. Traffic and load fluctuations are continuously monitored, forecasts made and routing strategies altered. Major changes, such as addition/deletion of nodes/links, are quickly integrated into all parts of the system by a simple and inexpensive software change.

Conceptually, the switching computers (or node processors) can be visualized as two parts. One half presents the interface to a specific customer, while the other presents a standardized interface to the rest of the network. This creates a communications subnet within the system, and one to which customers effectively plug in. The network management and personnel assume responsibility for all data communications within the network between customers. Communications system planning and staffing on the part of the customer are greatly reduced.

Standardized interconnection protocols allow different common terminal types to be used at any of their several speeds with any computer program. Standardization of software and hardware interfaces between the network's node processors and the customers' equipment allows customers to respond rapidly to new technological advances. Growth in the number of users and the variety of their needs can be rapidly accomodated as well. Outdated operating systems can be replaced and terminal ports rearranged with no outage due to the network. This also applies to the terminals and the computers with which they are connected by the network, whereas today's installations are bound by inflexible system hardware.

Distributed network configuration, where redundant paths between nodes are provided by different link sets, ensures communications security and reliability for link to node ratios greater than one. By comparison, this ratio approaches one for centralized topologies, which lack these two attributes. These link redundancy levels, three or four times higher than that of the minimum span network, provide optimal communication path survivability under highly adverse conditions. In addition, the distribution of switching capability throughout the network increases these benefits since users no longer rely on a single central switch. Because of built-in self-diagnostic ability, most faults that do occur are detected and corrected without the customer even being aware of the existence of the fault.

WHAT IS TECHNICALLY POSSIBLE?

Packet switched networks provide essentially error-free delivery of data within the network both to and from host computers and their terminal interface points. This data accuracy eliminates the necessity for the expensive error detection and correction techniques and equipment which are employed by entities using current data communications methods. Data security is also enhanced. Multiple paths and the interspersal of single packets with those of many other messages make it difficult to monitor any single data stream. The local loop, from user terminal to node processor, can be contained wholly in-house. For even greater security, message content can be encrypted without affecting the normal functioning of the network.

Packet switching is a substantially more efficient use of a scarce resource (communications channels) than other methods, and can possibly increase resource utilization efficiency to as high as 80%. This provides reduction in network cost for channel purchase. Savings in the overall network cost are shared proportionately among the customers since their transmission cost is determined by use, a pricing policy justified by the nature of the service, it being distance-independent with respect to time delay. Customer's costs for transmission of data are related primarily to volume of traffic, a parameter within his sphere of influence and prediction.

The flexibility, variety of service, and savings are passed on to the customers. Network computers can draw on each other's computer services as desired to obtain more complete backup and service capabilities. Resource interchange in the ARPA network presently yields annual savings of $4 million among its participants.

Packet switching is not the most economical technology for all purposes. For transmitting a long stream of data, a dial up telephone circuit used with good modems will in some circumstances produce lower costs. However, this type of usage is likely to be a very small volume of future data communications traffic.

The cost of terrestrial communications channels appears to limit the future price of computer-communications services. The communications component of total network cost became dominant in 1970. Further network cost reductions lie in the integration of satellite circuits into such systems. High capacity channels at a lower cost per circuit-mile are already available. The broadcast mode for packet techniques has already been implemented successfully by radio in the ALOHA network. Dynamic allocation of satellite capacity by slotted reservation techiques to increase throughput will be attempted with the CTS satellite in 1975.

Future developments in placing an intelligent payload in geosynchronous orbit will allow the satellite to act directly as a node processor, rather than its present function as a simple repeater. This may result in further cost reductions as well as minimizing problems from the fixed 250 msec. delay introduced.

STATUS OF EXISTING NETWORKS

In 1968, the Advanced Research Projects Agency of the Department of Defense embarked on the implementation of a new kind of computer network known as the ARPANET. This research effort became operational in mid-1971 with 15 sites. It has grown to over 40 sites with about 60 host computers spanning the contiguous United States, Hawaii and Europe. Continuing to grow at the rate of one site per month, the ARPANET is the most ambitious, advanced and well-known of the existing networks, and uses packet-switching technology in its fullest sense.

A partnership of 175 international airlines, SITA (Société de Télécommunications Aéronautiques) launched the first packet-switched network dedicated to business traffic in 1966. The system extends globally, connecting nine high level switching centers with over 7000 terminals, most of which are teletypewriters for administrative matters and reservation information. Although not a packet system in a purist's sense, the network is substantially similar to one and differs only in one respect, that of dynamic routing.

There is only one common carrier currently supplying packet switched communications services in the US and began operations on August 15, 1975 offering service to seven cities. Telenet Communications Corporation was formed in last 1972 to provide packet communications services. The firm is a subsidiary of Bolt, Beranek and Newman, a Cambridge research firm which was prime contractor to the Defense Advanced Research Projects Agency (ARPA) for the development and operation of the ARPAnet, the network which pioneered and proved packet switching technology. Several key members of the ARPAnet technical team are now with Telenet.

Foreign Packet Networks

France

The French PTT has an experimental network "Reseau a Communication par Pacquets"(RCP). Nodes are Paris, Rennes and Orleans with extensions to multiplexers in 3 other cities. There is also a university packet network called CYCLADES which is interconnected to the UK's NPL network. In service since 1973, this network now connects 14 computers via a 7 node topology. Although it is is still considered experimental, the objective is to have it acting as a university service bureau, making computer resources available to institutions throughout the country.

WHAT IS TECHNICALLY POSSIBLE?

England

The British Post Office has an Experimental Packet Switched Service (EPSS) serving London, Glasgow and Manchester. In addition, an experimental packet network has been operated since 1972 by the National Physical Laboratory (NPL) as a university research network to study the problems of connecting many different terminals to a network. This net has been interconnected with the French CYCLADES packet net since August 1974, the link being considered the first leg of a European Informatics Network(EIN). The potential of linking with the EPSS also exists.

The NPL net currently connects 20 host computers and 80 terminals and is carrying a million packets a day. One service on the set is a storage computer which is enabled to provide storage capacity to other, usually small computers on the net.

Spain

A packet switching network operated by the Spanish telephone company, CTNE, has been in operation since 1972 and now has 500 operative terminals, many in banks. Presently linking Madrid and Barcelona, future plans envision switching centers in each province. CTNE is very satisfied with its experience and is in favor of international packet networking.

Canada

The Trans Canada Telecommunication System plans to implement a packet switched network called Datapac, starting in July 1976. It will initially have four nodes, Toronto, Montreal, Ottowa and Calgary, with plans to cover 14 cities by 1980. Charges will vary between $1.25 and .70 per thousand 255 character packets.

European Information Network(EIN)-EIN is an international experimental venture involving nine countries, France, Italy, Netherlands, Portugal, Spain, UK, and Yugoslavia. Formalized by international agreement in 1971, it is planned to have nodes in London, Zurich, Milan and Ispra. As a result of its international character and the attendant administrative problems, progress has been slow but contracts have been awarded and work has begun.

6. Satellites:

A satellite like coaxial cables and microwaves, is a transmission medium that can be used for computer networks, facsimile, and telex. Fundamentally it makes no difference to the user what

channels or mix of channels are chosen for a given kind of telecommunication transmission because the quality of transmission is roughly the same over each medium. A sensible system simply picks the cheapest vehicle offered, and perhaps the user does not even know what set of circuits is used. (1) Thus while purists might disagree with the inclusion of satellites on the same list with uses to which they can be put, nevertheless they belong on a list of technologies that are making possible reliable, cheap, fast and long distance communication.

A significant contribution of satellites is that they make the costs of communication relatively insensitive to the distance covered.

There is general recognition that the domain in which costs have fallen most and will continue to fall most is long haul transmission. The costs of switching, the costs of billing, the costs of the local loop are by now the greatest part of the costs of a long distance call. (Those are costs that do not vary with distance.) Since there is no obvious breakthrough pending in those costs, the savings that will result from new long haul technologies may not bring total costs down much; but those variable costs that make the cost of a long distance call a partial function of

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(1) To be more precise, there are minor differences between transmission modes. The quarter second delay on satellite circuits or the slightly greater bandwidth on satellite voice circuits may make a difference to the engineer, but he can make these minor differences invisible to the user if necessary.

distance are tending to vanish. (1) Consider, for example, the advances in coaxial cable and the even more dramatic prospects of such devices as optical waveguides. As the footnote shows, each successive generation of carrier has much greater capacity and markedly lower costs per circuit. (2) The capacity that such devices as L-5 or waveguides offer will pay for itself only on the busiest routes. However, transmission costs are also falling in microwave transmission and in undersea cables. Thus even without the advent of the satellite, long distance transmission costs are becoming a minor part of the total bill. A T and T thinks nothing of routing calls intended to go up and down one coast of the United States from coast to coast and back again if more direct circuits

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(1) This point needs to be emphasized. Throughout this paper we take note of communication costs At the same time we keep emphasizing the falling costs of long-haul communication. The reader may sense a contradiction. There is none. Total communications expenses may stay put or rise even if the difference in the communication cost between 300 and 1500 miles were to fall to zero.

(2) Bell System Coaxial Cable Systems

Name	Capacity in voice circuits	Cost $/voice circuit/mile at 100% fill	
L1	1800	17.22	
L3	9000	6.49	
L4	32000	3.15	
L5	108000	1.21	
WT4	241900	1.02	(waveguide)

Source: Evidence offered in testimony to Hart Subcommittee, 1973, p.802 (Subcommittee on Antitrust and Monopoly, Committee on the Judiciary, US Senate); from statement by McGowan for MCI. Original source ATT testimony in FCC docket 18128.

are busy or incapacitated. Load levelling is far more important to A T and T than distance. It is clear that the marginal cost of transmitting extra miles is a vanishing number and even the average cost (which is the more important figure) is just pennies, even over such distances as across the USA.

If distance was already a minor factor without satellites, with satellites it has become trivial. For a signal that travels 22,300 miles up and 22,300 miles down, it can hardly be important whether the base of the triangle is 1200 miles or 12,000.

Indeed, US studies of future costs have tended to show increasing costs with distance up to about 300 miles, for it does make a difference whether a message travels only in the local switching system or has to go out onto the interurban switching system. But from 300 to 3000 miles will in the future make almost no difference.

7. Multiple Access Satellite Systems:

Long distance data communication costs have been reduced to a very low level by digital satellite technology. The major portion of the costs arise in the ground station, with the actual satellite relay costs being insignificant.

The INTELSAT tariff for the space segment for a 64 kbs preassigned duplex circuit is $18,000 (1) per year. Assuming 100% circuit

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(1) INTELSAT Tariff Schedule, 1975

utilization (1) the space segment cost per megabit is $0.0089.

After inclusion of earth station costs and the markup for supportive services and profit, the costs are an order to magnitude higher. The rate for a 56 Kbs data channel between earth stations in California and Hawaii is $5,800 per month, (2) which is equivalent to $0.035 per Megabit (about $0.015 per hundred words).

The costs are still another order of magnitude higher after the markup by the international record carriers and the very high half circuit charges (in the UK 2.5 times the US rate) imposed by foreign PTTs. A 56 kilobit/second circuit from New York to London leases for $316,000 ($0.15 Mbit). But that is still seven cents a hundred words.

Random access packet switching techniques would allow much lower costs by permitting many earth stations to access a satellite efficiently, (3) with complete interconnection via variable capacity virtual circuits. In these techniques, each earth station transmits packets at random to the satellite; correct reception of its own packets on the satellite's relay acts as verification of non-interference by another station's random transmission. In the event of an overlap in transmission with another station, the satellite's relay of the transmitted packet will be garbled. This

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(1) 365 days a year, 24 hours a day at the full data rate

(2) COMSAT tariff schedule, July 1975

(3) Abramson Norman, "Packet Switching with Satellites," Proc. 1973

triggers a retransmission of a packet after a random time delay to prevent both earth stations from again retransmitting simultaneously. Using such techniques, multiple access without centralized control can be achieved at a total throughput of 16% of the total capacity of the channel. By a modification of this system in which bursts of data are not wholly random but commence only at specified time intervals, a throughput of 37% (1) of capacity is achievable. A more complex technique described by Roberts (2) achieves yet higher throughput.

While this technique is wasteful of satellite capacity, it is very likely the most efficient method of providing service to a large number of low density users who require access to multiple information sources. At the seven character per second average rate for interactive communications experienced on existing networks (3) over 300 users could be serviced on one voice channel.

Other multiple access techniques such as SPADE and TDMA are designed to provide virtual circuit switched links of constant capacity for use with voice circuits. Where the random bursts of data are followed by lapses in transmission, the random burst system should prove more effective, although such links may have a

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(1) Kleinrock, L., Lam Simon, "Packet Switching in a Slotted Satellite Channel," Proc. National Computer Conference 1973, p.703

(2) Lawrence Roberts, "Dynamic Allocation of Satellite Capacity," Proc NCC73, p.715

(3) Blanc, Robert P, "Review of Computer Networking", NBS Technical Note 804, Jan. 1974.

place in international data networks.

Abramson has outlined a prospective satellite system which uses an INTELSAT IV transponder which is capable of 60 Mbs when used with a standard (96 foot diameter) earth station. In his system a smaller earth station is employed, reducing the transponder data rate into and out of each earth station to about 15 kbs. Higher peak data rates would be available since the distribution of the earth stations over many time zones would permit load averaging. Such a system would be capable of supporting 100,000 interactive terminal users at one time.

An alternative technique applicable for use between national packet networks would have each country transmit its international traffic on a single channel and monitor the channel from each country accessing the same satellite. Microprocessors would select out packets destined for national addresses from each country's transmissions and combine them into an incoming packet stream which would enter the national network for further distribution. Such a system would require one voice channel per country, which in the Atlantic basin would be less than a quarter of one transponder's capacity.

The alternatives to multiple access systems are unattractive. Providing a dedicated circuit between each pair of earth stations for N stations requires (N-1) factorial circuits which is prohibitively expensive and grossly wasteful of satellite capacity.

A star network in which every station is linked to a master station which does the switching involves two satellite relays which doubles the .25 second transit delay inherent in geostationary satellite systems to .5 seconds. With another .5 second delay on the reply from a computer, the minimum response time in an interactive system would be one second at best, which is higher than desirable.

The combination of the best of these satellite options with packet networks, and perhaps such other approaches as facsimile and polling systems on public switched networks, makes the technical prospect of highly economical global non-voice communication very promising indeed. However, the full utilization of these techniques lies somewhere in the future. Twenty years from now the international agricultural research centers will perhaps each have a satellite earth terminal linking it to a packet switched global data network. That is not available now.

We turn now to ask what can be done for the IARC's using some of the technologies that we have just described.

Alternatives for the IARC's

Can advanced communication technologies improve communications for the international agricultural research centers? Would such techniques be cost/effective? To answer those questions we designed and costed abstract prototypes of seven possible engineering

solutions. (1)

Those abstract system models were based on a hypothetical sixteen point network. The sixteen locations were arbitrarily chosen early in our study to permit designing to go forward. At the end of this report we propose a network based on the empirically ascertained needs of the IRAC's it differs slightly, but the differences do not affect the conclusions drawn from the hypothetical model.

In retrospect, the main emendation we would make in our hypothetical system, on the basis of interviews with the IARC's about their communication needs, would be to add a number of additional points in the USA: several universities and the Institute for International education and the Ford and Rockefeller Foundations in New York. (2) That change, however, is of no technical significance for the US communication network is so well developed that the addition of any additional points in the US is technically trivial. Similarly, Japan and other European points could be easily added.

The 16 points that we chose to link in the hypothetical communication network were

1. The International Rice Research Institute (IRRI), Los Banos, Philippines.

2. The International Maize and Wheat Improvement Center (CIMMYT), El Batán, Mexico.

3. The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

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(1) These were developed by Colin Warren

(2) Another change, given recent events, would have been to substitute another point for Lebanon. The precise point chosen for the exercise, however, is not important

4. The International Center of Tropical Agriculture (CIAT), Palmira, Colombia

5. The International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) Hyderabad, India.

6. The International Potato Center, (CIP), Lima, Peru.

7. The International Laboratory for Research on Animal Diseases (ILRAD), Kenya.

8. The International Livestock Center for Africa (ILCA), to be located in Ethiopia.

9. International Board for Plant Genetic Resources and FAO, (IBPGR) Rome.

Cooperating Regional Centers:

10. Costa Rica, Centro Agronomico Tropical de Investigacion y Enseñaza (CATIE)

11. Zaire

12. Lebanon - ALAD

13. Taiwan, Asian Vegetable Research and Development Center (AVRDC)

14. Israel

15. World Bank, Washington, D.C.

16. AID, Washington, D.C.

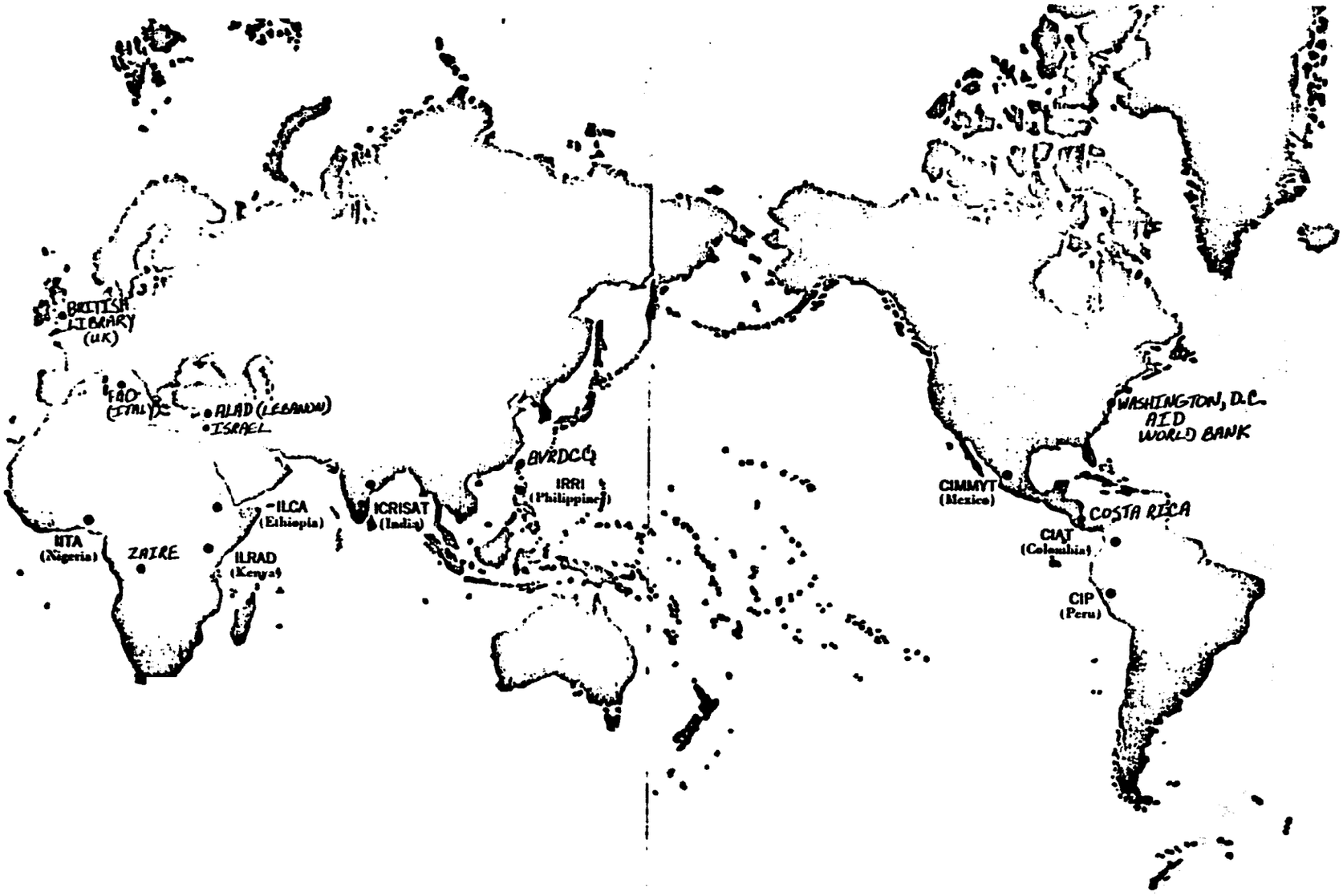
Figures 2.3 and 2.4 map the sixteen geographic locations of the points in the hypothetical network and depict the Intelsat satellites to which each has access. Satellite communications between Indian Ocean points and the USA or between the East Asian

points (The Philippines, Taiwan, and India) and any Latin American or African points (except Kenya) would require two hops with the message going from one terminal either to the USA or to Kenya and then from there to the other terminal. That would create some problems for voice communication, but not for message delivery.

The seven alternative communication systems that we shall examine are:

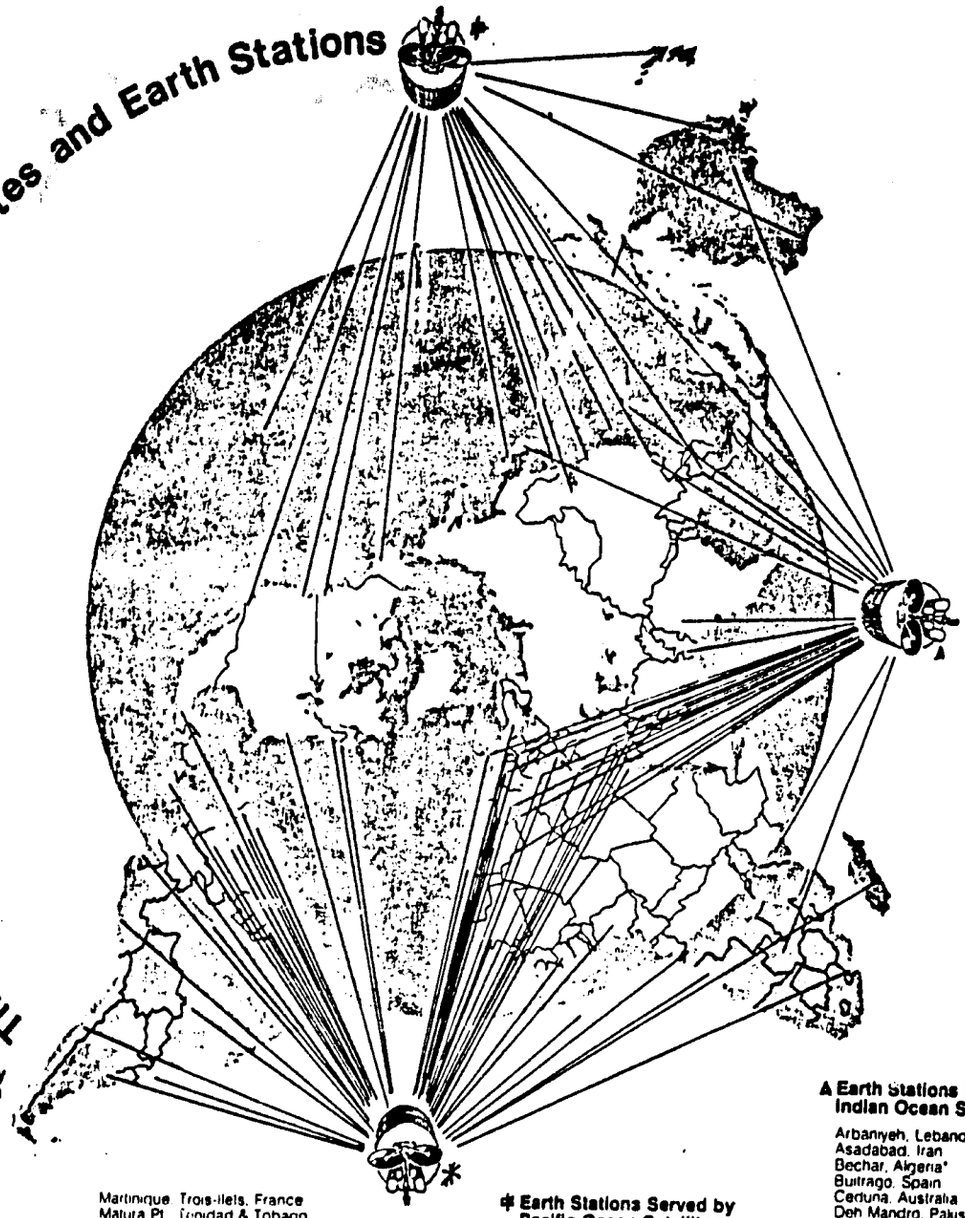
1. Use of the international switched telex network
2. A leased teletype network
3. A leased network of voice grade (AVD) switched lines
4. Polling via the international switched telex network
5. Polling via the international switched telephone network
6. Use of Intelsat with small ground stations
7. Use of advanced multiple access satellite technology

Some of those alternatives (such as the switched telex network) would involve a dispersed network in which each node could communicate with each other node by some more or less direct path. Most of the systems would involve the creation of a star network in which there is one central switching and processing point, presumably Washington, with which all other points communicate and where messages are sorted out and forwarded to their destinations. (See Figure 2.5).



MAP OF NODES OF HYPOTHETICAL POLLING SYSTEM

Figure 2.3



*** Earth Stations Served by Atlantic Ocean Satellites**

Abidjan, Ivory Coast
Andover, Maine (U.S.)
Asadabad, Iran
Ascension Island, U.K.
Balcarce, Argentina
Baqa, Jordan
Barbados, Barbados
Boane, Mozambique, Portugal*
Buitrago, Spain
Burum, Netherlands
Cacuaco, Angola, Portugal*
Cairo, Egypt
Camatagua, Venezuela
Cambita, Dominican Republic
Cayey, Puerto Rico (U.S.)
Choconta, Colombia
Cuiaba, Brazil*
Emeq Ha'ela, Israel
Etam, W.Va. (U.S.)
Fucino, Italy
Gandoul, Senegal
Goonhilly Downs, U.K.
Grand Canary Island, Spain
Jugoslavija, Yugoslavia
Lantate, Nigeria
Lessive, Belgium
Longovilo, Chile
Leuk, Switzerland
Lurin, Peru
Managua, Nicaragua
Manaus, Brazil*
Martinique, Trois-Ilets, France
Matura Pt., Trinidad & Tobago
Mill Village, Canada
Moscow, U.S.S.R.
Nkoltang, Gabon
Nsele, Zaire Republic
Philibert Tsiranana, Malagasy Republic
Pleumeur Bodou, France
Prospect Penn, Jamaica
Quito, Ecuador
Raisting, Germany
Sehouls, Morocco
Sintra, Portugal
Tangua, Brazil
Tarum, Sweden
Thermopylae, Greece
Trou-Biran, French Guiana, France
Tulancingo, Mexico
Umm Haraz, Sudan
Utibe, Panama
Zamengoe, Cameroon

*Domestic, Non-Standard

\# Earth Stations Served by Pacific Ocean Satellites

Brewster, Washington (U.S.)
Carnarvon, Australia
Hong Kong, U.K.
Ibaraki, Japan
Jamesburg, California (U.S.)
Kum San, Korea
Lake Cowichan, Canada
Moree, Australia
Paumalu, Hawaii (U.S.)
Peking, China
Pulantat, Guam (U.S.)
Sentosa, Singapore
Shanghai, China
Si Racha, Thailand
Taipei, China
Tanay, Philippines
Warkworth, New Zealand

A Earth Stations Served by Indian Ocean Satellites

Arbanyeh, Lebanon
Asadabad, Iran
Bechar, Algeria*
Buitrago, Spain
Ceduna, Australia
Deh Mandro, Pakistan
Djatiluhur, Indonesia
Fucino, Italy
Goonhilly Downs, U.K.
Hong Kong, U.K.
Jeudah, Saudi Arabia*
Kuantan, Malaysia
Lakhdaria, Algeria*
Longonot, East Africa
Mwembeshi, Zambia
Ouargla, Algeria*
Peking, China
Pleumeur Bodou, France
Raisting, Germany
Ras Abu Jarjur, Bahrain
Reunion, France
Riyadh, Saudi Arabia*
Sentosa, Singapore
Si Racha, Thailand
Taipei, China
Tanay, Philippines
Thermopylae, Greece
Umm Al-Aish, Kuwait
Vikram, India
Wattayah, Oman
Yamaguchi, Japan

Figure 2.4

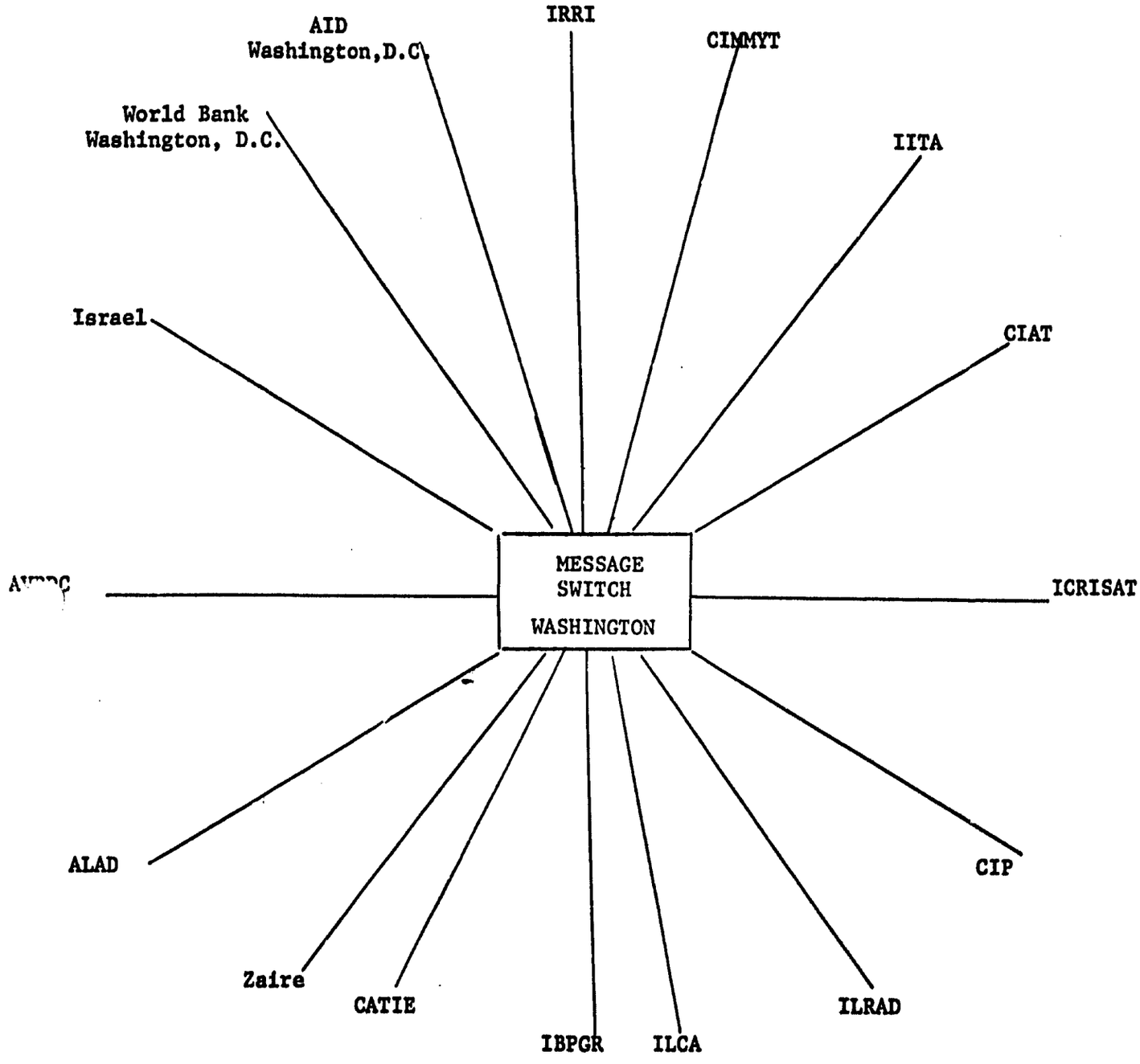

AID
Washington,D.C.
IRRI
CIMMYT
World Bank
Washington, D.C.
IITA
Israel
CIAT
MESSAGE
SWITCH
WASHINGTON
ICRISAT
ALAD
CIP
Zaire
CATIE
IBPGR
ILCA
ILRAD

Figure 2.5

1. The Switched Telex Network

Telex is available in virtually all countries today. Most centers do use it, and all could. No technological innovation would be involved, though in some instances (e.g. IIRI) the telex at the capital city office would have to be supplemented by a special telex line to the field station. The main change would be an organizational one, involving a decision to use telex more extensively. It involves putting the terminals in convenient locations and having telex directories readily available. In the following chapter, where we consider economics, we will evaluate the savings that would result from more extensive telex use.

Here it is suffice to note that a telex normally operates at a theoretical 66 words a minute, which allowing for carriage returns, etc. amounts to a practical maximum of about 60 words a minute. Even when there is a one minute minimum, and especially where there is a longer minimum, it is economic to batch short messages and send them all at once so as to efficiently utilize the time for which one pays. For example, a 75 word message would be billed for two minutes even though only a fraction of the second minute is actually used for transmission. Heavy telex users find it worthhwile to rent or buy a terminal with some memory, so that messages can be typed in, and then automatically transmitted all together at full speed, rather than have a typist type the messages while on line. The latter procedure is inefficient due to the inevitable hesitations and interruptions. The simplest, cheapest

memory is a paper tape. Electronic memories on intelligent terminals are rapidly growing in number and falling in price.

Maintenance in isolated LDC locations is, however, a problem for those newer terminals. Which brand of intelligent terminal could be serviced would vary from country to country. Maintenance is a problem even for conventional teletypes which the PTT's of virtually all countries are accustomed to servicing. Typewriters are mechanical devices with moving parts. They are less reliable than solid state electronic equipment. Paper tape which is also mechanical would not add much to the maintenance problem. CRT's tape cassettes, floppy disks or core memory are of the same sorts as are currently used in other equipment at the IARC's, e.g. in computers. They are thus clearly maintainable in that environment.

2. A leased Teletype Network

The only reason to establish a private teletype network would be the resultant economy if the level of usage of the switched network rose above some break even point which would be the cost of leasing a circuit. The cost of a leased network is a constant regardless of amount of use while the cost of using the switched network varies with the minutes of usage. As we shall see later the break even point on our hypothetical system would come when each of the 16 nodes was transmitting for about 1 1/4 hours per day.

If the traffic exceeded that level of transmission then a leased

circuit network would be economically advantageous. In any system that does not hold traffic in long waiting ques, some hours every day must be wasted. If a system were so loaded that there was no idle time left on any circuit, clearly the system would not be able to handle the traffic from the busier stations or peak loads. Except at those peaks, some portion of the system must be idle. Let us assume a system with an average of four hours idle time a day per terminal, 10 hours of transmission, and ten hours of reception. Such a teletype system could handle about 158 pages of double spaced typewriter text a day to and from each terminal. (1)

That traffic volume could be doubled on a full duplex system by having two typewriter terminals at each node, one to send and one to receive. Thus the capacity of a leased teletype system would be about 316 pages per day per node at about the same cost as 19 pages per day per node on a telex network.

Figure 2.6 illustrates the situation. From one page per node per day up to 19 pages per node per day, use of telex is cheaper, with a variable annual cost of $2953 per daily page of traffic per node. (2) At a level of traffic of 19 pages per node per day (which costs $55,000 per node per year), a leased teletype network becomes cheaper. For the same $55,000 it can handle up to 158 pages per node per day. To exceed that limit a second terminal must be added

---

(1) 66 wpm X 10 hours X 60 minutes/hour = 39,600 words per day. 39,600 ÷ 250 words/page = 158 pages per day.

(2) A year is assumed to be 260 working days.

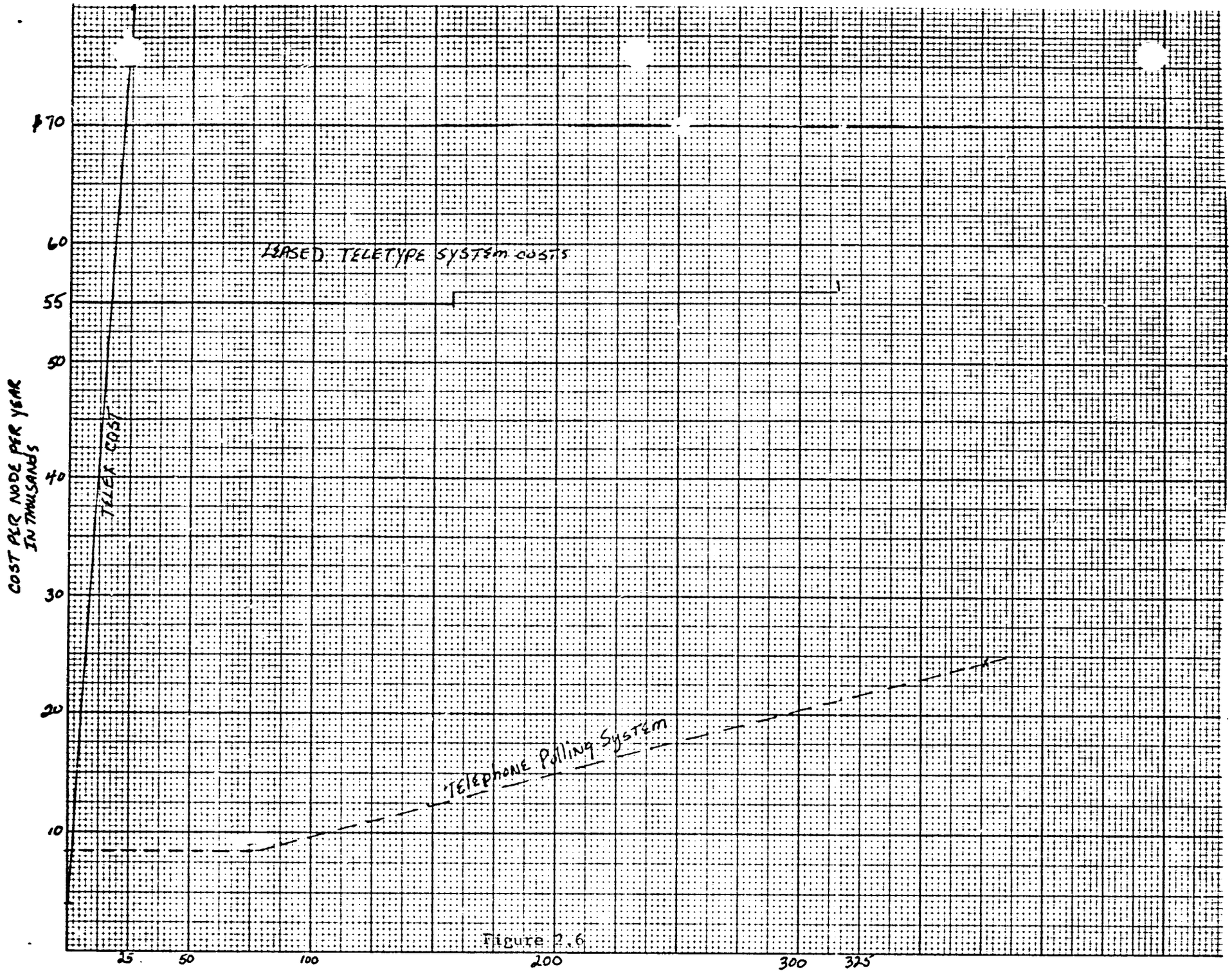

COST PER NODE PER YEAR
IN THOUSANDS
$70
60
55
50
40
30
20
10
LEASED TELETYPE SYSTEM COSTS
TELER COST
TELEPHONE POLLING SYSTEM
25
50
100
200
300
325

Figure 2.6

at $900 per year, allowing up to 316 pages per node per day for a fixed $56,000 per node.

A leased network would be a star network with a minicomputer switch in the USA. To link every pair of points among 16 nodes would take 120 circuits, instead of 15 for a star net. If several points were along a single trunk, the 120 could be reduced somewhat, but more switch capacity would be needed. A star is clearly the most economical system, particularly since most traffic by each IARC is with the USA.

3. A leased Network of AVD Circuits

A leased AVD circuit is a leased telephone grade line used to carry either voice or data traffic, i.e. Alternate Voice or Data. As noted above, the bandwidth of such a voice grade line is much greater than that of a telegraph line; it must be to carry voice. The disadvantage of a private voice grade network is its cost. Its great advantage is that it can be used for conversations and for facsimile as well as for messages. It can even be used for computer networking. Indeed, it is common among leasors of voice grade lines to multiplex them so as to simultaneously carry voice and teletype traffic. Typically they are multiplexed as voice + 2 or voice + 4 teletype channels.

Clearly the power, flexibility and convenience of a voice grade network far exceeds that of a teletype network but at about double the cost.

WHAT IS TECHNICALLY POSSIBLE?

Considering again a star network with the private switch in the United States, we can again estimate total capacity. Since telephone networks are duplex links (allowing parties to talk from each end simultaneously), it is possible to have separate transmit and receive terminals at the nodes operating at once.

Telephone lines in the United States are widely used for data transmission at 4.8 kbps (4800 bits per second.) Transmission of this sort requires specially conditioned lines. Indeed with good modems it is possible to transmit at 9.6 kbps. On the other hand without circuit conditioning and in "noisier" telephone systems, 2.4 kbps is more practical; non-US systems sometimes are only capable of reliably transmitting at 1.2 kbps. In our cost-benefit analysis we shall do our calculations at 4.8 kbps; one may divide by two or more for more conservative assumptions.

Traffic running for 20 hours a day at 4 kbps would carry 345 X 10 to the 6 bits/day. (1) If the system were to only carry text, that number of bits would amount to about 30,000 pages per node per day.

Assuming 45.5 bits per word, (2) 345 X 10 to the 6 bits per day = 7.6 X 10 to the 6 words per day.

Assuming 250 words per page 7.6 X 10 to the 6 words per day = 30,360 pages per day.

Needless to say, no Center will send or transmit 30,000 pages a

---

(1) 20 hours X 60 min X 60 sec X 4.8 X 1000 = 345 X 10 to the 6.

(2) 66 words per minute is equivalent to 50 bits per second or 3000 bits per minute. So 1 word is 3000/66 = 45.5 bits per word.

day. However, a leased line telephone system would not be used for text alone; the bulk of the capacity would undoubtedly be used for conversations, facsimile, or computer networking.

There is much usefulness of each of these modes of communication to the IARC's. Clearly the ability to send reprints and graphs by facsimile or to use remote computer systems and data banks on line is of potential interest, but only at an appropriate price.

Polling Systems

The three sytems discussed thus far all provide for instantaneous communication whenever anyone at any node of the network chooses to dial up. The two leased line systems (telex or voice-grade) represent a fixed cost for a facility that would be available 24 hours a day whenever anyone wished to use it; for that the cost is high. The switched telex system uses the public circuits whenever anyone at any node dials a number; costs on that system can be reduced by batching the messages rather than by sending each as a separate call. Still the telex messages may be sent at will if so desired. A still more significant economy can be realized by accepting the discipline of batched messages sent with limited frequency and at a high data rate.

That kind of batching is the basic idea behind a polling system. It should be less expensive than the three systems just described because the option of instantaneous communication is forgone. Messages are batched, and only sent periodically to a switching

computer, which sorts and relays them to their destinations.

Relatively few communications of the IARC's need to be instantaneous, and those few generally require voice communications rather than text messages. Business traffic such as orders, payments, travel arrangements, and memos, and scientific traffic such as reports, reprints, and even genetic file searches can well be handled on a next day delivery basis. Thus for message traffic, it makes much sense to save money by batching messages.

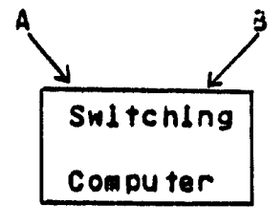
A polling system consists of an intelligent terminal with some memory at each node and a switching computer at the center of the star. Periodically, the switching center sequentially polls each node, activates it, orders it to transmit its stored messages, receives them, and stores them in its memory. The switching computer then sorts the messages by address and proceeds to a second cycle through each node; the center is now operating as a transmission terminal, delivering to each node all messages addressed to it.

The difference between a polling system operating over switched telex and one operating over switched telephone lines is in the data rate. Let us, therefore, consider what a telex polling system can deliver and then examine the higher capacity telephone system.

4. Polling of Telex Machines

A polling system operating over telex lines makes no economic sense because the dominant cost is the data transmission cost, which is charged at the same rate for the polling system as for ordinary telex traffic. To route all messages through a switching computer at the hub of the star doubles the message traffic and requires some additional hardware costs. All of that for outshadows the savings from batching.

Consider a message from point A to point B such as diagrammed below.



On a polling system, it is sent from A to the switching computer and charged as one message - say $3.00 if it is one minute i.e. 66 words. Then it is sent from the computer to B as another message, which for example would cost an additional $3.00. It could be sent directly from A to B as a single message peesumably at about the same $3.00. The $3.00 figure is a typical US-overseas telex charge. Charges between other points may be substantially higher, but not so high as to eliminate the advantage of direct communication.

We may, therefore, dismiss a telex based polling system as a choice that is generally dominated by ordinary telex.

5. Polling by Telephone

A polling system that uses the international telephone switched system, however, has many advantages. The batched messages to and from each node can be transmitted in a very short time due to the considerable available bandwidth on the voice grade lines. Let us do initial calculations assuming the use of 4.8 kbps modems.

In a three minute call it would be possible to transmit 862,000 bits. (1) That is about 19,000 words or 76 pages. (2) Each node polled would transmit all its traffic intended for all other nodes combined to the switching computer during a single poll; it would receive all its traffic from all other nodes in one call from that computer. Assuming that in each case the total material transmitted was less than the 76 pages that could be sent in a minimum three minute call, the cost for the two calls to the most remote point on the network would be only $19.00. (3)

Table 2.5 indicates the daily communication costs of a system for a single poll assuming a US switching center.

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(1) 4.8 kbps X 3 min. X 60 sec = 862 kb

(2) 862,000/45.5 = 18,945. 18,945/250 = 75.8.

(3) India excepted.

Node	Rate	Cost for 3 minute call
Philippines	$3.00	$9.00
Mexico	2.65	7.95
Nigeria	3.00	9.00
Columbia	2.65	7.95
India	4.00	12.00
Peru	2.65	7.95
Kenya	3.00	9.00
Ethiopia	3.00	9.00
Costa Rica	2.65	7.95
Zaire	3.00	9.00
Lebanon	3.00	9.00
Taiwan	3.00	9.00
Israel	3.00	9.00
Italy	2.25	6.75
	40.85	122.55

Table 2.5

Long Distance Phone Rates

That cost incurred twice a day 260 days a year comes to $63,726.

To this must be added the cost of the polling equipment and its maintenance. We have no figures based upon past experience for an international polling system, for none exists. In the US, rentals of the switching computer at the hub of the star run about $1,000 a month. The intelligent terminals at the nodes rent for about $200

a month. That would suggest that $50,000 a year would cover the cost. We estimate an additional $10,000 per year to take account of the unknown costs of keeping the equipment operating abroad.

In addition 16 modems at $2,400 apiece amortized over three years, would add $13,000 a year to the cost.

Our estimate then of annual cost is:

Communications	$64,000
Nodes and computer	60,000
Modems	13,000
	$137,000

That system could expand beyond 76 pages per node by simply adding minutes to the polling calls. Each additional minute would cost only the extra per-minute telephone charge and allow an additional 25 pages of text.

There is large room for expansion of traffic on a polling system beyond the minimum levels that we have analyzed. The central switching computer talking to 16 nodes six minutes apiece is in active communication only 96 minutes a day - roughly an hour and a half. If the need existed it should be feasible to expand operations say five times to 8 hours a day without impinging on busy peak telephone hours. Table 2.6 illustrates the cost and the effect of such expansion.

Length of each one-way poll	Total Cost per yr. of system	Pages sendable per day per node	Cost per page sent
3 minutes	$137,000	75.8	$.43
6	201,000	151.6	.32
9	265,000	227.4	.28
12	329,000	303.2	.26
15	393,000	379.0	.26

Table 2.6

Polling Costs by Length of Call

Some additional advantages as well as some qualifications of a telephone polling system have to be noted before we conclude our discussion.

One additional advantage is that the telephone facilities on which the system rests are simply the Center's ordinary phone lines. Furthermore the polling presumably would be done during off-peak hours. To a few points, e.g. Italy, there are reduced nighttime rates; more importantly, though, there is greater efficiency derived from the ability to communicate during these hours because of the greater ease in completing a circuit in the dead of night. Even places like India and Nigeria which are normally terribly hard to reach during business hours have a good chance of being reached if the poll is scheduled for the off-peak hours.

WHAT IS TECHNICALLY POSSIBLE?

A further advantage is that, if needed, a polling system can be coupled with remote job entry for computer operations. The type of intelligent terminal that receives the messages, can read them onto a tape cassette or similar storage medium. For message traffic that is then run off as typewriter printout. If the message is computer data, however, the cassette can be loaded on the computer.

There are, however, several problems that need to be recognized. First, ideally a polling system should use direct distance dialing. (All domestic polling systems do.) The switching computer dials the number of the node being polled. If the circuit is busy the computer acts as a "camp-on" device, repeatedly dialing the number until it gets through. Direct dialing without the intervention of an operator exists from the USA to less than half of the countries in our 16 point network.

IDDD exists	IDDD does not exist
Philippines	Nigeria
Mexico	Columbia
Taiwan	India
Israel	Peru
Italy	Kenya
USA	Ethiopia
	Costa Rica
	Zaire
	Lebanon

We shall consider in detail later in our study ways of coping with that problem. The most primitive way would be to have a person put the call through and as soon as the connection is obtained switch on the computer transmission. There are also special technological fixes that are possible with the co-operation of local PTTs. Finally one can rely in part on the fact that the international IDDD network is growing rapidly. The majority of nodes will presumably have it within a couple of years. Nonetheless the absence of IDDD to many places is a very severe limitation to a system that is designed to operate unmanned in the dead of night.

Another qualification already noted is that the assumption that the system can work everywhere at 4.8 kbs is unduly optimistic. There will be no problem with the international telephone circuits. With some of the countries, particularly those where the field station is in a remote rural location, however, the telephone lines are likely to be too noisy to transmit data accurately at that rate. Such places will have to fall back to a 2.4 kbs transmission rate which will require either calls that are twice as long or will handle only half as many pages. Indeed in some extreme cases, as where the messages must travel over HF radio or where lines are particularly bad, it may be necessary to use a 1.2 kbs transmission rate.

Finally, the biggest obstacles of all are legal problems which derive from national restrictions on the use of telecommunications facilities. Until January, 1976 the FCC-approved tariff for

International telephony provided for the use of the switched telephone network only for voice traffic. It was therefore illegal to operate an international polling system. That has now been changed. Other governments, however, have regulations that could be prohibitory or creat difficulties. Mexico, for example, prohibits tramsmission of data over voice lines. Other countries limit the modems that may be used to ones they supply.

Such regulations are dubious at best. There is good reason to believe that a petition might be acted on favorably, even if there is no overall change in policy for as worthy a cause as the food needs of the LDCs.

6. Use of Intelsat With Small Ground Stations

The aforementioned five alternative systems, use off-the-shelf technologies. They do nothing that is not done every-day at least within the USA. Barring regulatory problems they could be in operation in six months. The next two systems we discuss are more experimental. There are significant uncertainties about them -- not about their technical possibility but perhaps about engineering solutions, and certainly about costs.

It would be possible to develop a system which would place a satellite ground station at each of the IARC's, allowing them to communicate internationally, bypassing the inadequate terrestrial facilities at least at the research stations themselves.

Similar direct satellite telephone and data traffic exists or is being installed to and from remote locations in a number of applications. The UN has been given a portable ground station to use with the Symphonie satellite for peace-keeping operations. The Canadians have been experimenting with small ground stations to provide two-way telephone and one-way TV via Anik to arctic villages. Small ground stations are being installed on off shore oil rigs. The Marisat and Marots systems are being developed for communication with shipboard antennas. And there are, of course, military applications. Rugged portable data terminals exist that a man can carry on his back and can use to communicate via satellite to other units.

Clearly, it would be possible to put a ground station at each IARC. But first there needs to be a satellite system that could serve them and one must estimate the cost.

At present the obvious satellite system to use is Intelsat. It is the agreed international system, covering the globe. Intelsat, however, was designed for use with national ground stations having 95 foot dishes. Its purpose is intercontinental traffic with domestic distribution generally remaining on terrestrial circuits. That design ably serves the needs of the advanced countries. They have extensive terrestrial circuits in place. The sophisticated ground stations can receive weak radiation from the satellite, allowing close spacing of satellites on the potentially crowded geostationary orbit. For LDC's, however, it would be useful to

have numerous widely scattered ground stations to substitute for the terrestrial lines that they do not have.

It is possible to use Intelsat with smaller dish antennas, but a penalty charge is assessed since to use a small dish one uses more of the satellites resources than with a large one.

Comsat has developed a 15 foot terminal that costs less than $150,000. Amortized over three years the annualized cost may be taken as $50,000 a year. It accesses the Intelsat 4 global beam.

The space segment costs are partly a matter of Intelsat policy. Regular rates are $3 million per transponder per year; special rates have been offered for unused capacity without back-up (e.g. to Algeria) as low as one third of that. The 15 foot terminal requires a bandwidth of about 3 per cent of the transponder.

Let us postulate that the sixteen nodes share two way circuits to the satellites in whose footprint they fall. Circuits are needed for at least the Atlantic and Indian Ocean satellites. So eight half-circuits are required. (1) Multiplying 3 per cent of $3 million, i.e. $90,000 by 8 we get a space segment cost for the system of $720,000 per year. Add 16 $50,000 terminals, or $800,000, and the total cost of the system is $1.52 million dollars per year. This is for four special voice grade lines of 56 kbps.

---

(1) Two ways x two satellites x 2 circuit halves.

On such a system one could provide all the capabilities noted above for a private line network of voice grade circuits. It could provide voice service, facsimile, and computer networking, as well as message traffic. To send 400 pages per node -- a larger amount than we have generally discussed above -- would require only 22 minutes of one full circuit.

Clearly that is an expansive and expensive solution to the communications problems of the IARCs.

7. Advanced Multiple Access Satellite Systems

Much cheaper satellite systems are in use for certain military, earth observation, and meteorological purposes. Many of these require much lower bit rates. For specialized communications purposes such low capacity satellites might be economical if they were available. (1)

The systems that would be economical would operate in earth coverage mode, with all stations within the footprint receiving all traffic, but reading only that addressed to it. Calculations have been made for bit streams of 75 bps, 2.4 kbps and 16 kbps. The first speed requires a 14dB G/T terminal which rents for $1500/month while the higher speeds operate with a 23dB G/T

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(1) G. P. Petrick and C. M. Abrahamson, "Economic Considerations For Low Capacity SHF Satellite Communications Earth Terminals", AIAA Paper No. 74-459, 1974. Cf also B.I. Edelson, "Small Earth Terminals for Satellite Communications", Astronautics and Aeronautics, June 1973, pp. 40-46.

terminal which is leased for $2000/month. Calculations are presented in Table 2.7.

Rate	Terminal cost per mo.	Monthly Space segment one-way circuit costs	Monthly costs: 16 terminals+ circuits on two satellites	Annual cost
75 bps	$1,500	$375	$24,750	$297,000
2.4 kbps	2,000	1500	35,000	420,000
16 kbps	2,000	10,000	52,000	624,000

Table 2.7

Costs of Alternative Satellite Services

How adequate is the capacity that each of these provide?

The 75 bps system can handle telex traffic. Seventy-five bps is 100 words per minute, or in other words somewhat more than a normal teletype line. If the ten hours for one-way transmission on the Atlantic satellite were shared by ten nodes, then with one hour available for each node it could send (or receive) 60 x 100 = 6000 words or about 25 pages.

The 2.4 kbs system has enough bandwidth to carry computer applications, facsimile, or a polling system - though having a polling system on leased lines may not be particularly useful. If

limited to text transmission it could handle 475 pages of text originating at each node each way in 10 hours. (1)
The 16 kbps system has still more capacity. If fully loaded with text it would carry over 3,000 pages to and from each node each day. That is a rate of five pages in a minute.

The cost per page of a system drops with the size of the system, provided that the traffic is heavy enough to keep the system occupied as a result of economies of scale. (2)

Table 2.8 might imply that one can dismiss the larger systems from consideration for no one has any use for 100 million pages of text or even 13 million, but that perhaps be a mistake. Pages of text are just a measure. In fact, the higher speed systems can make sense if most of the capacity is used for remote computing, information retrieval, facsimile, or other uses besides text transmission. Those other uses consume large amounts of bandwidth. If those other uses kept the system busy, the cost per page figure would continue to represent a reasonable estimate of the true cost of whatever text was transmitted. The adoption of such systems would, however, have to be justified, if at all, by other

---

(1)

$$\frac{2{,}400 \text{ bps} \times 60 \text{ sec} \times 60 \text{ min} \times 10 \text{ hrs}}{45.5 \text{ bpw} \times 250 \text{ wpp} \times 16 \text{ nodes}} = 475 \text{ pages per node per day}$$

(2)

$$\frac{16{,}000 \times 60 \text{ sec} \times 60 \text{ min} \times 10 \text{ hrs}}{45.5 \text{ bpw} \times 250 \text{ wpp} \times 16 \text{ nodes}} = 3038 \text{ pages per node per day}$$

requirements than text transmission alone.

Rate	Annual cost $	Pages transmitted in a year	Cost per page
75 bps	297,000	98,742	$3.00
2.4 kbps	420,000	1,976,000	0.21
16 kbps	624,000	12,638,080	(0.05)
56 kbps	1,520,000	92,443,520	(0.016)

(1)

Table 2.8

Cost of Satellite Systems

(1)
This figure is subject to special error in that we have not explored the kinds of terminal equipment that would be required to handle such volumes of output. There is no reason to consider that since we conclude that such data rates would be justified only for other purposes than text transmission and those purposes would control the terminal facilities.

Problems

At the beginning of this chapter we examined the new techiologies that may help bring down the cost of long distance text and data communication. In the second part of the chapter we examined how some of those technologies could be used by the International Agricultural Research Centers within the next couple of years to solve some of their communications difficulties. However, in underdeveloped countries there are several practical problems that are likely to obstruct tha implementing of any such improvements. Specific problems that we need to consider are maintenance, the quality of telephone lines, the absence of automatic switching, and the regulatory policies of the PTT's.

MAINTENANCE

Maintenance is the subject of constant complaints in the LDC's, yet computers considerably more complex than anything that we are here discussing are kept in operation. Maintenance is a problem for which there is no panacea, that will always be with us, but which is improved by adhering to a few basic principles.

In the first place it is important to select equipment for high reliability. A detailed evaluation of alternative hardward goes beyond the scope of the present research project. If the advice of this report is accepted and the CGIAR or AID wish to pursue further the installation of advanced communications equipment in the

IARC's, one of the immediate next steps would be to commission an engineering study of the various terminals and minicomputers now on the market to evaluate each brand as to its ruggedness and maintainability in remote rural areas in the LDC's. The manufacture of terminals is a highly competitive field. There are at present as many as 70 product lines offerred by nearly forty companies. (1) Some have CRTs for visual display, which has the advantage of reducing the amount of mechanical action; it is the mechanical parts of a typing device that are most likely to wear out. Some method of producing hard copy on paper is necessary, however. Some terminals use impact printing, some use thermal printing on special paper. Prices range from under $1000 to over $20,000. Some have auxiliary memory such as paper tape, cassettes, or floppy discs, some do not. Some have upper and lower case, some only upper. These devices vary in their reliability and maintainability.

Maintainability depends not only on quality of manufacture but also on design. Some devices have been designed to emphasize plug in replacement of defective modules. Probably even more important is the service organization; is it present around the world? It may be necessary to have a system using different terminals in different places depending on local availability of service.

Maintenance may cost more than the terminal itself. Texas Instruments, for example, rents the kinds of terminals we are

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(1) Cf. survey of "Interactive Hard Copy Terminals" by Jackson W. Granholm, Datamation, vol. 21, no. 11, Nov. 1975, 51-61.

discussing for between $15 and $30 a month in the U.S.A. without maintenance, but charges $85 to $150 a month with maintenance. In many locations it may well be worth considering having a duplicate machine on hand.

THE QUALITY OF TELEPHONE LINES

There are three main segments to the circuits used by the IARC's. There is the international leg from the United States or wherever to the port of entry in the LDC. Secondly, there is the leg from that satellite earth station or cable port through the international exchange and then to other exchanges within the capital city. Finally there is the leg from the international exchange in the capital city to the rural location where the IARC has its field station.

The international leg presents only one problem, shortage of circuits to some countries at peak hours. The quality of the signal is good. A repeated comment in our interviews with people at the IARC's was that they could phone more easily to Washington than to somewhere fifty or one hundred miles away in the country where they were located.

Within the capital city, or between the international port where the international circuits come in and the capital city, the quality of service ranges from poor to good, but is generally fair. In Lagos it is a struggle to make a phone call even within the city

during business hours, and the lines to the airport have been frequently out of order. That, however, is the exception accounted for in part by the extraordinary speed in the growth of the city. In most of the countries where IARC's are located there is little problem communicating within the capital city or in communicating abroad from it, at least during off hours.

The critical communication problem in many LDC's concerns the last leg from the capital to a rural location which may be only a relatively few miles away. In Nairobi and in Lima the Agricultural Research Center is at the edge of town and within the city telephone exchange. Thus they have reasonably good service. In the Philippines, on the other hand, IIRI in Los Banos is thirty miles outside of Manila, and has to rely on HF radio as its link to Manila. In communicating from the US to ICRISAT in Hyderabad, India, it is relatively easy to reach Bomoay. The problem is to get a free line from there to Hyderabad. In general the rural lines, and in some places the ordinary urban lines too, are too noisy to be used for remote computing, and may create difficulties even for ordinary conversation. In such instances, text transmission must be sent at a low data rate so as to minimize the errors. At low rates data can even be sent over HF radio successfully; ships have been doing that all through the century. Where the ordinary local lines or the local exchange is too unsatisfactory, it may be necessary to install a private direct line or microwave circuit to the capital city or to the international exchange.

AUTOMATIC SWITCHING

As we have already noted, the necessity to go through an operator is a major disadvantage for the kinds of applications that we have in mind. Where direct dialing is possible one can use a camp-on device to keep dialing the desired number until it is reached, and then without human intervention, have the stored messages transmitted. Automatic dialing is now virtually universal within metropolitan centers. As we have noted, it is spreading rapidly for international calls. From the USA direct dialing was available to 22 countries a year ago; the number is now 35.

Centers like CIAT in Cali, Columbia or IITA in Ibadan, Nigeria cannot phone anywhere outside their own locality without going through the operators at the local exchange.

One can think of two technological approaches to the problem of establishing unmanned operations, short of waiting the decade that it will take for direct dialing to become more nearly universal. One possibility is to have the switching computer play a recorded message to the operator in the appropriate language. One suspects, however, that the telephone management would not like that, particularly if it kept coming back every few minutes to a human operator who had just announced that there was an hours waiting cue. The other approach would be to run private lines from the IARC to the satellite ground station and have an automatic switch for that line right there. That would require special co-operation by

the local PTT to allow the IARC to install its own switching computer at the ground station. Technically that would present no problem, but bureaucratically it probably would. Organizations of less international status than the international agricultural research centers would not be likely to be given such permission.

BUREAUCRATIC RESTRICTIONS

The restrictions placed by PTTs on communications innovations are likely to be far more severe than any technological difficulties. In many countries it is extremely difficult to obtain a private line; it is rarely barred by local regulations, but it may take years to get it installed. PTTs, in general, seek to discourage private line expansion.

Also many PTTs do not permit the customer to attach equipment that he owns to the telephone system. In particular, many countries require the customer to rent modems from the PTT, not to buy his own. Since modems differ greatly in quality, this may force the customer to use a lower data rate than would have been made possible by a better modem.

PTTs also generally protect the postal and telegraph monopolies. They are likely to see in a private message handling system a threat to their monopoly and their revenues. Some countries, also, are concerned about the international import and export of data. In fact, countries that take such restrictive postures are defeating

their own purposes and harming their own communications development. The installation of advanced facilities in a place like an international agricultural research center is a step towards making a better communications system available through the PTT on a national basis. That, indeed, is the reason why AID became interested in this project at all. The IARC's were simply picked as ideal insititution to examine in a demonstration project, in the hope that from their experience local learning and expertise would follow. Ideas tried out by the IARCs would spread. One would hope that host governments would see in this project a chance to experiment with procedures that they could then apply to their own government offices and local institutions so as to improve their communications facilities.

CHAPTER 3

WHAT IS ECONOMIC?

In Chapter 2 we examined various new technologies for long distance communication and some of their costs. In this chapter we compare the costs of the alternative systems more closely so as to arrive at some judgments on relative cost/effectiveness.

It is helpful to distinguish long run estimates based on what becoming technologically possible from short run estimates based upon current prices of available services and equipment available off the shelf. Let us start with the long term limits of what may happen to the costs of communication.

Long Term Trends

DISTANCE INSENSITIVITY

We have noted above in Chapter 2 (p. 40) that communication costs have fallen most and will continue to fall in long haul transmission.

We noted that that is due particularly to the characteristics of satellite communications, but is also the result of advances in coaxial cable, optical wave guides, and microwave.

We noted that existing sutdies show increasing costs with distance up to about 300 miles, but above 300 miles, distance makes almost no difference.

ABUNDANT BANDWIDTH

Even if long distance communication costs become almost the same as that for local communication that does not tell us what is likely to happen to those communication costs.

No simple prediction makes sense. We leave aside inflation and deflation, for we are talking about real costs, not money costs. Still we would make opposite predictions for the trend measured in bits and the trend measured in consumer services. In the developed countries there is every reason to expect that consumers will spend an increasing amount on communication, but that is because the services they expect are becoming increasingly luxurious. Radio gives way to black and white TV and then to color TV and then probably to multi-channel CATV, pay TV, large screen TV, video recorders and video cassettes. Basic voice telephone is supplemented by, or is gradually superseded by, camp-on and forwarding devices, and data communication. As a result of these expanding services, consumer usage, measured in bits, is likely to grow astronomically, and consumer expenditure will rise some. Furthermore, a large part of the cost of communication is the cost of maintenance and of personal service rather than the cost of transmitting bits. Programming all sorts of software and

entertainment, keeping receiving sets and terminals in working order, billing, directory assistance, sales promotion, and similar matters come to be the dominant costs instead of the transmission itself. The cost of delivering stripped down basic service, which may often be what LDCs need, may well follow a declining trend even though labor intensive and elaborate services go up in cost.

Indeed, there is every reason to expect a continuing decline in costs of transmission measured in bits per dollar. That decline is due in part to advances in electronics and in part to growth of volume.

Electronic transmission is a classic example of an industry with economies of scale. Circuits of greater bandwidth cost very little more than circuits of less bandwidth. Table 3-1 shows the present cost per bit of various types of circuit.

Clearly, the way to keep communication costs low is to aggregate the traffic in such a way that it shares a small number of wideband channels, which are kept busy. That is the basic idea behind both packet switched networks and polling systems. In each system messages are sent into a node computer which is an accumulator of traffic. The collected messages are transmitted in a short burst at a high rate of speed (the ARPAnet at about 50 kbps or about 1000 words of text per second). For this to be economical it is assumed that other traffic will keep the transmission lines busy the rest of the time.

By transmitting messages in this way communication costs could go down to $.002 per page.

Table 3-1

Communications costs for one unit of international electronic mail

	Message size	
	1,000,000 bits	10,000 bits
Dial up telephone and 4800 bps modem	$6.94	$0.07
Leased line	$0.44	$0.004
IDDS	$0.43	$0.004
Digisat	$0.19	$0.002

For LDCs this analysis has certain implications. First, LDCs should emphasize the development of low bandwidth communications since those can be highly economical. For mass communication this means an emphasis on radio before TV. For message traffic this means an emphasis on text transmission. A given switched network can carry much more traffic in the form of text than of voice conversations.

Second, LDCs should transmit those low bandwidth messages over the highest bandwidth circuits that they can keep busy. There is no

contradiction here; rather it is an unusual case where one can have one's cake and eat it too. Phone service is necessary because some business requires conversation. However, no LDC can keep up with the demand for phone service. A partial solution is to provide computer controlled message switched text service on the scarce telephone lines, and by pricing and other means to encourage diversion of as much of the traffic as possible onto that economical use of the plant.

Third, in this era of satellites, LDCs should co-operate in creating regional and global satellite consortia for domestic as well as international communication. No small LDC and indeed no small country even if highly industrialized, has enough communications traffic to justify having its own satellite or even to justify its leasing of large numbers of point to point circuits on a satellite. The USA has circuits on the Intelsat system to each of 75 countries. (1) Typical numbers of circuits linking LDCs to other countries are shown in the following table. (2)

Mexico	12
Peru	14
Columbia	11
Nigeria	5
Kenya	8
India	18
Taiwan	12
Philippines	15

(1) Intelsat System Status Report, March 3, 1975.

(2) Ibid.

Most of those circuits go to and from Europe and America. As is shown in Table 3.2, very few link LDCs to each other. Indeed in 1975 Intelsat circuits between LDCs numbered about 900 as against 5300 circuits between an LDC and an advanced industrialized country and 5100 circuits among industrialized countries. The fact that two LDCs do not have a circuit between them does not mean that they cannot communicate. They can do so via a third country to which they both have circuits, e.g. the USA. That, however, requires a double hop, and extra costs. An all point distributed network of the kind that tends to evolve naturally is not optimal for the LDCs for they are the source or target of only a small part of the traffic.

The same logic applies to domestic traffic within an LDC. Circuits between numerous points on a distributed (rather than star) network are likely to be underused.

There are means by which all non-voice traffic to or from a country can be loaded onto one or a few circuits. In Chapter 2 we described how a multiple access satellite system works. All the traffic is broadcast on a single frequency. Computers at the various ground stations pick out only those messages which are addressed to them. As we noted, all the international (non-voice) message traffic to almost all countries could be handled on a single phone circuit apiece. Using a shared international satellite, an LDC could presumably also put all its domestic

message traffic on a single two-way phone circuit (1) at a cost below that of domestic mails, not to mention the present cost of telegrams.

Our long run prognosis (of particular saliency for the LDCs) is that the costs of electronic communication of text can be brought down to very low levels, well below that of the mails. However, to achieve those economies will require use of batch transmission, and message switching and will also require sharing by many users of high bandwidth circuits and of satellites.

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(1) The theoretical top limit for a single phone circuit is about 400,000 pages a day. The practical limit is, of course, substantially below that, but well above the daily message traffic for most LDCs.

Table 3.2

	US	Italy	Isr.	Leb.	Zaire	Ethiopia	Kenya	Nigeria	Taiwan	Phil.	Mex.	Costa Rica	Columbia	Peru	India
US	X	107	44	9	3		7	7	35	32		13	54	39	18
Italy	107	X	11	7	5		7	7	2	2	9		4	3	2
Israel	44	11	X												
Lebanon	9	8		X											
Zaire	3	5			X										
Ethiopia						X									
Kenya	7	7					X								5
Nigeria	7	7						X							
Taiwan	35	2							X						
Philippines	32	2								X					
Mexico		9									X		3	3	
Costa Rica	13											X	1		
Columbia	54	4								3			X	2	
Peru	39	4								3			2	X	
India	18	2					5								X

Number of
Intelsat Circuits Among Countries in Prototype Study
(December 1974)

WHAT IS ECONOMIC?

Immediate Implications

The prospects that we have just outlined will not become available immediately. They involve large departures from present ways of doing things. A good deal of experimentation needs to be done to get from here to there.

The short run advice given the IARC's in this report is in the nature of recommendation of such experimental steps. We are recommending measures that move towards the long run goals of a low cost text and data communicationsystem for the LDC's, but only to the extent that is possible with present commercially available services and equipment.

We proceed in this section of the report to examine the alternative systems outlined in Chapter 2 to see what kinds of service each offers for the dollar at the present time.

Telex, as we noted above, is an existing, widely used, publicly available service. Its cost is a simple function of the amount to which it is used. We, therefore, made two estimates of telex costs: one for what we regarded as a minimum of significant usage, and one for as high a level of usage as would keep its cost below that of a private teletype network. (See Fig. 3.1). The minimum level assumed was that each node would communicate with four of the fifteen other nodes each working day, and that each of those four connections would last just three minutes, i.e. 66x3=198 words.

On Figure 3.1 below the low estimate of telex use is point 1A and the high estimate is point 1B, and the line between them represents intermediate levels of usage. At low levels of usage telex is relatively cheap, though moving very small amounts of text. At higher levels telex is clearly dominated by other alternatives.

We should note, however, that there is one other alternative that is so expensive that we did not even calculate it, namely telegrams. Telex is mostly used as an alternative to telegrams, as indeed it should be. (It should be used by the IARCs more than it is.) It has limited attraction. At very low levels of use it is attractive because without large, new fixed costs, at those levels the costs remain low. The telex is there already and could be used tomorrow just by deciding to use it.

The costs of a leased teletype network and leased voice/data network were calculated by adding together the current leased line changes from the US to each of the 15 spokes. (1) Teletypwriter leases were assumed to be $75 a month. Modems were estimated to cost $4,000 apiece, amortized over three years.

The method for calculating costs for polling and satellite systems has already been explained in Chapter 2. We are now ready to compare the economics of the various systems by examining Figure 3.1 and Table 3.3

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(1) For a teletype network 50 baud half circuits were calculated and then the total doubled for a full duplex network.

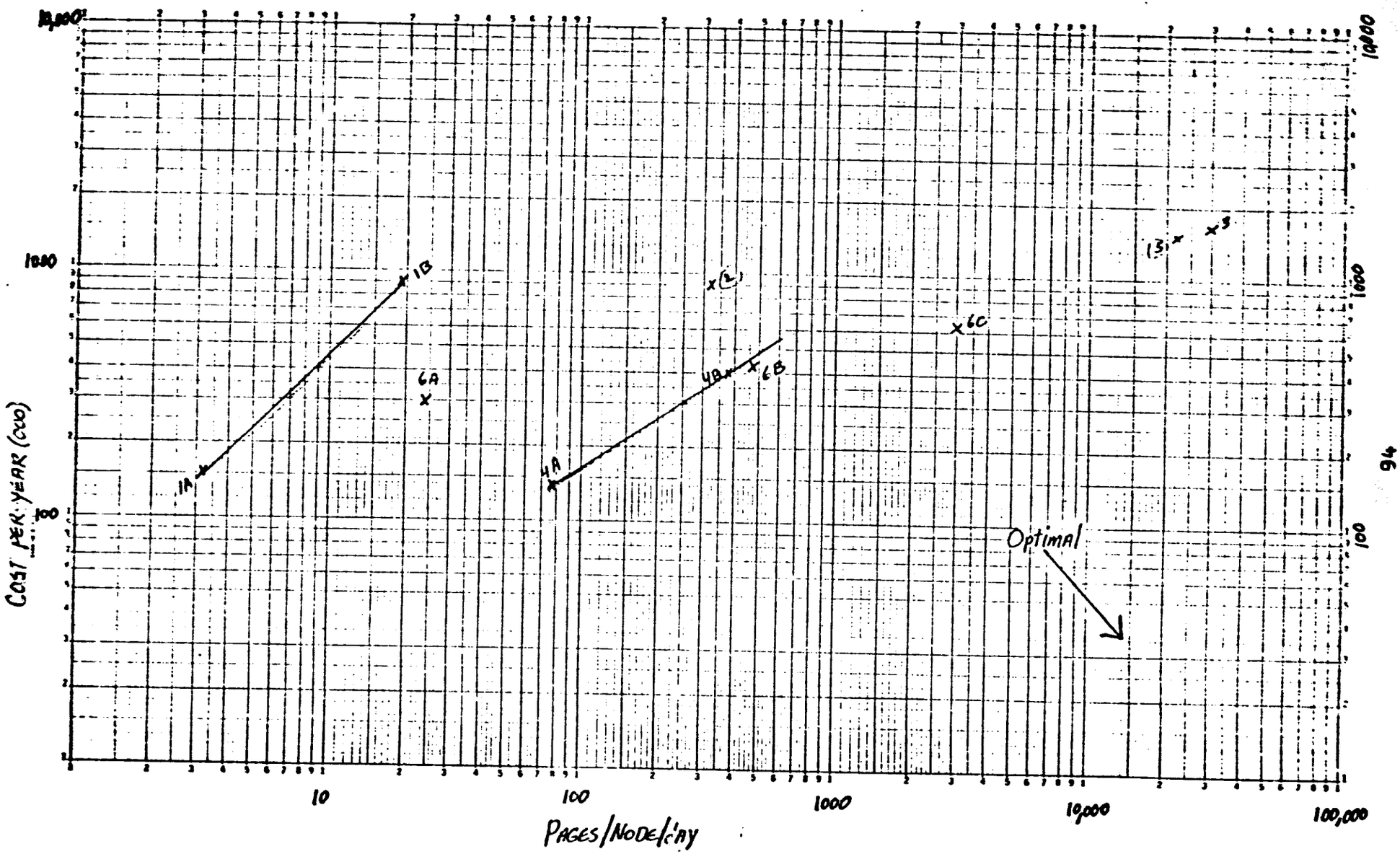

Figure 3.1
Comparison of Telecommunications Systems

The system that seems most attractive under most circumstances is a telephone polling system. For that system, we have made a low usage and high usage estimate because on a polling system, as on telex, one incurs bills with the carrier that are a function of usage. The low usage estimate is point 4A on Figure 3.1, the high usage estimate is point 4B. Intermediate usage is shown by the line between them. The low usage estimate assumes that all traffic is moved in 3 minute phone calls -- the billing minimum in the United States -- so that represents a lower bound on costs.

To interpret Figure 3.1 one should keep in mind that the most desirable values are toward the lower right hand corner. One wishes to spend as little as possible and transmit as much as necessary. One might examine the graph by moving ones eye upward, up the cost levels. Suppose one wished to spend only about $150,000 or less for text and data communication for all of the IARC's combined. One wishes the maximum possible traffic at that price. A polling system is the one that gives it. Moving up to levels of two, three, and four hundred thousand dollars that is still true. At $420,000 another alternative seems better. If one is ready to spend that much one ought to begin considering multiple access satellite alternatives with small ground stations. These become highly interesting at the high levels of traffic that would be generated by on-line computer systems.

For message traffic alone the polling system seems to be the most attractive alternative. It dominates all alternatives up to the

point where there is a need for more than about 450 pages of traffic per terminal per day.

It should also be noted that polling systems represent an off the shelf technology that could be put into operation within 90 days to countries with which the US domestic network has direct dialing. The problem involved in putting countries without direct distance dialing on the system are also soluble. The multiple access satellite systems on the other hand would be experimental developments, the details of which would have to be worked out; no such satellite service is being offerred by any vendor today. Thus a major conclusion of this study is that telephone polling systems could economically provide large amounts of communications capacity to the IARCs. This possibility should be explored further.

In closing this chapter, let us note what the estimated costs of such electronic transmission of messages for the IARCs would be. The cost per page is presented in the last column of Table 3.3. The costs in that column, it should be emphasized, are calculated on the assumption that the system is used to full capacity. A private line voice/data network would cost about $1,640,000 a year and could deliver over 125,000,000 pages of text for 1.3 cents per page. But the cost of the system would not change if it were carrying only 125,000 pages, but the cost for each page would then jump to $13. Not all the listed systems have equally fixed costs, but in each case the computed marginal cost per page cannot be assumed to hold at less than full use of the system.

The costs for the most attractive systems -- telephone polling or a multiple access satellite system at 2.4 kbps -- range between 43 and 26 cents per page. (A page it will be recalled is taken as 250 words, a normal double space typewriten page.) This is still somewhat more expensive than the post. A densely printed or typed single sheet with say 500 words can be mailed for 26 cents. Printed matter is even cheaper. However, costs in the 20s to 40s of cents with next day delivery are clearly highly competitive with use of the mails and much below present telex and telegraph costs.

Technically, it is possible to go the next step, to systems that bring the cost of sending a page down to a nickel or even less. That is not possible, however, on the scale of an experiment involving only the International Agricultural Research Centers. It requires a volume of traffic far larger than that which the IARC's would generate. Also, as we note in Table 3.3. the handling of that volume of traffic would require computer capabilities both at the terminals and the center far beyond the intelligent terminals and minicomputers we have discussed in this paper. The requirement for more advanced computers is not included in our cost estimates, but it does not follow that our estimates are too low. They may equally well err in being high, for more powerful equipment that costs more in total may cost less per unit of traffic handled. All we can say is that the figures for futeristic systems should be used with more caution than those for off the shelf equipment which is now commercially available. The broad conclusion is clear.

WHAT IS ECONOMIC?

Beyond the first steps toward better communication in the LDCs that can be taken even by the IARC's or other similar institutions alone, there is a future prospect of data and text communication at costs two orders of magnitude below present levels.

	Cost/year (000)	Pages/day/node	Cents/page
1A Telex-low usage	$149	3.2	11.3
1B -high usage	897	19	11.30
2 Leased teletype	897	316	.68
3 Leased voice/data	1,640	30,360*	.013*
4 Telephone polling (4.8 kbps)†	137	76	.43
4A -low usage			
4B -high usage	393	379	.26
5 Comsat	1,520	22,222	.016
Multiple access & small dishes			
6A 75 bps	297	24	3.00
6B 2.4 kbps	420	475	.21
6C 16 kbps	624	3038*	.05*

*These systems have a capacity that could not be filled by message traffic. The cost/page figure is therefore unrealistic unless other uses were found for the system, in which case different terminals might be required, which might either increase or decrease the cost estimate.

†At 2.4 kbps instead of 4.8, the pages transmitted would be cut in half and cost per page doubled.

Table 3.3

Costs of Alternative Systems

CHAPTER 4

IS IT USEFUL?

The most important questions have not yet been raised. We have shown above that there are ways of electronically delivering text and data among countries for costs substantially lower than those presently used. Does that, we must ask ourselves, make any significant difference to the LDCs? We have also shown that by use of a telephone polling system it should be possible to substantially reduce the communications expenditures of the IARCs and/or greatly speed up their communications abroad. Is that we inquire a matter of any great importance to them?

We address ourselves in this chapter to those two questions, first the general question about communications and development, and then the specific question about the IARCs.

The Communications Needs of the LDCs

COMMUNICATIONS AND DEVELOPMENT

There is a large literature on communications and development. It has recently been summarized by Frederick Frey in the Handbook of Communication. (1) His bibliography has about 400 titles. Perhaps

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(1) Ithiel de Sola Pool, Wilbur Schramm, et al., eds. Chicago:

the crucial issue was raised by Daniel Lerner in 1958 in The Passing of Traditional Society. (1) He presented the hypothesis that the growth of mass media have a psychologically broadening effect which causes modernization and development. Numerous later writers sought to challenge Lerner's assertion of a causal relation, arguing that the undoubted presence of a correlation between development and the growth of communication could be explained just as well by the opposite direction of causality. However, the Lerner hypothesis has stood up well after numerous attempts to test or challenge it. (2) It is not the whole story, but the evidence is strong for there being a causal relation between modern communications and development.

The mechanisms through which this can take place are many. Lerner based his thesis to a large extent on the psychological process of broadening of empathy. Others have noted the breaking of the hold of tradition, the diffusion of innovations, (3) the raising of

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Rand McNally, 1973

(1) Glencoe, Ill.: The Free Press.

(2) Hayward Alker, "Causal Inference and Political Analysis", in Joseph Bernd, ed. Mathematical Applications in Political Science, Dallas: Southern Methodist University Press, 1966. Phillips Cutright, "National Political Development: Measurement and Analysis", Am. Sociological Review, 28 (April) 1963, 253-264. Donald McCrone and Charles F. Crudde, "Toward A Communications Theory of Democratic Political Development: A Causal Model", Am. Political Science Rev. 61 (March) 1967, 72-79. Gilbert Winham, "Political Development and Lerner's Theory: Further Tests of a Causal Model" Am. Political Science Review 64 (Sept.) 1970, 810-818.

(3) Everett Rogers, Diffusion of Innovations, New York: Free

expectations, and the broadening of the arena of political and economic action. (1) Whatever the mechanism or mechanisms, the growth of communications does seem to be a major factor in stimulating development.

A priori, that conclusion is highly plausible. Anyone who has tried to introduce an agricultural innovation, as the IARCs have, or to change nutritional or procreational habits is acutely aware of how important is the human process of achieving understanding and motivation.

As a working hypothesis we can take it that the improvement of education, organizational communication, and mass communication can contribute greatly to the process of development.

There is an additional point that should be noted. In a world of increasingly scarce physical resources it is becoming increasingly difficult to assure every human being on earth the same amount of iron, steel, copper, beef, airplanes, automobiles, and highways that have been enjoyed by the profligate civilizations of the West. There are, however, certain modern goods that do not draw as excessively on those scarce resources. Communications are among these. To enable all the worlds population to enjoy the music, the

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Press, 1962; Modernization Among Peasants: The Impact of Communications, New York: Holt, Rinehart, and Winston, 1969.

(1) Ithiel de Sola Pool, "The Mass Media and Politics in the Modernization Process", in Lucian Pye, ed., Communications and Political Development, Princeton: Princeton University Press, 1963.

drama on film, the news, the knowledge, and the means of expression that modern media provide is far more feasible than to provide everyone with certain other things.

Beyond these generalizations, we can also note a number of much more specific ways in which the growth of the newer technologies of electronic communication can contribute to the current needs of the LDCs.

The less developed countries of the world require large injections of information in the form of technology transfer if they are to have economic growth and development. However the means for acquiring it are largely beyond their reach. Today a chasm separates the research facilities available in developed countries such as the Library of Congress, Weidner and New York Public Libraries, the British Museum, the Moscow State Library - from the extremely limited research facilities in LDCs.

With the development of database publishing to cope with the flood of new information, the LDCs position will worsen. The LDCs will not have access to such information resources unless some method to facilitate information transfer is devised. Given their lack of resources they cannot be expected to make much use of modern information retrieval systems or computer communication unless present rates fall by at least an order of magnitude.

Such an order of magnitude diminution in the rate for long-haul computer telecommunication is not out of the question. It seems

likely that an international data communications network using packet-switching technology could make access to data bases available from anywhere in the world at a communications cost of less than a nickel per 100 words. With such a network the information gap would rapidly be narrowed. A researcher in a university or planning office in an LDC without adequate reference sources of its own could retrieve a fact from whatever data base he wished anywhere in the world for little more than the cost of a domestic telephone call, something he could afford.

In short, as advanced countries increasingly transfer their reference materials from hard copy libraries to computerized retrieval systems, the LDCs will either fall further behind in information capacity, or will begin to catch up depending upon whether they are linked to these new information stores by telecommunications or not.

For a telecommunications system to serve the LDCs effectively as a bearer or technical knowledge, it must have certain characteristics. It must be cheap. It must also, be reliable, relatively rugged, and not require highly sophisticated maintenance and operating personnel. It must operate even in the absence of an elaborate infrastructure of stable electric current, national microwave or cable networks, and smoothly functioning telephone service. Finally it must link the LDC at its will to any possible sources of data, not just to ones in a favored metropole on which it is dependent. Those are not insoluble requirements. There are

technical options in the satellite systems chosen, in the possibilities of message switching, and in the pattern of networking which may make these desiderata achievable.

International computer communication using store and forward message switching is a technology particularly well suited to the need of the LDCs. It bypasses, rather than being dependent upon the problems of the ordinary phone system. With the ordinary voice telephone call, both parties have to be on the spot at the same time, which can be very frustrating if it takes a couple of hours to complete the circuit. With a store and forward system the message sits in the transmitting computer until the circuit is available and then gets sent to the terminal for which it is destined. That may happen at any hour of the day or night. Furthermore, low cost ground stations can be installed in remote regions, bypassing non-existant or overloaded microwave or coaxial long lines. Moreover, sophisticated data processing operations can be done by remote access to locations where the prerequisites exist. The main limitation on local facilities at the grass roots is the servicing of terminals, which suggests that in many locations simple CRTs and typewriter terminals will be the order of the day for a time to come; these will convey orders to more sophisticated equipment located where it can be serviced. Thus all that the local service must provide is the capability of carrying low grade code such as that which currently delivers telex or telegrams. International computer communication is well within the

state of the art for the LDCs.

There is no doubt that in the short run those countries that first develop data facilities gain a jump on those that follow later. Those countries that have not developed adequate data and computing resources may have to use them where they exist by means of telecommunication. A question of importance is whether that is a self-perpetuating situation or a self-correcting one. The evidence is quite strong that it is not a self-perpetuating situation.

First let us look at some analogous historical situations. Karl Deutsch has analyzed international and domestic mail flows, scientific journals, and scientific citations. (1) What he found surprised him. He found that the proportion of foreign material declined with the maturation of the social system. Originally development would take place in one or a few locations. Consequently there would be much interaction between those centers and the rest of the world. Gradually, however, local businesses, or research centers, or journals were founded and people interacted more with others who were conveniently close to them. Contrary to the standard cliche about the world growing smaller, international interaction as a proportion of all interaction declined with time in maturing societies.

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(1) "Shifts in the Balance of Communications Flows", Public Opinion Quarterly, vol. 20 no. 1, pp. 143-160.

Every one of us can give apparent counter-examples from our own experience of rapid growth of international contacts, but ask yourself if they are not in innovative stages of a process.

There are, however, also other counter-examples: cases where foreign dependence acquires a self-perpetuating character. That tends to be the case in highly capitalized activities, not in the kind of intellectual activity that Deutsch discussed. If an oil field is developed in country A, its customers in other countries become significantly dependent on it. If superpower B sells jet fighters to a developing country, the latter becomes significantly dependent on B for training and parts. If a foreign investor opens an industrial plant in country C, there will be a continuing relationship over many years to follow.

In short, one must distinguish the developmental pattern that follows on different kinds of international relationships. Examples of quite different international patterns are offerred by agriculture, extractive investments, industry, and intellectual activities. Foreign investments in agriculture whether by settlers or by creation of a plantation system have profound social effects which usually conclude in more or less violent intergroup conflicts because so many thousands or millions of ordinary people are directly affected in their whole way of life. Investments in extractive industries are usually seen by the local people as particularly exploitive because few local facilities are

established, and so the end of the process is often expropriation or nationalization. Investment in heavy manufacturing has quite different effects. It is much more favorable to development, but also has the partially self- perpetuating character noted above. The intrusion of service and intellectual activities has a quite different effect because they are labor intensive and the initial practitioners have no way of keeping their monopoly.

The development of movies illustrates the point. Once upon a time in the 1920's and 1930's Hollywood had a franchise on the world cinema market. Hollywood pictures were made for the American audience, but they had a universal human appeal. As a result local entrepreneurs set up movie houses everywhere - luxurious palaces in some rich cities or benches in a shed in some developing villages. But the films were mostly made in Hollywood. That did not last long, however. In India, in Japan, in Turkey, in Mexico, local producers discovered that they could make movies too. The actors and technicians were not paid like the Hollywood stars or union cameramen. Production, being labor intensive, turned out to be cheap, if not slick. What is more, the local audience liked the local product; it was better attuned to their taste. So the original inflow of Hollywood films, by leading to the opening of movie houses, laid the foundations for a local industry. Far from Hollywood's activities being self-perpetuating, they turned out to be self-eroding. Today, most American movie makers find that they must go into co-production with foreign makers if they are to

succeed at all

To a large extent that is the pattern that one can expect from international computer communication. If technicians in a less developed country are trained to operate on a modern computer from a remote terminal, gradually, but fairly rapidly, programmers will be trained and analysts will learn to use the computer. Soon they will be doing their own input and developing their own data bases. In short, the main barrier to entering the game is trained humans and access to a machine. Remote access provides both at an early stage. Soon minis and then larger computers will follow, once the skilled personnel exists. Telecomputing accelerates, rather than inhibits, the development of computing in the LDC.

There is an element of the situation that is less flexible, less a function of personnel training and more a function of fixed capital investment. In the past the computer itself might have seemed like a massive capital item that LDCs could not easily support. In this day of powerful minis that is no longer a consideration. True, very large operations may be done by remote computing to take advantage of facilities the LDC does not have. But even that is a useful learning experience by which some computer technicians learn how to do thing that they will do on their next generation of maxi-minis soon after.

So it is not the need for capital investment in large computers that checks the spread of independent computer activities to the

LDCs. More important in that respect is likely to be data bases. Putting together a listing of all the physics articles published in the past decade is a massive job and when someone has done it once, it is not sensible to do it a second time. It is therefore partly true that those countries that get a jump on data base publishing are likely to keep it for some time. Nonetheless data base publishing is still in its infancy. There is still vast room for countries to get into it, and clearly many will. Also, some data bases are inherently regional or national in their content. Nonetheless, for this one kind of international computer communication (namely information retrieval from data bases) our general conclusion that a lead in international computer communication is not self-perpetuating, but rather self-eroding, should perhaps be slightly qualified.

In general, it seems clear that it is in the interest of the LDCs to give substantial priority to telecommunications development.

ADVANCED SYSTEMS FOR THE LDC'S

It is often assumed that if an LDC cannot make its ordinary telephone system work satisfactorily, then it certainly cannot use sophisticated new technology such as a packet switched computer communication network using satellite transmission. That is a fallacious conclusion One can imagine someone saying, just before the transistor radio revolution hit the LDCs that if those countries could not maintain a conventional press or wide

dissemination of ordinary tube radios, how could they handle the new advanced technology of the transistor. As that example makes clear, there are some advances in technology that make operation and maintenance easier. One has to examine the particularities of any advanced technology before one can assess its appropriateness to the LDCs. Advanced or Intermediate Technologies:

The satellites now available were optimized for the needs of the developed countries, not for the needs of the LDCs. We can explain this by comparing two sets of satellites which we shall call "conventional" and "high powered". The current commerical satellites such as Intelsat, Anik in Canada, Westar in this country, what Hughes is building for Indonesia, are all what we call conventional. They mostly use the 4-6 gigaherz (GHz) bands which are fairly crowded so the bird must radiate a rather weak signal (5 watts). Reception requires a large expensive dish. The standard Intelsat dish is 95 feet in diameter and so the ground station costs one to two million dollars. At considerable loss in efficiency, and thus cost, one can operate with smaller antennas. Some countries use 50 feet dishes that cost about $250,000. Antennas are now being built for off-shore oil rigs, that cost $140 to $150 thousand. For one two-way telephone channel one can use a 16 foot dish. To receive TV (one-way) one needs a 32 foot dish with such satellites. However, for the broad-band two-way and many voice channels required for a public communication system, conventional satellites require expensive ground stations and so

few of them will be built.

In a developed country the sparseness of ground stations does not matter, since the scattered ground stations feed into the terrestrial network that is already there. Intelsat messages are picked up on either the East or West Coast and from there go over the Bell system or Western Union lines.

For an underdeveloped country like Indonesia the need is for a quite different system that will have ground stations scattered on every island and district town, since the landlines are not there. To do that economically requires bringing down the cost of the many ground stations, even at the expense of using a somewhat more expensive satellite. That leads to the use of higher powered satellites on uncluttered parts of the spectrum such as the 12-14 GHz band. NASA's ATS-6 which was used in the Rocky Mountain and Applalchan experiments and is now being sent to India for village broadcasts is an example. However, that portion of the spectrum and that type of satellite are still experimental and only partly understood. Nonetheless given such a 20 watt satellite, Bruce Lusignan of Stanford estimates that one could send TV one way to $4000 ground stations and that for $20,000 to $40,000 one could provide a rural town with one-way video and some two-way voice channels with switching capability. In short, for a very small investment an isolated rural location could join the modern world, given a high powered satellite.

When such advanced satellite systems come into use, as they surely will, there will be thousands of ground stations for each satellite, so savings on the ground station will clearly dominate the cost equation. This then is an example of an advanced technology at the limit of the state of the art which is of particular interest to LDCs.

Another example of an advanced technology that should interest LDCs is packet switched data networks.

IS IT USEFUL?

Stages of Development:

If developing countries simply imitate the sequence of steps followed by those who came before them in adopting new technologies they miss the opportunity of rapidly closing the technological gap which separates them from the technologically advanced nations. In the history of technology, it is a common phenomenon that the later countries which adopt a technology, adopt it in its more advanced forms, skipping over the stages of development followed by the pioneers. For example, telephone initally spread more rapidly in the USA than in Europe. As a result the Bell System had a large investment in manual switchboards at the time when automatic dialing was coming in. By the 1930's, two-thirds of Western Europe's telephones had automatic switching but less than half of those in the US had this capability.

Developing countries benefit from many current examples of this ability to skip stages and close the gap.

Centralized Services:

Though developing countries can and should use some advanced technologies, they often can do so only in a few locations. The difference between an LDC and an advanced country may not be great in the kinds of things done in the top intellectual and organizational centers, but rather in the extent of diffusion of advanced methods. The econometric analysis or computer facilities in the top university or central planning office may not differ

much between a European country and an Asian one, but the back up, and numbers of such centers may differ greatly.

The implication of that fact is that many advanced activities must be centralized in the LDC's, and their benefits diffused by telecommunications. In an advanced country it is possible to have many good libraries, computer centers, medical centers, or teacher training institutes. A developing country may have only one of each, and therefore has much greater need for putting that one on line to the whole country. Training teachers by TV, advising medical technicians by telephone, backing up local administrators by on-line services may be even more important in a developing country than a developed one.

The international agricultural research centers with their outreach programs are examples of isolated centers of development whose influence on the rural world around them could be increased by better communication facilities.

IS IT USEFUL?

The Communications Needs of the IARC's

A SURVEY OF IARC COMMUNICATIONS

To ascertain the current communications practices and needs of the IARC's we conducted a survey, asking eight of them what they were doing now in international communication, and of what problems they were aware.

As a further test of the present communication situation of the Centers, we conducted the survey by telephone, completing all eight interviews after some 88 attempts. (1) In general, once the calls were completed, sometimes at 2:00 AM US time, the quality of transmission was usually quite adequate, at least at the US end; although not always at the IARC. The difficulty of getting through to those places which could not be dialed directly, made it clear to us why the IARCs use the phone as little as they do.

The main finding of the survey was that telecommunications are now used by the IARC's almost wholly for administrative traffic. Scientific communication is almost entirely by human travel or by the mails. Scientists would be happy to communicate with greater speed and reliability than the mails now provide, but present alternatives are so far out of reach that the researchers have not given much thought to the communication problem.

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(1) Another reason for the telephone interviews was economy. They cost no more than a quarter of what it would have cost to send an interviewer around.

THE INTERNATIONAL AGRICULTURAL RESEARCH CENTERS

Table 4.1 provides a list of the international agricultural research centers, including their location, budget, senior staff. Currently, there are seven international centers in operation, with an eighth about to being its program. A ninth center is still in the planning stage. Each of the centers specializes in research in selected areas of food production.

Co-ordinating their support is the Consultative Group on International Agricultural Research (CGIAR). This body, under the joint sponsorship of the World Bank, the Food and Agricultural Organization of the United Nationsl (FAO), and the UN Development Program (UNDP), consists of 33 governmental and non-governmental organizations which through this framework support the activities of the centers and of related programs devoted to improving the quality of food production in the Third World. Table 4.2 lists the various organizations supporting the CGIAR. It is the goal of the directors of CGIAR that each center recruit the most capable scientists, regardless of nationality and exchange information with each other as well as with other research institutions throughout the world which conduct research on matters which can affect food production in developing areas. Heavy emphasis is put on the diffusion of new farming methods to farmers, who can then apply the techniques to increasing food production in their countries; the centers are not, therefore, ivory tower institutions, concerned with acquiring knowledge for its own sake, but are heavily involved

in its practical application. As part of this function, each center maintains extensive outreach programs in which citizens of developing countries are trained at the institutes themselves, or in their own countries, perhaps even in their own fields. There is, therefore, close collaboration between the international centers and many national agricultural research centers.

As can be seen, from Table 4.1 the centers are of varying sizes, in part due to the fact that some have only recently begun operations. With many of the centers in the early stages of growth, budget figures include significant amounts of capital expenditures for construction of necessary facilities. Some of the centers are involved in similar research, although in different areas of the globe. Figure 2.3 in Chapter 2 above shows the locations of the centers relative to each other.

In addition to the international centers, CGIAR also supports some activities of the Asian Vegetable Research and Development Center in Taiwan, and the West African Rice Development Association. The International Board for Plant Genetic Research (IBPGR) is also funded by CGIAR. This organization seeks to facilitate the exchange of genetic reserach data among the centers and other important institutions.

Table 4.1 - The International Agricultural Research Centers

Center	Gross Financial Requirements* (1975) (millions $) core operating & capital budgets	Senior Staff(1975)* (Senior Scientists & Administration)	Area of Specialization
CIMMYT (Mexico)	7.9	55	Maize Wheat (sorghum & barley)
CIP (Peru) (1972)	2.7	19	Potato
IITA (Nigeria)	9.7	73	Root & Tuber crops; Grain legumes; Cereals; Farm Systems for humid tropics
IRRI (Philippines) (1960)	8.7	49	Rice
CIAT (Colombia)	7.0	46	Rice, Maize, Beef, swine, cassava, beans, farm systems for lowland tropics
ICRISAT (India) (1972)	9.1	46	Sorghum & Millet; Grain legumes Small-scale farming in dry regions
ILRAD (Kenya) (1975)	3.1	21	Control of animal diseases
ILCA (Ethiopia) (1975)	2.6	19	Animal husbandry
AVRDC (Taiwan) (affiliate)	(unavailable)	15	Vegetable Production in Asia

*Source "Integrative Report", CGIAR, July 11, 1975 (except for AVRDC)

Table 4.2

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

July 11, 1975

Consultative Group Members

A. Continuing Members

Countries

Australia	New Zealand
Belgium	Nigeria
Canada	Norway
Denmark	Saudi Arabia
France	Sweden
Germany	Switzerland
Japan	United Kingdom
Netherlands	United States

International Organizations

African Development Bank
Asian Development Bank
European Economic Community (FED)
Food and Agriculture Organization (FAO)
Inter-American Development Bank
International Bank for Reconstruction and Development
United Nations Development Programme (UNDP)
United Nations Environment Programme (UNEP)

Foundations

Ford Foundation
International Development Research Centre
Kellogg Foundation
Rockefeller Foundation

B. Fixed-Term Members Representing Developing Countries

Asia Region	Malaysia Thailand
African Region	Morocco
Latin American REgion	Argentina Brazil
Southern and Eastern European Region	Israel Roumania
Near Eastern and South Asia Region	Egypt Pakistan

Communications and the International Centers: The Problem

Importance of Effective Communications

Essential to the successful operation of the international research centers is the capability of each of the centers to communicate with the rest of the world. Good international communications is especially important to these centers, since they are usually located away from the major intellectual and cultural centers of the Western world. The implications of this for the operations of each center are numerous. Electronic communication is currently used by the IARC's mostly for administrative matters. Phone calls, telexes and telegrams mainly concern travel arrangements, employment, purchases, and funding. The directors we interviewed saw administrative efficiency as the main gain from better telecommunications. Only rarely do the scientists use anything but the mails to transmit technical information. But when it happens it can be important.

A scientist working on a project at one of the centers, for example, might require a reprint or other relevant information as part of his research. This information might not be available within the host country. Thus, a request would have to be made to a source in a foreign land. Poor communications can contribute to delays in the reception of the important information, thereby impeding the progress of the work being conducted. For the scientists to be informed on the latest developments within their fields requires considerable expensive travel by their researchers.

Each of the centers must make important purchases in the US or Europe. Poor communications can interfere with the ordering process. Furthermore, contact with CGIAR headquarters in Washington, D.C. should be efficient in order to facilitate financial reporting, explanation of budget requests or other administrative matters.

Efficient communications is necessary for the success of the various outreach and special programs conducted by each of the centers, as well as for maintaining contact with former students who have returned home and are seeking to implement the lessons they learned at the centers.

Since the centers are intended to serve as depositories of data for ongoing research, each of them should be readily accessible to inquiries by interested researchers from all points of the world.

Good communications are also necessary to relieve the feeling of isolation which might occur among some scientists from developed countries who have been relocated to the centers. The inability to communicate rapidly with one's friends and colleagues as well as receive the latest information on cultural and political events at home might discourage some very capable people from working at a center, thus depriving the institution of his expertise.

In short, communications impacts upon the research, administrative, and social aspects of the centers. Poor communications can have deleterious implications for the fulfillment of the missions of

each of the centers.

To gauge the extent to which the centers communicate, we examined certain activities of the centers which would serve as helpful indicators of this.

Information, Documentation, Library

Each of the centers is involved in some sort of information service in which it provides reports on its current research and activities to interested people and organizations. In addition, each has its own library and documentation system in which reports and data relevant to ongoing research are collected and kept for use at the center. All of the centers have created genetic resource collections which are made available to interested parties.

Information services include such activities as general newsletters of current research, annual reports, and technical publications dealing with the results of recent work. Table 4.3 summarizes expenditures in each of these areas for each of the centers. (1)

Table 4.3 - Summary of Information, Documentation, and Library Budgets ($1,000:1975)

CENTER	INFO.	DOC.	& LIBRARY	Total
CIMMYT	$430	X	$10	$440
CIP	2	41	9	52
IITA	169	188	X	357
IRRI	231	106[1]	106[1]	337
CIAT	X	X	X	434
ICRISAT	136	75	X	211
ILRAD	8	4	15	27

1. Combined library and documentation expenditures
X Information unavailable

(1) ILCA was not studied because it has only very recently begun operations.

The scope of these activities depends upon the extent of the center's operations and the research and documentation role it is supposed to play in respect to the other centers and to the developing world, in general. Comparisons of figures may also be misleading because similar activities may be organized by different centers in different ways; in addition, some centers have not yet reached anticipated levels of operation. Thus, for example, CIAT's expenditures in 1975 for information, library, and documentation was reported in excess of $500,000, while that of ILRAD was reported as only $27,000. (That is due to a large extent, to the fact that ILRAD is a recently established center.) IRRI, which plays a major role in global rice production, also has relatively high expenditures in this area.

In general, combined expenditures in 1975 for all of the international research centers for library and documentation was $1.5 million, or 5% of all core operating expenditures.

In the area of library and documentation, holdings of the centers vary. ICRISAT, for example, had less than one thousand books and bound volumes of periodicals as of March, 1974, when it was still in the early stage of its development. IITA, on the other hand, had over 7500 books, 12,000 periodical volumes, and over 2,000 pamphlets and reprints as of December, 1974. While it is difficult to draw implications from mere numbers of volumes in a library, it can be inferred that the relatively small number of volumes on hand in the specialized IARC libraries suggests a need for information

from outside sources in order for research to be successful.

Each of the centers is creating collections of information on genetic data. The purpose of this is to establish specialized information centers which can readily provide genetic information to those organizations and people in the agricultural development community who require it. These data bases are being organized into a structured network by the IBPGR in the Communications, Information, and Documentation System (CIDS) project. For this network to be effective, however, each center requires communications facilities through which it can rapidly access data stored in foreign locations and be easily accessed in turn. The centers currently lack this capability.

Outreach and Special Programs

The outreach and special programs of the international centers constitute a very important part of their activities. These programs involve the stationing of personnel of each center at other locations. This might involve the sending of staff to work with other national research institutions or with other international centers. Such programs imply a need for communications between the off-site personnel and their home centers on various research, administrative, and personal matters. Let us summarize some of these activities.

The largest expenditure for outreach programs was made by IRRI. That center spent over $2.8 million last year and placed staff in such places as Sri Lanka, India, Indonesia, the Philiipines, Bangladesh, Pakistan, Egypt, and Thailand.

IS IT USEFUL?

IITA spent over $1.6 million in 1975 for off-site programs. These programs were conducted in Liberia, Tanzania, Nigeria, Sierra Leone, and Zaire.

CIMMYT budgeted $1.3 million in 1974 for off-site outreach programs in such locations as Ecuador, Kenya, Central America, Algeria, Tunisia, Turkey, Pakistan, Nepal, Zaire, Tanzania, and Bangladesh and at the CIAT and ICRISAT headquarters.

ICRISAT spent $804,000 last year for programs in West Africa (Nigeria, Senegal, Upper Volta, and Niger).

CIP conducted programs in Latin America, Africa, the Near East, West Asia, and Southeast Asia, at a total cost in 1975 of $430,000.

ILCA sent personnel to Mali, Kenya, and Nigeria at a total cost of $330,000 in 1975.

AVRDC has an outreach program at IRRI and a sub-center in South Korea.

In general, combined expenditures in 1975 by all of the centers for outreach was $10.4 million. For IRRI and CIP, expenditures for these activities were about one-third of their total budgets for last year.

The degree of communications stemming from these activities depends upon the extent of the programs. Thus, CIMMYT and IITA, both of which have extensive activities throughout the world, may have a relatively high need for communicating with these other locations. As the outreach programs of the centers increase, so will the need for greater communications capabilities.

Each of the centers trains people from various developing countries. Once they leave the centers, it is very likely that the trainee would wish to communicate with the center for various reasons. From the standpoint of the centers, such communications

would contribute to reinforcing the training which they provided. Consequently, effective communications is important for this area of activities. Research Related Communication

Scientists involved in research sometimes require information which is locally unavailable. This information may involve such things as reprints, results of an outreach programs or experiments, or consultation with a colleague in a distant land.

Most requests for reprints are usually made to the US Library of Congress, the USDA Library in Maryland, or the British Library in England. Universities and research institutions in both the US and UK are often the object of information requests. One center expressed a desire to access the extensive computerized literature search systems available in the US but which, it is presently unable to do.

Some of the centers have a need to communicate with other centers which do similar work. For example, CIAT, IITA, and IRRI extensively exchange information in the area of genetic data resources and library materials.

Some centers belong to research networks devoted to specific crops. For example, IRRI serves as the hub of the international rice research network while CIAT and IITA serve as relay centers in Latin America and Africa, respectively. Institutions in the US and numerous other developing countries also belong to this network. ICRISAT and CIMMYT are "hubs" of other research networks. The

"hubs" are supposed to provide leadership, systematic information exchange and coordination and advisory services for the other members of the networks. A major goal is for the creation of collaborative and joint projects among the participating institutions of each network. Effective coordination of the work of the member institutions of these networks requires effective communications.

In conclusion, each center must have access to facilities which enable it to communicate with other institutions, and, in turn, be accessible for information requests from locations throughout the world.

Several efforts are being made to facilitate the exchange of information relevant to current research among the international, as well as other national agricultural research centers. One of these is AGRIS, the International Information System for the Agricultural Sciences and Technology. The goal of this system is to systematically collect, organize, and make available abstracts of recent articles in the fields relating to agriculture. The need for such a system is indicated by the fact that over 200,000 new titles in agricultural biology have been published annually in recent years

AGRIS is organized on two levels. The first level consists of a comprehensive and rapid documentation service which will provide an index of current information in all fields of FAO responsibility.

The second level contains specialized services, including the dissemination of abstracts and deep indices. On this level, information centers and data banks would be utilized.

Numerous national research centers are contributing to this network. The processing and merging of input from various sources will be accomplished at a central point, which will be an FAO center.

Present plans for level C- 1 call for the publication of a monthly index, AGRINDEX, containing approximately 6500 citations.

Level II will involve the creation of specialized information centers, data banks and data analysis centers responsible for the selection of indexed articles in specific fields. Articles will be organized in three fields: veterinary medicine, forestry, and tropical agriculture. The main activity of this level will be the preparation and dissemination of abstracts through bibliographic and abstracting services.

AGRIS is under the general direction of the FAO which will coordinate the interaction of the subject-related centers.

A complement to AGRIS is CARIS, the Current Agricultural Research Information System. In the process of being established, it is currently being funded by CGIAR but will become the responsibility of FAO in 1977. The purpose of CARIS is the establishment of an international information system which will collect, process and

disseminate basic data on research institutions, workers, programs and operations in, or on behalf of, developing countries. Its goal is the improving of communication between research institutions and researchers and to help in evaluating the existing research effort by identifying current research being done, by whom, in what location and noting any major gaps and weaknesses in the total agricultural research effort.

The CARIS project involves the creation of liaison offices in all participating countries and the establishment of CARIS centers throughout the developing world. The local centers will be responsible for the collection, indexing and processing of data which will be sent to a coordinating center that will serve as a world clearinghouse for information and which will establish a data base for the preparation of directories and data base tapes.

The creation of data collections as part of AGRIS and CARIS at various locations throughout the world will require efficient communications systems for the international agricultural centers to have easy access to them and therefore be able to effectively utilize the services.

The Agricultural Libraries Information Network (AGLINET) has been created within the framework of the International Association of Agricultural Librarians and Documentalists to organize, at regional and international levels, cooperation among agricultural libraries. Hopefully this network, in conjunction with improved communications

facilities, will improve the process of information exchange among the international centers and between them and the major agricultural libraries in the world by locating relevant citations. AGLINET is designed to complement AGRIS.

Earlier, we briefly referred to the Communications, Information and Documentation System (CIDS) of the IBPGR. The major goal of this network, whose headquarters are in Boulder, Colorado, is to assemble a list of available genetic resources, the locations where they are maintained, and any other information regarding their sources of origin and agronomic characteristics. CIDS will involve the exploration, collection, conservation, improvement, and breeding of genetic resources. It will provide documentation data and experiment results. CIDS will involve the creation of individual centers whose function is the collection of data on specific subjects, which, when coordinated, will form a functional network. (It is the hope of many in the agricultural development community that participating nations will establish the CIDS, CARIS and AGRIS liasion offices and centers at the same locations, in order to facilitate the exchange of information.)

Data will be published in catalogues as well as put onto an anticipated computerized storage and retrieval system. CIDS already has an on-line system. In order for the voluminous data in genetic resources to be efficiently stored and retrieved, efficient communication links are required among the participating centers.

Communications Facilities of the IARCs

The communications facilities of the centers vary considerably in sophistication, reliability and speed. The major media through which the centers communicate are the mails, telephone, telex, and cable. Transportation is also a form of communications. However, since we are concerned with communications which lend themselves to transmission through postal and telecommunications media, and since the extent to which transportation substitutes for this among the centers cannot be determined from available information, we will disregard this activity except for noting its potential effect.

Table 4.4 summarizes the communications expenditures of each of the centers. Communications is not a large budget item for the Centers. It is small compared to travel, for example. That is one reason why there has not been much pressure to rationalize communications practices - to use telex rather than cables, for example. Cost is seldom an inhibition to a phone call or cable because the few dollars it costs are minor compared to the hundreds or thousands of dollars of travel costs, or purchase orders, or budget revisions with which the communication typically deals. However, a sharp fall in communication costs could change that picture drastically. At several dollars a call or message, scientists do not make much use of telecommunications. At costs lower by an order of magnitude a whole new class of users would enter the system for research rather than administrative communications.

Table 4.4 - Communications Facilities and Expenses

Center x	# External Phone Lines	Internal Extensions	Telex?	International Expenses (monthly - 1975) Mail	Phone	Telex	Cable
CIMMYT[1]	10 + 4	142 + 4	No	(2 mo.) 4250	3800[2]	---	1830
CIP	7(4 + 3)	40 on 4 +3	No	500	333	---	500
IITA	10	300	No	30,000[3]	9000[4]	---	30,000[3]
IRRI	Private (microwave to Manila)	X	Yes (in Manila Office)	2180	1925	122	1000
CIAT	20	180	Yes	X	4500[2]	700[2]	2000[2]
ICRISAT	58 (32 in residences)	69	Yes	2000[2]	2600[2]	600[2]	750[2]
ILRAD	3	30	No	500	2800[5]	---	2800[5]
AVRDC	5	X	No	280	106	---	387

1. Includes 10 lines & 142 extensions at El Batan; 4 lines in Mexico City office.
2. Includes local and international
3. Total - Post & cable, 1975 budget estimate
4. Total - 1975 budget estimate
5. Telephone, telegrams and postage for 1974

X = information unavailable

When comparing expenditures of the various centers several caveats should be kept in mind. 1 - Lack of reliable service by one medium might necessitate the use of another medium which might be more expensive. 2 - Expenditures are a function of postal and telecommunications rates, which vary from country to country. 3 - The mails are extensively used for transportation of seed and are not therefore solely a medium of communications. 4 - Accounting methods vary in how particular services are recorded. 5 - The figures might not reflect added costs resulting from poor communications facilities; for example, travel to an earth station to place an urgent call which cannot be made from an agricultural center because of inadequate phone service there.

On the basis of telephone interviews and correspondence with relevant personnel in each of the centers, it is evident that communications problems result from a variety of factors, the major ones being, to varying degrees in each center, lack of adequate communications facilities at the centers, inefficient use of existing communications facilities, and poor national systems of communications in the countries in which some of the centers are located.

IITA, for example, in Ibadan, Nigeria, very rarely attempts to place international telephone calls because of the long delays involved in getting through if one gets through at all. Telephone communications to other points within Nigeria, even to nearby Lagos, are also poor. (Substantial optimism was expressed,

however, about likely future improvement in Nigerian communication.) Problems plague ICRISAT, which is located in India, and CIAT, in Colombia.

Our own experience in attempting to place calls to the centers illustrates the problem of telephonic communications with the centers. In order to successfully place reach eight centers we made 88 attempts. The most frequent reason for failure to obtain a connection was busy circuits either at the international or national level, the latter involving the connection between the gateway in the developing country and the center. Table 4.5 summarizes our attempts to telephone the centers. A further complication which we encountered was that in some instances, although we had gotten through, the connection was so poor that we had to hang up and place another call.

In the course of our research, we placed calls to each of the agricultural research centers under study. In making these calls, we had a dual purpose in mind: one, to collect information relevant to our study from each center, and two, to measure the efficiency and reliability of international telephone service to each of the centers.

Our experience in attempting to make connections with each center is summarized in Table 4.5.

Circuits Busy	Dial: no Result	Dial: no Answer	Wrong Number	Person not there	Success
31	36	2	4	5	10

Table 4.5 Summary of Attempted Calls to Centers

In all, we placed 88 calls and made 19 completions. However, in only 10 instances did we reach the person with whom we wanted to speak. In four instances we learned that we were dialing an incorrect number which had been given to us and in five other instances we got through to the center but the person with whom we wanted to speak was unavailable. Thus, in general we had a

successful circuit completion: total attempt ratio of about 1:3.5 (19:69), which reduced to about 1:8 (10:78) for total successful completions to total of calls placed.

In terms of our table headings, "circuits busy" refers to either the international or national link; "dial: no result", to any other reason why we did not make a connection including such things as failure of the overseas operator to answer, failure of the operator to call back within a significant amount of time, and/or a circuit disconnection; "dial, no answer" signifies that a phone was ringing but was unanswered; "person not there" refers to the unavailability of our intended source; and "wrong number" and "success" are self-explanatory.

By far, the most rapid connections were made with those centers whom we were able to dial directly. In those cases, we did not have to bother with an overseas operator and cirults were usually available. Even when they were not, we were able to discover this quickly. By far, the most rapid connections were made with centers which could be directly dialed fom the US. Those were CIMMYT and AVRDC.

Telephone service, however, was not the only target of dissatisfaction. Complaints by center personnel were often made about the postal systems of their host countries. Several centers mentioned that it normally took two weeks for a letter to reach its destination in a foreign country. If a response was required, this meant at least another two weeks for the return, assuming no administrative work at the other end. The complete two-way communication, therefore, would take at least a month! Such slow communications can have a very negative affect on the progress of research.

In addition to delays, some centers reported the frequent loss of mail by the postal authorities.

IITA has opted to send certain important materials by air pouch in order to avoid the delays inherent in the public postal system.

Cables are a widely used medium of communication by the centers, although CIAT, CIP, and ILRA reports delays in cable delivery to certain destinations.

Four centers possess or are about to possess telex. IRRI possesses a telex, but it is not located on site at Los Banos, but in the center's Manila offices. The public network's facilities linking Los Banos and Manila were inadequate to meet the requirements of a telex in Los Banos. IRRI is constructing its own microwave link between Los Banos and its Manila office, which will make possible direct international electronic linkage with Los Banos, if desired.

As a result of delays in mail sent by one of the Latin American centers, that center undertook a survey to determine the reliability of the posts for correspondence to different sections of the world. The results indicated that all postal communications addressed to Algeria, Egypt, Lebanon, Nepal, Pakistan, Thailand, Tunisia, and Zaire be enclosed in another envelope and sent to a major philanthropic foundation in New York with a request to forward the mail. The experiment also indicated that for mail to India, Nigeria, the Philippines, and Turkey, use of the forwarding facilities of the foundation would not improve the time for

delivery of mail.

One center reported that while it possessed a telex for several years, it did not avail itself of this service as much as it would have because it did not have an international telex directory, which it had ordered several times, but did not arrive for three years.

In general, for all media, better reliability and less delays are found for communications with developed countries, particularly the United States, than with LDCs. Many respondents reported better international service than they got within the country. The poorest quality of communication links occurs when two less developed countries are attempting to communicate. In some cases it is extremely difficult for a center to communicate with its outreach staff located in a remote area and with other international centers. Such poor links impede the development of an integrated network of international research centers which would coordinate their activities and disseminate agricultural expertise to less developed countries.

Following is a summary of the communications behavior of each of the centers:

IITA reported that it very rarely attempted to place international telephone calls due to the poor reliability and delays arising in the local telecommunications system. It does not possess a telex and does not plan to obtain one because it claims that most of its "customers" with whom it communicates lack telex facilities.

The regular mails have been found to be inadequate. Consequently, for important administrative and fiscal matters, for the exchange of scientific materials, personal correspondence with the US, and

for communications with the outreach program in Zaire, air pouch is used. Scientific and personal correspondence with non-US locations is usually through the regular postal system.

The most frequent source and destination of communications is the US, which accounts for about 50%. This is followed by the UK and Western Europe, Canada, Mexico, and West Africa. Hence, the bulk of communications is with three main areas: North America, Western Europe, and West Africa. Of the scientific traffic, 45% is with the UK and Western Europe, while 35% is with the US.

Due to problems with the telecommunications and postal networks of Nigeria, and the mail system, the options available to IITA are limited. For very urgent communications, the center is forced sometimes, to send somebody a distance of 75 km to the Lanlate satellite earth station, from where an international telephone call may be easily placed. Telephone calls from the US to Nigeria are normally booked by the overseas operator who maintains a que and calls back in one or two hours. The bottleneck is encountered in trunk lines in Nigeria.

AVRDC in Taiwan rarely uses the telephone for internnational communcations. When it does, it does so for administrative and important scientific matters. The mails are used for distribution of annual reports, information documents, and normal correspondence regarding scientific and administrative matters. Both the telephone and postal systems are reported to be of good quality. Indeed postal service within Taiwan is asserted to be better than in the USA. A censorship problem exists, however when journals contain any reference to the People's Republic of China. Taiwan can be directly dialed from the US.

This center does not possess a telex facility. It transmits a fairly large volume of cables

Most communications are with the US. Over 40% of postal expenditures are for US destinations. Other frequent locations are Asian countries such as the Philiipines, Korea, Japan, and Thailand, particularly to outreach personnel.

It would appear then, that the superior communications capabilities available to this center enable it to choose media based on cost, convenience, and urgency. Perhaps an explanation for the small use of international telephone is the major time difference between Taiwan and the US, the country with which AVRDC communicates most frequently. There is a 13 hour difference between Taiwan and the East Coast of the US.

CIMMYT in Mexico has good telecommunications capabilities. Like AVRDC, it can be directly dialed from the US. Most of its telephone communication is with the US, UK, and Latin America. Cables are also extensively sent, usually to the US, Canada, Latin America,

and the Middle East. Mexican regulations forbid data transmission over the phone lines. This center will shortly acquire a telex machine.

CIMMYT uses the mails for distribution of its scientific and information publications. Speed of delivery depends upon whether air or surface mail is used. The most frequent mail destinations are the US, Latin America, the Middle East, and Africa. Due to the poor postal systems of some developing countries, CIMMYT sends some mail to them through the offices of a sponsoring Foundation in New York City.

CIAT in Columbia, has complaints about communications facilities. Its telephone connection to Cali, the nearest major city, is poor; consequently, it is contemplating the construction of its own microwave link for this 15 mile route. Currently, it communicates with Cali, some of its field sites and the National Agricultural Research Institution through the National Radio Telephone Network. Delays in the mails are frequently encountered. It possesses a telex with which it extensively communiates with its purchasing agent in Miami, Florida. It also uses telex for domestic communications due to the poor telephone network.

Due to delays in the regular mails, it takes a long time for CIAT to receive scientific publications. Some journals take three and one-half months to arrive. In an attempt to improve this situation, the center will shortly innovate a system whereby journals are mailed to its agent in Miami, who will then send them by air cargo to Colombia. CIAT believes that this will reduce the time of delivery to one month.

The locations with which CIAT communicates most frequently are in the US and Latin America.

ILRAD in Kenya relies on air mail for scientific communication. It reported difficulties in cable delivery between it and West African locations. In one instance two of three cables sent to the Sahel were lost, while the third was only delivered after ten days. ILRAD also reported much difficulty in obtaining a second leased circuit and a post office box. It uses the box of the Rockefeller Foundation.

Most communications are with the US, Canada, UK, Western Europe, and West Africa, essentially three main geographical areas. It relies heavily on literature search services provided by the USDA.

ICRISAT, in India, experiences difficulties with the Indian telephone system. Most communications are sent by mail although urgent search requests are transmitted by telex. Telephone service between the US and the Bombay operator is relatively good, but it can take many hours to get a trunk line from there to Hyderabad. Communication with Delhi is also difficult. Private lines in India

are quite cheap if they can be obtained, but regulations on the uses of the communication system are very restrictive.

IRRI, in the Philippines, suffers from poor telephone service from Manila to its site in Los Banos, 40 miles away. It is establishing its own microwave link to Manila. At present it rarely uses the telephone for international communications. When a message is urgent, it is usually sent by telex or cable. IIRI has three telexes in Manila. The typist there may get the text from Los Banos by HF radio.

The center communicates mainly with the US and with its outreach staff on location in various countries. There is direct dialling from the US to Manila, so when the microwave link is completed there can be direct dialing to IIRI.

CIP in Peru reports that its telecommunications with the US are excellent. To varying degress, problems exist in communicating with other regions, particularly those in less developed areas. For example, cables are not a reliable means of communicating with India. Occasionally, cables do not reach a European destination.

While it takes 1 1/2-2 months for journals to arrive at CIP from the US and Europe, this is not seen as a problem since most potato-related literature is published in two journals and CIP usually receives relevant information published in these journals long before they are published.

CIP communicates most with the US, in particular, to three areas: Washington, D.C. for AID and CGIAR, New York City for IIE and Raleigh, N.C. It also has significant communications with the other international research centers.

Some Conclusions

To a large extent, the communications capabilities of many of the centers are limited by the underdeveloped communication systems of their host countries. Similarly, if the connections between its rural location and the capital and/or the satellite earth station are poor, a center will not be able to transmit data to a computer nor will it be able easily to avail itself of the international telephone network.

Several centers have attempted to deal with the problem of poor telecommunications to their rural sites by establishing alternate means of telecommunications. IRRI, for example, is constructing a microwave link between Los Banos and Manila; CIAT and ICRISAT are contemplating similar links between their centers and a major city in their respective countries. Apparently, then, a partial solution to the problem of poor public telecommunications to the rurally located centers is the creation of private lines for the outermost link of the communication net.

Offices in major cities are better able to access the international facilities, Thus, an international telex message sent by someone in a center would first be sent over the private circuits to an office in the major city, automatically switched and then sent by the telex located there, to the foreign destination. For incoming messages, the process would be reversed.

The country with which all of the centers communicate to the greatest extent is the United States. Communications relate primarily to administrative matter, because CGIAR headquarters is locate here, as well as purchasing agents such as IIE and important philanthropic foundations, particularly Ford and Rockefeller. Furthermore, major intellectual resources, such as the various retrieval services, libraries, and research institutions are found in this country. Most of the communications of all kinds are probably to the Washington, D.C. area since CGIAR and AID are located there, and such libraries as NLM, NAL, and LOC, are in the

area.

To a much lesser extent, most of the centers communicate with the UK and Western Europe.

Other frequent communication are regional. CIMMYT has an important amount of communications with Latin America, while AVRDC communicates extensively with Asian locations. Other centers also have important communications with other regions where their crop is grown and where outreach or experimental programs are located.

The choice of medium of communication depends upon a variety of factors, including speed and reliability of service, the urgency of the communication, its cost, the availability of the service, and the time difference between the center and the point which it wants to contact.

It would appear, then, that the large volume of communications between each center and the US and the urgency attached to them (since they relate to current administrative, travel and purchase matters) imply a need for more formal communication links between the centers and the US. Such a system should save money over existing methods of communication and be more efficient. Given the existing telecommunications facilities in the countries in which the centers are located, a polling system between a communications center in the US, probably in the Washington, D.C. area and each of the centers would serve to provide a relatively cheap and efficient means of communication. Such a polling network would also be a

star network for communications among the centers, whereby a message from one center to another could be routed through the US polling center. This would substitute one LDC-LDC telecommunications link which is usually technically inferior, for two US-LDC links which are technically superior, and probably provide more rapid delivery of the message. Such a network would be efficient for the transmission of short messages, particularly those related to administrative matters and literature search requests.

One alternative that would be physically easy, but is politically unsatisfactory would be to take advantage of the US governments international communication facilities. AID posts in each LDC have access to good communication facilities to Washington. However, it may not be appropriate for the US government to get into the situation of a common carrier even for institutions which it is helping to fund.

In closing, improvement in the present telecommunications capabilities of the international agricultural research centers is necessary. The present felt need is for better administrative communication between the centers and their agents and sponsors. Looking from the outside, however, it seems to us that equally important is the need of the scientists for better ways of obtaining technical information. Scientists should not have to wait weeks for the results of experiments or for searches to be requested, made and reported to them. On line communication

systems are not now a perceived need of the scientists at the Centers for that seems to them beyond any realistic hope. There is every reason to believe, however, that if such a facility becomes feasible and cheap the scientists would use it extensively.

A PROPOSED EXPERIMENT

The present study points to telephone polling as the most economical and flexible approach to improving the communications of the IARC's. The next step in establishing such a system would be to commission a detailed engineering study, requiring field examination of each location. The present study was not intended to be that, nor to go beyond identification of an approach. Our general recommendation may perhaps best be presented in the form of a preliminary plan, based on, but departing from the initial one by Colin Warren that was described and costed out in Chapter 2. The plan presented below reflects that analysis and also the statements of needs that emerged from the interviews.

At a number of locations, specifically where direct dialing does not yet exist, there are unsolved problems to the plan; there are, however, several alternative lines to their solution. Where international direct distance dialing from the US is not yet implimented, the alternatives are a private line, or human intervention to make the phone connection, or a specially implimented direct switch at the ground station, or a tape recorder camp-on device to ask the operator for the connection.

If private leased lines are installed to the direct dial network, these would be chosen to link countries to the automatic system with the shortest leased lines. Rate policies of different countries, however, may make longer routes cheaper than shorter ones. Current leased line rates have not been explored by us.

If Europeans create direct dialing links to some points before ATT, then routes could go via a European node. That may quite likely happen.

Whereaver direct dialing exists it is easy to add (or substract) new nodes to the system. We have, therefore, listed possible nodes in the USA, Japan, and Europe rather generously in our system design. The only hardware required for a node is the $200-a-month terminal. There is no necessity to poll all nodes with equal frequency. Some nodes could be polled only every other day, others more than once a day. We expect once a day would be normal; experience can be the guide.

Since the busiest nodes will be CGIAR, IIE, and AID, the main switching computer should be in the Washington or perhaps New York area to transform some toll charges into local calls. (1)

We have not attempted to enumerate the US universities or European centers that should be linked. Boulder, because of the genetic

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(1) Alternatively, if the system buys time on a commercial polling computer it would use that company's WATS lines, or for AID, Autovon.

information retrieval system and the British Library are obvious examples. Others can be added as experience dictates.

Perhaps we can best explain the alernative solutions to problems by running through some of the problem situations at various centers.

ILRAD is on the Nairobi telephone exchange. Its local service is reasonably good and the satellite ground station is only 5 miles away. Two obvious options are 1) to obtain permission for a direct dial connection at the ground station or else 2) to have a daily call placed by a person through an operator; as soon as the connection is successfully made, the stored messages would be transmitted. The latter arrangement would require a buffer at the central switch where messages would sit between the completion of the connection and the time of a poll (or vice versa).

IITA has a somewhtat different problem. The Nigerian system cannot handle the traffic that is waiting to be served. That is the bottleneck to more circuits from abroad.

IITA is outside of Ibadan, 45 miles from the satellite ground station and 110 miles from Lagos. Direct dialing is possible from IITA to Lagos, but international calls require an operator and typically are delayed by an hour or two.

This suggests that for IITA a direct leased line to the ground station would be most desirable. If it is not possible to get permission for a direct dial connection switch to the international circuits, at least the problems of the local phone system would be bypassed. By scheduling the call for the daily nadir of business it should be possible to get through.

IIRI's main problem is the Los Banos-Manila link. Manila can be dialed directly from the USA. From there to Los Banos service is so inadequate that IIRI is installing its own microwave line. When that is installed, IIRI should be able to function on a world polling system.

ICRISAT's problems of communication are probably the hardest of any. An international call to Bombay, or to the ground station 150 miles South of Bombay is relatively easy to place, but must be done through an operator. The scarcity of lines is from Bombay to Hyderabad. If a small switching computer with memory were located in Bombay or near the ground station, it could feed and be fed by the terminal in Hyderabad at non-peak times during the day at any data rate that worked, even down to teletype speed. The international poll would then only need to reach that relatively accessible point in India.

In Latin America there is direct dialing from the USA to Mexico, Costa Rica and Venezuela but not to Columbia and Peru. One alternative would be to lease private lines from a subordinate

switching center in Costa Rica or Venezuela to one in Bogota, and on to Lima. (1) Another alternative is to serve Cali and Lima out of Washington in the same way as described for ILRAD in Nairobi.

CIAT, however, is not in the capital, Bogota; it is in Palmira 15 miles out of Cali. CIAT's main communication problem is the rural service from Palmira to Cali. CIAT is planning to install a microwave link to Cali, after which that problem should be solved.

The system we have just described, polled daily, would put administrative mail on the desk of every node within one day after the message was typed. It could be used for relatively short messages of scientific information which could be conveniently typed in, e.g. bibliographic references or genetic strain listings. It could also be used for longer scientific information that was already in computer readable form such as batched computer data or retrievals. As usage grew, the main adjustment that would have to be made would be adding to the memory that is located at the central switch so as to handle the added volume of material that is stored pending delivery. The communications costs would only rise in relation to the volume of traffic. The system should, therefore, grow gracefully.

As direct dial facilities became universal, fascimile might begin

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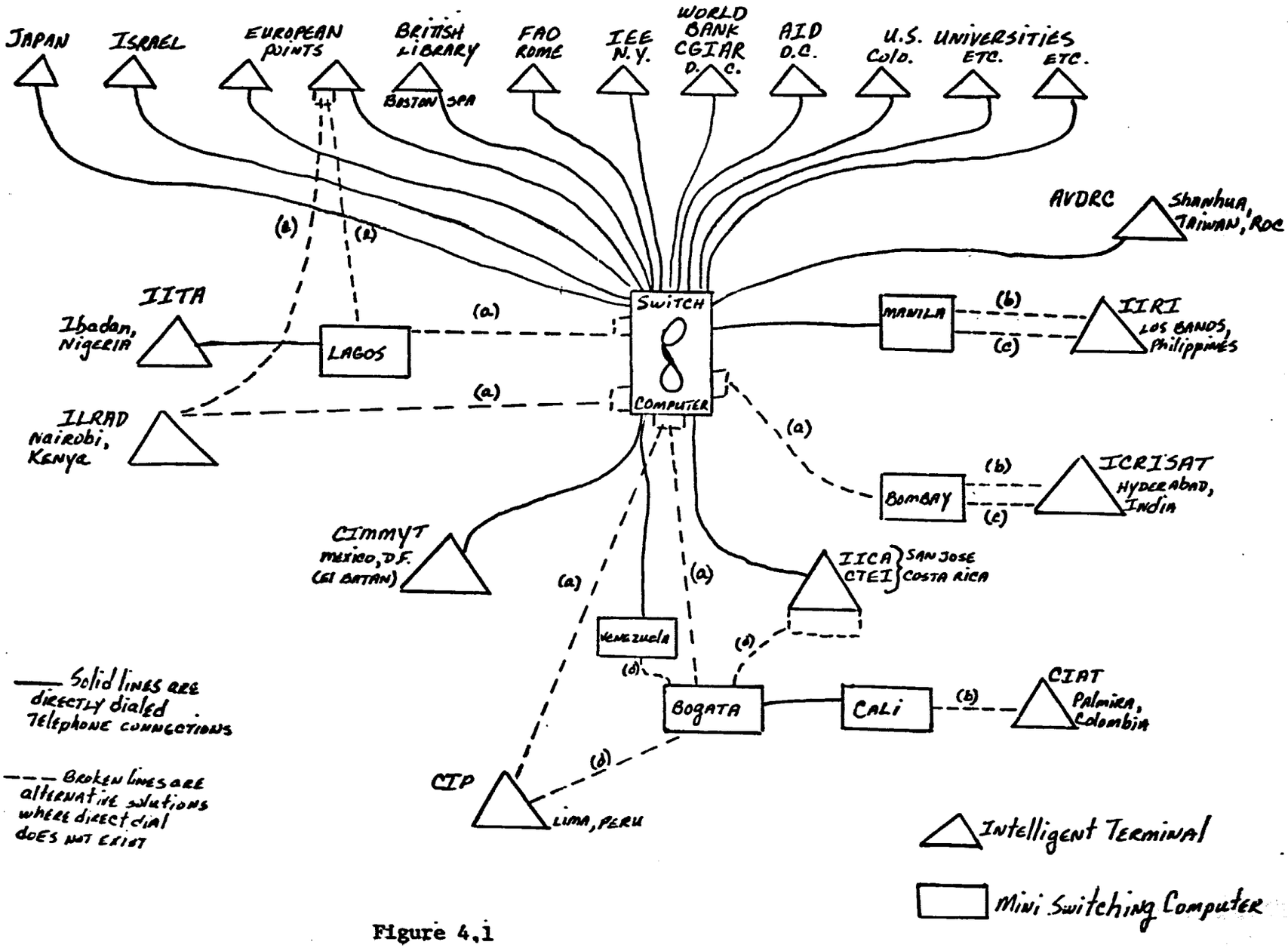
(1) Caracas to Bogota is about 700 miles. San Jose to Bogota is about 1200 miles. From Bogota to Cali is about 200 miles and Bogota to Lima about 1200. Thus it would take about 2000 miles of private line to complete the linkage of the listed centers.

also to be used on phone lines (not by way of the polling facility) in order to transmit text that was not in computer readable form.

All these developments, have become possible now that the FCC has clarified the right of US telephone subscribers to use their phones in that way.

Pending the development of a polling system, our only immediate advice to the IARCs concerns two administrave measures that can cut costs for some centers. Some centers use telex well, but a number of centers are spending more than they need to on cables rather than using the substantially cheaper telex. Secondly, some centers are saving on journals by subscribing at their US offices and having their purchasing agent send the journals in batched air shipments. Other Centers tend to pay the higher international subscriptions, and individual unit mail rates. They also lose time that way.

Looking forward into the longer run future, perhaps a decade from now, perhaps fifteen years, the Centers can look forward to doing much of their research in a co-operative mode via an international computer network with fellow scientists all over the world. The outreach program may become largely a teleconferencing program. The costs of real-time text and data linkage may turn out to be lower than are letters today. The telecommunications link will be not just an administrators tool, but an essential tool for the scientists too.


JAPAN
ISRAEL
EUROPEAN POINTS
BRITISH LIBRARY
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FAO ROME
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Shanhua, TAIWAN, ROC
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COMPUTER
MANILA
IIRI
LOS BANOS, Philippines
ILRAD
Nairobi, Kenya
BOMBAY
ICRISAT
HYDERABAD, INDIA
CIMMYT
MEXICO, D.F.
(EL BATAN)
IICA
CTEI
SAN JOSE
COSTA RICA
VENEZUELA
BOGATA
CALI
CIAT
Palmira, Colombia
CIP
LIMA, PERU
(a)
(b)
(c)
(d)
Solid lines are directly dialed telephone connections
Broken lines are alternative solutions where direct dial does not exist
Intelligent Terminal
Mini Switching Computer

Figure 4.1