Department of Applied Analysis
and Computer Science
Research Report CSRR 2040

April, 1971

THE INTERDEPENDENCE OF COMMUNICATIONS AND DATA PROCESSING: ISSUES IN ECONOMIES OF INTEGRATION AND PUBLIC POLICY

D.D. Cowan
L. Waverman *

Faculty of Mathematics

University of Waterloo
Waterloo, Ontario
Canada

Department of Applied Analysis
&
Computer Science

Department of Applied Analysis
and Computer Science

Research Report CSRR 2040

April, 1971

THE INTERDEPENDENCE OF COMMUNICATIONS AND DATA PROCESSING: ISSUES IN ECONOMIES OF INTEGRATION AND PUBLIC POLICY

D.D. Cowan

L. Waverman *

* Assistant Professor - University of Toronto,
Department of Political Economy.

The basis of this report was a study undertaken for the Department of Communications - Ottawa. This report does not necessarily represent the views of that Department or the Canadian Government.

TABLE OF CONTENTS

Introduction

The interdependence of communications and data processing has been a subject of much controversy in recent years. Communications networks are beginning to use computers to switch messages, while a time-sharing data processing system may perform such traditional communication functions as polling and switching.

A communications network is part of a computer utility in that the network connects users both to the computer and to mass storage and also connects computers to each other. A computer utility, although primarily used for data processing and data bank functions, can also be considered as a communications system in that it allows various users to communicate with each other and with the services supplied by the system.

Since the communications companies employ computers for communication tasks and since computer utilities and communications networks bear a strong resemblance to each other, it has been suggested that economies might result if the communication companies were allowed to do both data processing and communication functions.[1/] However, since data processing appears to be a competitive industry,[2/] while communications is provided by regulated public utilities with monopoly franchises, the merging of the two services within one firm requires that either the regulated monopoly be allowed to offer a competitive processing service or that the competitive industry be allowed to intrude on the monopoly's communications franchise.

1/ See especially, F.C.C. Docket No. 16979, Regulatory and Policy Problems presented by the Interdependence of Computer and Communications Services and Facilities, March 1967.

2/ Entry is relatively easy, barriers are not large, concentration is not high.

Many of the fears of allowing public utilities to offer competitive services revolve around the notion of the utility being able to compete unfairly perhaps pricing below marginal costs in the competitive services and making up this loss by increasing prices in the monopoly area. 3/ The carriers have the means to engage in discriminatory practices since many data processors must come to the carrier for the provision of communications links. 4/ The carriers would also have the incentive to engage in such practices, since monopolizing the processing industry would prevent processors from integrating back into the carriers' domain, communications. 5/ However, preventing communications utilities from offering processing services may lead to a less efficient allocation of resources if the long run incremental costs of the carriers' provision of these services is lower than the costs for independent firms.

Many countries are today facing the dilemma of how to maximize efficiency and yet prevent the extension of monopoly power by regulated utilities into competitive areas. The F.C.C. at this time of writing is still contemplating final policy. It is likely, however, that this final policy will closely follow the interim guidelines established in late 1970, namely that Western Union and non-Bell carriers may

---

3/ These views are expressed by (among others): United States Department of Justice, Response, F.C.C. Docket No. 16979. D.A. Dunn [5].

4/ Bunker Ramo charged Western Union with discrimination in the provision of adequate lines and repairs.

5/ The recent literature on rate base regulation also suggests reasons for this thrust into competitive areas - increasing the firm's rate base and thus its absolute profits (Averch & Johnson [1], Baumol & Klevorick [2]).

offer data processing services through an arms-length subsidiary.[6/] Bell, has not been allowed to offer data processing services for sale under any conditions.[7/] In the United Kingdom, the G.P.O. which has the complete monopoly on communications services is presently offering data processing services through an operating agency of the office. In Sweden, the Government has not yet decided on whether the telephone utility will offer competitive data processing services. In Canada, the Department of Communications will shortly make a policy pronouncement.

The purpose of this paper is to examine one aspect of the problem - whether in fact, communications and processing services are interrelated to the degree that present or future computer technology would allow cost savings where both services are provided by the same firm. Such cost savings may arise because the firm may use one computer for both services, because one standby machine may be used as backup for both services, because communications costs may be reduced by advantageous interconnection or because of a host of other factors not discussed here.[8/]

Just because 'computers' are being increasingly used for communications purposes does not necessarily mean that the same computer can handle both communications and processing functions. There are many different types of computers, each with activities that it does best, some computers have large memory banks, some simple operating procedures, others

---

6/ F.C.C. Interim Guidelines, 1970.

7/ By the consent Degree of 1956, A.T. & T. is forbidden from offering services other than regulated telecommunications services. A major dilemma for the F.C.C. is then that if processing is regulated for its interdependence with communications, Bell could enter.

8/ These other factors include economies of maintenance, finance and research and development. We have cursorily examined these elsewhere and found them to be small. (Cowan & Waverman [3]).

very fast computation time. Computers then are not a homogeneous input.

What we propose to show is that under current technology and in the foreseeable future (5-7 years), it would not be wise practise to offer both communications and processing services on the same computer, for a public service (as opposed to a private or individual company or group of companies internal service). For present technology and demand patterns, the two functions of communications and processing require distinct operating, reliability and design criteria. As a result, different types of computers are being used for the two functions.

When we turn our attention to possible future developments (8-20 years away), the potential for integrating the two functions appears to increase since the operating characteristics of communications networks and processing networks will become similar. However, we still feel that the advantages of specialization are likely to outweigh the economies of scale resulting from utilizing a single large computer for both functions.

Our examinations of the possibility of utilizing a standby communications computer for processing indicates negligible economies. In addition, the question of advantageous interconnection does not strike us as important. As a result we see little economies of integration for communications and processing networks now in widespread operation.

The recognition of the lack of economies of integration should be an important ingredient into public policy. Were economies of integration in fact high, then social costs would be increased if the two functions would be separated. Carriers could correctly argue that their exclusion from the processing industry would lead to a duplication of facilities,[9/] a reduction in efficiency and generally higher prices for both communications and processing.[10/]

Independent processors could likewise argue that their exclusion from the provision of communications services would increase social costs and that they therefore must be allowed to compete with existing communications carriers. These arguments are tantamount to suggesting that where the economies of integration are high, we have not two separate services - processing and communications, but only one product - teleprocessing. The interface between communications and processing would be indistinct and blurred. Public policy would then be faced with a real dilemma. On the one hand, refusing to integrate the services would certainly raise social costs. On the other hand, allowing the two services to merge might result in an extension of the existing carriers' monopoly, since the carriers already had the communications service and could offer processing easily, while processors would have to acquire communications facilities, i.e. intercity and intra-city communications circuits. It would be in the interests of

---

9/ Western Union Telegraph Company, Response, Docket No. 16979, March 5th, 1968.

10/ Ibid.

the carriers to refuse or delay such circuits and the time delay for independent processors in building such circuits would be large. Under high integration economies, if the regulatory agency was determined to keep processing competitive, rules of behaviour for carriers would have to be formulated i.e. the processing industry might become regulated also.[11/]

Fortunately, the world is not as complex as pictured in the above paragraph. In the remainder of this paper we show that economies of integration, the interdependence of processing and communications functions, are minimal now and in the near future. Public policy is therefore easier to make since no losses of social efficiency would result from preventing integration.

The absence of integration economies may be used by some as a reason for integration, arguing that independent processors would have nothing to fear since the carrier by reason of its communications franchise, could not offer lower costs. Many of the arguments against integration are not concerned with the costs of the carriers but with the prices they are likely to charge. Without going deeply into the entire issue,[12/] without discussing many other issues raised such as creamskimming or the economies of scale in finance and research and development, we feel that carriers should be prevented from

---

11/ The reader may draw an analogy between this hypothetical case and the extension of regulation over trucking services by the Interstate Commerce Commission.

12/ See Matheson & Walker [8] for a detailed description of the issue.

entering the competitive processing industry.[13/] The reasons are simple. We can see no social advantages or resource saving of such integration, while the possibility of carrier discriminatory actions and the costs of regulation exist.

The remainder of this paper proceeds in the following manner. First, a number of terms and concepts are defined. While this section is rather tedious to read, the terminology is necessary to understand the possibility of integration both under different communications facilities and under various network configurations. We next discuss the characteristics of communications and processing functions to determine whether there are distinct or similar operating, reliability and design criteria under present and future conditions. The next section considers the possibility of providing both services as coresident on one computer in a localized network (essentially a computer providing the services between two points). In this section are discussed the social consequences of the communications utility being able to add on processing facilities within the same building as its switching facilities (advantageous interconnection). We also attempt to discuss the arguments that computers used as backup facilities in communications systems might be an important addition to the data processing facilities of the nation. We then turn our attention to several forms of proposed distributed communications networks (where localized networks are joined together to permit resource sharing) and analyze the possibility of integration economies in such future systems.

13/ We hold this view for the U.S.A. For other countries, other goals such as national identity or infant industry arguments may require a reversal of this policy.

Communications Methods and Terminology

This section of the paper presents the basic concepts of message transmission using both the telephone (voice) and teletype machine (printed message or "hard copy").

Circuit Switching

Consider a large number of different sites, each containing a telephone or teletype. In order to guarantee that persons at any two different sites can communicate, the telephones or teletypes should be able to be interconnected for the duration of a message. This interconnection could occur in many different ways; e.g. all telephones or teletypes could be connected to all other telephones or teletypes by pairs of wires. Since such a solution would not be economically feasible, communication systems generally operate by connecting all telephones or teletypes to a central location, called a switching office. The switching office contains equipment collectively called a switching system which connects any two telephones or teletypes together on demand (establishes a circuit).

Circuit-switching (or line-switching) consists of machinery which establishes the circuit and maintains it for the entire duration of the message.

The switching system is a rather complex device which interprets signals such as those produced by dialling and establishes a connection, and it can consist of either an electromechanical device or a combination of electromechnical devices and an electronic computer. Electronic computers such as A.T. & T.'s ESS (Electronic Switching System) have only recently been used in this function. These computers have been specifically designed to perform a communication function.

The computers of a line-switching system are used to set up a physical path between the incoming and outgoing lines in place of electromechanical devices which perform the same task at a far slower rate. The computer itself does not handle the data transmitted, but scans both incoming and outgoing lines to ensure that calls are are connected and disconnected correctly. Electronic switching systems are designed and constructed to be extremely reliable and therefore include elaborate hardware and software provisions to allow recovery from errors and faults via automatic self-diagnostic analysis. 14/

Existing line-switching computers do not have many of the facilities necessary for high-speed data processing. The memory cycle time of an electronic switching system (SP-1 - 6 microseconds, ESS 1- 5.5 microseconds) is far higher than the average cycle time of a modern

---

14/ A.T. & T.'s ESS 1 is designed to have a maximum of 2 hours downtime in 40 years of operation. Of the 100,000 operating instructions controlling ESS 1, 50% are used for fault diagnosis and error recovery. Similar figures hold for the Canadian SP-1 system of Northern Electric.

data processing computer (IBM 360/85 - 100 nanoseconds). Line switching computers presently do not contain arithmetic units capable of multiplication or division, nor do they have means of accessing on-line storage. Computers equipped for data processing usually have a large repertoire of programs to assist the programmer. There are usually translators for several of the standard programming languages and an elaborate control program or operating system. None of these facilities have been designed for the computers in a switching system.[15/]

Store and Forward Message Switching

It is evident that a telephone call because of the interaction between the two persons involved, requires a circuit during the entire conversation. However, a message such as a telegram does not have to be sent directly over a circuit from sender to receiver; it can actually be delayed in transit without altering the intent of the message. Since the message can be delayed in transit, the characteristics of a system to send messages such as telegrams, can be quite different than those for a telephone conversation.

After the message switching system recognizes the user of a teleprinter it allows the user to send a message; a message which is preceded by the address of the receiver. This message is sent to the switching system which stores the message and forwards it later to its destination.

15/ It is possible to design such added features for a specialized line switching computer - the resulting end product probably would be a slow, expensive general purpose computer.

The switching mechanism for storing and forwarding messages is usually a digital computer system with a drum or disk file which can hold a large number of messages. This technique is called <u>store and forward message switching.</u>

In this case, the message is actually manipulated by a computer in transit, whereas in circuit switching the computer only establishes the connection for the message, the message does not actually pass through a computer.

Since the message can be stored and forwarded when a connection to the receiver is free, fewer lines are required to any given set of receiver locations. There are many other advantages to store and forward message switching systems and these are presented in the literature. (Martin, [9], [10])

Several types of digital computers are presently used in message switching systems. These are the UNIVAC 418 (Western Union, Bell Canada) and the UNIVAC 1108 (Western Union); CN/CP Telecommunications uses special purpose machines, the Collins C8401 (now used primarily as a reservation system for the railways), the Collins 8500 and the Philips DS714. Many of the digital computers used for message switching are general purpose processors and usually have operating systems, compilers, etc., available.

As the messages in a store and forward system are actually processed by a computer, they can also be modified in transit. For example, sales records which have been transmitted from branch offices to a head office could be summarized by the computer and forwarded to head office at the end of a business day.

Packet Switching Systems (Hold and Forward Concentrators)

The message switching systems described in the previous section assumed that an entire message such as a telegram was sent, stored and forwarded as one unit. It is not necessary to send an entire telegram but we could store and forward smaller units or transactions such as a single line of a telegram. This is sometimes called a packet switching system. Although the unit of message is smaller, the packet switching computer can and does perform many of the same functions as a message switching computer i.e. it also utilizes the transmission lines more effectively and computations can be performed on the individual packets.

Computing Services

Computing services presently available can be divided into many different categories by functional characteristics but can usually be thought of as special purpose and general purpose. The types of services offered on such systems can be characterized for the purpose of this paper as limited data processing and general purpose data processing.

Limited Data Processing

Limited data processing can be described in terms of the input data supplied by the user to the processing or host computer. In this case, the input data are not run as a program on the host machine (a program is a set of characters which will be transformed into and executed as a sequence of machine language instructions on the host computer). Some examples of limited data processing tasks are

(i) payroll calculations where the program is resident in the host computer and the only input data are the time-records of the employees.

and (ii) airline reservation systems where the input data is a request for information and where all the programs are available in the computer.

General Purpose Data Processing

General purpose data processing is defined as any task for which a digital computer program can be written. In particular, the data a user submits to a computer can be run as a program on that computer, i.e. it actually directly controls the behaviour of the computer. Programs written in various languages such as FORTRAN or PL/1 are submitted as input data to a translator which then produces a program to control the computer.

Hybrid Services

Hybrid services are usually considered to be a combination of computing services including both message switching and data processing where a message is processed and switched. Either of these two activities may be the primary service offered with the other activity as an incidental offering. While F.C.C. regulation revolves on these notions of primary and incidental activity, they are difficult divisions to make operationally.

Integration of Data Processing and Switching Functions

It has been suggested that economies of integration might arise from the technical possibility of performing two or more functions on the same computer equipment (not necessarily a hybrid service for the processing and switching might involve different sets of data). Thus, the integration of data processing and communications in a company might produce economies in several different ways:

(i) By allowing electronic data processing and switching to be co-resident on a computer thereby producing economies of scale [16/] and utilizing spare capacity in off-peak periods.

(ii) by utilizing the spare capacity available on a stand-by switching computer,

and

16/ The concept of a rule of thumb such as Grosch's Law that the computing 'power' of a computer installation increases as the square of the cost lies at the heart of belief that vast economies of scale are waiting to be tapped by the company which can create a vast 'utility' of users. Grosch's Law, best empirically measured by K.E. Knight (6, 7), has been called into serious question. Knight himself states "We cannot build larger and larger computers at reasonable costs since at any point in time there are absolute limits to the size and speed obtainable... The most powerful computing systems we could possibly build today or tomorrow would not be the most economical." (6, p.54). Even Knight's estimates of economies of scale exaggerate true economies because his cost estimates do not include the costs of operating systems, i.e. costs which rise with the size and the number of different tasks to be handled.

(iii) by utilizing the advantageous position that the communications company may have in connecting to its own line and message switching equipment.

These three topics will be discussed in general terms and then applied to specific computer configurations in an attempt to determine the magnitude of any resulting economies.

Integration of Data Processing and Switching Functions on a Single Processor

It has been suggested that the integration of data processing and either line or message switching on a single processor 17/ can produce savings for both activities, since the fixed costs of the machine are spread over two activities rather than one. A look at the criteria for reliability and design of present and possible computer equipment that would be used in switching systems or for data processing should reveal whether this type of integration will actually produce such savings.

The operating characteristics of a communications systems and a computer utility are presently quite dissimilar. The input to a communications system consists either of a number of pulses or tones followed by an analogue signal, or a string of pulses.

17/ From our discussions with people in the communications business, it would appear that line switching computers (A.T. & T.'s ESS and Northern Electric's SP-1) will not be used for anything but line switching in the foreseeable future. Although many of the arguments presented in this section apply to them also, we intend to concentrate primarily on message switching systems.

In both cases, the input to the system has little or no effect on its reliability. Most malfunctions are caused by spurious signals such as noise or by a fault in the switching mechanisms or lines. In other words, communications systems failures are rarely caused by input data.

A general purpose computer utility on the other hand, has quite different operating characteristics. Computer utilities suffer from the same problems as a communications system; moreover, since the utility also attempts to significantly alter its input data and perhaps even allows the data to control the processor as a program, failures (especially software failures) can and do occur with far more regularity. In the ideal situation (one which is yet to be closely approximated) in a computer utility, such failures should only affect the person who caused the problem. Even here, such a failure could be catastrophic, destroying several hours work. This type of failure is certainly not characteristic of communications systems.

Reliability Criteria

It is well known that the reliability criteria for switching and processing are somewhat different under today's technology. In electronic switching systems "system outage is regarded as catastrophic; however, individual errors are not so bad". (9, p.336). The reason that system outage is catastrophic is, of course, the fact that we have come to regard telecommunications capability both through telephone and message switching [18/] as an almost essential service. Therefore, the entire community cannot tolerate a period when such service does not exist.

At present, general purpose data processing requirements have almost the reverse criteria. Random errors are very serious, while complete system failure may not be catastrophic.

A random error in the switching function usually means that a few subscribers re-dial while systems failure may destroy a large number of conversations in a large section of the country. [19/]

Reliability criteria for errors in transmission are, of course, very different for voice and data communications. A random error caused by noise will affect the quality of conversation, but voice communications will not be radically affected (i.e. a small short disturbance in a long spoken message will not change the content of the message). In the case of data transmission, however, noise

---

18/ Since non-military message switching is not as essential today as the telephone system, one suspects that system outage is not quite so disastrous. In non-military message switching the degree of catastrophe is perhaps more application-dependent than in the telephone system.

19/ The costs of crashing a switching system vary among systems. For example, A.T. & T.'s ESS 1 operates by maintaining a map in memory of the entire system network. A malfunction therefore, destroys all the links. Northern Electric's SP-1 does not operate on this 'map' basis, and a crash destroys only those calls in the process of being connected. The crash of a message switching computer destroys the content of all messages which are in the process of being stored or forwarded.

introduced into the line while transmitting data can cause errors which could be quite serious. At the present time, most systems appear to error-check data received to ensure that it has been received correctly.

Random errors in data processing cannot be tolerated since their presence does not become known and may be propagated through many hours of computation thereby completely destroying the validity of any answers. At the present time, allowances can be made for a significant and lengthy system crash in a computer utility since it is fairly easy to recover from such crashes without too much loss of data.

It would appear that today the reliability criteria for a communications system and a computer utility differ substantially. A communications system can tolerate some random errors and no system crashes, while a computer utility has nearly the opposite characteristics.

In the future the reliability characteristics of both computer utilities and communication systems will become more stringent. Interconnection of computers will increase both general computer use and data transmission. (This increase will reduce the tolerance for both system crashes and random transmission errors)

The software and hardware presently used in data processing systems are such that fairly frequent system crashes do occur. Therefore, at present, it would be inadvisable to allow general purpose data processing and switching functions to reside on the same machine; however, limited data processing with carefully written and tested programs should be feasible. Certainly, the user must not be allowed to generate or modify code for the machine. Since future requirements on computer utilities probably will be as stringent as communications systems, and software and hardware used in a computer utility will become more reliable, we anticipate that it may be possible for communications functions and general purpose data processing functions to reside on the same computer. However, considering the problems we have today designing large operating systems, we would anticipate a delay of some years before general co-existence is feasible.

Design Criteria

It was mentioned previously that the input data to a communications system and a computer utility would be manipulated in a completely different manner and would have a different effect on the computer and communications system.

In particular, in a line switching or message switching system, the input data are transferred from input to output while in a general purpose computer utility, the input data may actually be a program which will be allowed to control the computer. These constraints on the input data can make the design of switching computers and general purpose computers quite different. In the case of switching computers, the volume of data is well-known and therefore the design problem is specified. In the case of the computer utility, the nature of the input data is so ill-defined that all cases cannot be enumerated or even anticipated. Therefore, the design becomes more general and introduces many added features such as paging, segmentation and memory protection [13] - in order to handle many difficult problems. From this discussion, it would appear that the general purpose computing and switching functions should not reside on the same computer.

In summary, it should be clear that general purpose data processing should not be performed on the same computer as message switching. The reliability requirements of a message switching system are much higher than can presently be expected from a computer system devoted to general purpose data processing. Also, the design of a message switching system or any other system is usually significantly simplified when the job to be performed is made narrow or more specialized. Certain well-defined limited data processing tasks could be co-resident with message switching functions. However, such tasks use time which must be stolen from the communications function of the computer, thereby limiting the number of terminals it can handle at any instant in time. Therefore, in a large system the amount of data processing done in the message switching processor should be severely limited or completely curtailed.[20/] This strongly suggests that the two tasks should really be run on separate interconnected computers.

Numerous discussions and observations have led us to the conclusion reached in the previous paragraph. The presence of

---

20/ A message switching system with a relatively light load such as a specialized application might also be able to accomplish significant data processing tasks.

specialized electronic and message switching computers suggests that there are advantages to specializing the technology for switching away from general purpose computers. Three companies (Western Union, CN/CP, and Northern Electric) stated that it is less expensive to split the communications and processing tasks and to process them on two interconnected machines, one of which was a specialized switch. 21/ Of course, reliability considerations, at least for the present, also point the way to separation of the tasks of switching and general purpose data processing on different interconnected computers.

To conclude this discussion, it appears that since switching and processing should be offered on two separate but interconnected computers, (a fact which appears to be forced by both reliability and design considerations), no economies of scale or economies from use during off-peak loads can occur.

Utilization of Spare Capacity on a Standby Computer

Electronic switching and message switching systems have spare capacity. The spare capacity exists in two ways: first, the machines are installed with the capacity to handle peak load traffic. Therefore, at times other than peak loads, 22/ these operating processors have spare capacity (this was discussed in the section on

---

21/ "In the case where there is a significant communications load to be processed, it is more feasible to interface the communications terminal with a separate computer, dedicated to communications functions, which is, in turn, coupled to a processor dedicated to computational and retrieval functions." Western Union, Response of Western Union Telegraph Company, before the F.C.C. Docket No. 16979, March 5th, 1968.

22/ It is likely that the peak telephone switching load and any peak data processing load would occur at the same time. Therefore, it is unlikely that spare capacity could be utilized in this way.

integration of data processing and switching functions on a single process). Second, both electronic switching systems and message switching systems maintain spare processors for reliability purposes. In the case of line-switching, two computers often are operated in parallel so that a continual check on the status of the system can be maintained. Message switching systems on the other hand, contain a fall-back processor for every two (CN/CP) or three (Western Union) operating processors.[23/] This scheme is used so as to minimize any serious system outage.

It has therefore been argued, mainly by Western Union, that allowing telecommunications utilities to offer data processing services will generate economies of integration by spreading the overhead of the spare message switching computer over both communications and processing. Of course, such data processing services will have to be on an interruptable basis since at any time, the stand-by processor may be asked to take over the switching function. It would appear that in this case, assuming the use of a general purpose computer for message switching (perhaps not a valid assumption) that some economies of integration would arise.

The magnitude of this economy depends on two factors - the percentage of Western Union plant investment which is accounted for by stand-by message switching computers and the importance of these

---

23/ Western Union feels that this spare computer will be used only 5% of the time for switching purposes.

stand-by computers in the data processing industry. Western Union plans to construct within the next few years, a national message switching centre in Virginia consisting of three UNIVAC 1108's; one of which will act as stand-by. The long run plans of the company (20 years) envision five such centres.

The immediate future will thus see only one UNIVAC 1108 available for utilization for processing services. The costs of such a computer with auxillary equipment (fastran drums, tapes, etc.) ranges from $5 million to $8 million. Western Union's 1968 investment in plant amounted to $917 million (at historical cost).24/ Of this plant investment, $260 million was in message transmission and reception equipment, repeater and terminal equipment and switchboards and distributing frames. Assuming no other investment, the addition of three UNIVAC 1108's adds $15-$25 million to plant investment. The cost of the single spare message switching computer then amounts to .009 of Western Union's total plant investment or .028 of the company's investment in message transmission and switching equipment. The utilization of this stand-by machine also for data processing would not significantly alter Western Union's communications cost. In addition given the present number of computers in the U.S.A. - 50,000 - 60,000,the availability of one more machine on an interruptible basis would

---

24/ F.C.C. Common Carrier Statistics, 1968.

not make a major impact on demand either.

In twenty years, perhaps five such machines (or their 1990 equivalent) will be available.[25/] Again, the investment represented by these computers will represent a minor portion of both Western Union's plant investment and the universe of computers with processing capabilities.

25/ Fewer than five stand-by machines will probably exist in 1990. As the number of computers in a message system increase, there may be fewer and fewer stand-by computers. In the future, the failure of one computer system may be relieved by distributing the load of the failed computer over other computers in the remaining message switching network. This possibility is discussed in the last section of this paper.

Advantageous Interconnection

Single company ownership of both the message switching computer and data processing computer may produce economic advantages, since the two interconnected computers can be placed close together, thereby almost eliminating transmission costs between the two machines.

Consider a message switching system with attached data processor. If these were both in the same company (not necessarily a communications company) and physically close to each other (within 50 to 100 feet), then a message which required some data processing would travel the path shown in Figure I. 26/

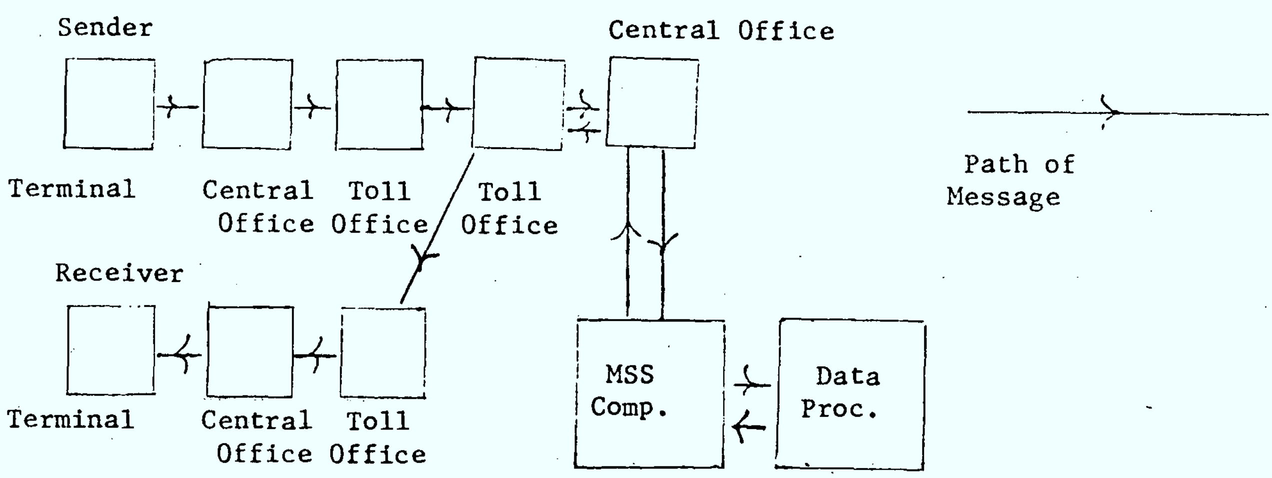


Figure I

26/ It is assumed that the message switching computer(s) and the data processing computer(s) are close together and do not use telecommunications links to transmit data between themselves. This assumption may not be correct.

If the message switching computer and the data processing computer were in different companies (perhaps in different cities), then a message which required some data processing might travel the path shown in Figure II.

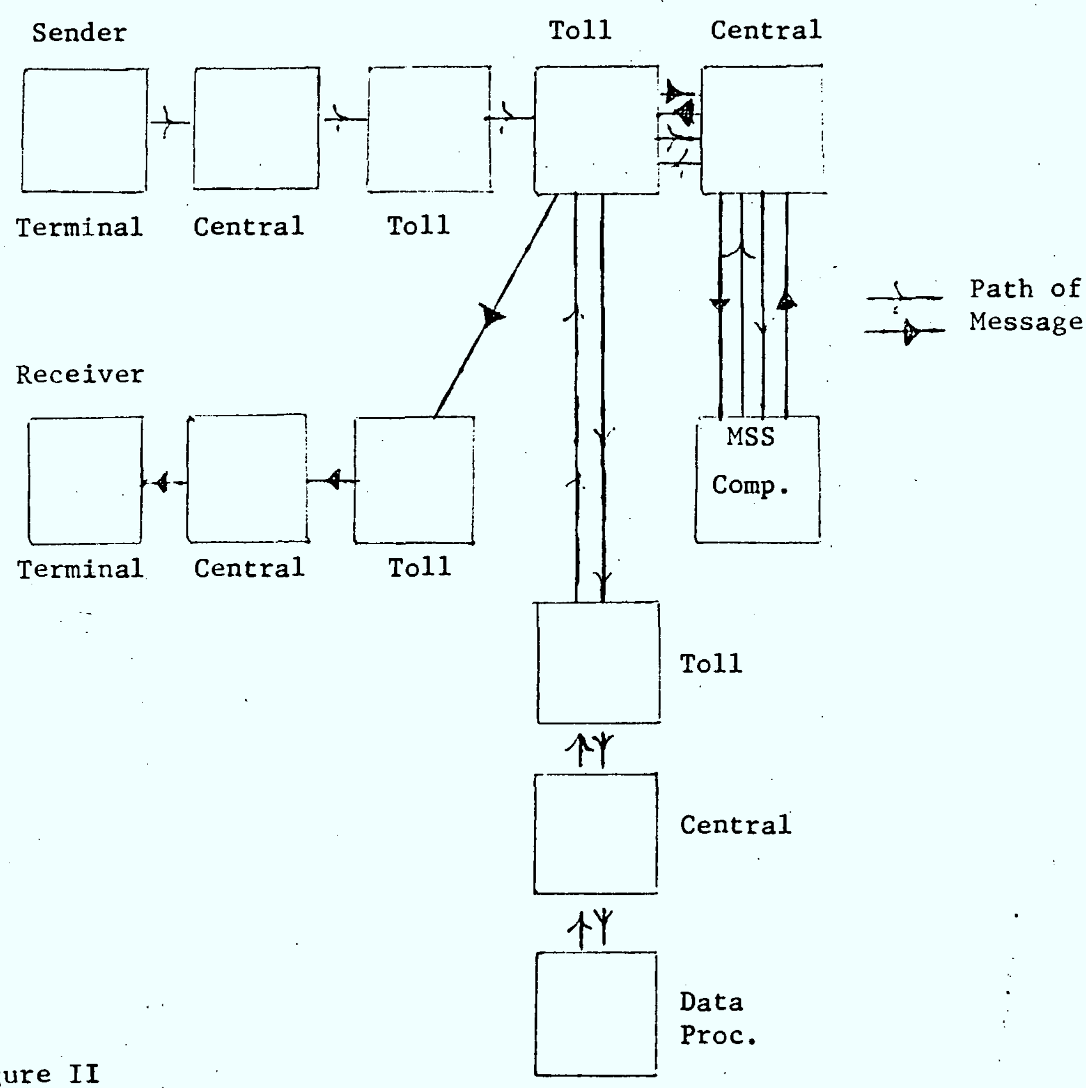


Figure II

The number of toll offices shown in Figures I and II may vary considerably, depending upon the communication distances between transmitting and receiving terminals and the data-processing computer. Of course, no switching may be required if the computers are connected by a private line.

The costs for a communication link between the two computers are given in Table I and Table II.[27/] These are the minimum costs for data transmission using Dataphone 50 and Series 8000 service respectively for a period of one month at an average daily two-way transmission rate of 600×10^{6} bits per day. Tables III and IV give these costs for a five-year period, the normal depreciation period for a computer.

Tables V and VI present the marginal economies of integration after Tables III and IV have been adjusted by the five-year monthly rental of a short direct communications link.

Such a discussion would seem to indicate that substantial economies of integration exist in advantageous interconnection, although only if the computers are separated by large distances, since intracity transmission costs appear to be quite low. However, this is not an argument suggesting that existing communications firms

---

27/ These costs are the prices charged for the services by A.T. & T. These prices reflect the true social costs of transmission only to the degree that A.T. & T. prices are at long run incremental costs. While it is difficult to prove that high profits are not made on these services, the evidence suggests that in fact these prices are close to costs. There is a competition on these data transmission services (Western Union). Past studies have suggested a low or negative rate of profit on private line facilities based on fully allocated costs.

have an advantage over independent utilities in offering processing services. From Table V, it can be seen that the company which incorporates switching and processing at the same location can save approximately $388,000.00 over a company 200 miles away at a transmission rate of 6 x 10^8 bits over 5 years. If all the customers for data processing services were in New York, then the utility located in New York would have costs approximately $78,000.00 a year lower than its competitor in Boston. Note however, that the only savings that a communications firm which located its processing unit in New York would have over a New York based communications firm cum computer utility would be approximately $22,000.00 per year (the cost of intracity transmission). This saving of $56,000.00 per year is available to any utility which located in the neighbourhood of its customers. If all customers were in New York, it is unlikely that any utility would locate outside that city. This $56,000.00 annual saving is not an economy of integration, but it merely represents the savings available to the firm which best discerns the market.

Transmission Rate (Kilobits/sec) / Mileage	50
Intracity	2430
Up to 50	3750
51 - 150	5070
151 - 300	7050
301 - 600	9250
601 - 1200	11450
1201 - 2000	13650
2001 -	15850

Minimum Monthly Charge for an Average Daily Transmission of 6×10^8 bits Using Dataphone 50 Service

TABLE I

Transmission Rate (kilobits/sec.) / Mileage	50
10	2000
100	3350
200	4850
300	6125
400	7175
500	8225
1000	11975

Monthly Charges for Varying
Mileages for Series 8000
Private Line Service

TABLE II

Transmission Rate (kilobits/sec.) / Mileage	50
Intracity	146
Up to 50	225
51 - 150	304
151 - 300	423
301 - 600	554
601 - 1200	687
1201 - 2000	820
2001 -	952

Minimum Charges for 5 Years
For an Average Daily Transmission
of 6×10^8 bits Using Dataphone
50 Service in Thousands of Dollars

TABLE III

Transmission Rate (kilobits/sec.) / Mileage	50
10	69
100	150
200	240
300	326
400	373
500	442
1000	668

Charges for 5 Years
For Varying Mileages For
Series 8000 Private
Line Service in Thousands of Dollars

TABLE IV

Transmission Rate (kilobits/sec.) / Mileage	50
Intracity	111
Up to 50	190
51 - 150	269
151 - 300	388
301 - 600	519
601 - 1200	652
1201 - 2000	785
2001 -	917

Marginal Economies over 5 Years for An Average Daily Transmission of $6x10^8$ Bits Using Dataphone 50 Service in Thousands of Dollars.

TABLE V

Transmission Rate (kilobits/sec.) / Mileage	50
10	34
100	115
200	205
300	291
400	338
500	407
1000	633

Marginal Economies over 5
Years for Varying Mileages
For Series 8000 Private
Line Service in Thousands of Dollars

TABLE VI

SUMMARY I

Potential Economies from Technical Factors, Present Technology and Configurations

The next several paragraphs deal with present computer communication configurations in an attempt to summarize the conclusions about economies of integration in the foreseeable future (5-7 years).

A number of assumptions have been made about the capability of individual companies to provide communications services of various kinds, namely, it is assumed that:

(i) Any company can obtain the same communications services as the communications firm can supply itself.

and (ii) As a consequence of (i), that any company can obtain a computer and offer a message switching service.

Assumption (i) implies that a situation similar to the one which gave Western Union (SICOM) an advantage over Bunker Ramo (Telequote) could not occur. In this case, Western Union was providing a cheaper communications service to its own system (SICOM) than it was to its customers, Bunker Ramo, and Scantlin Electronics. This cheaper service was not an economy of integration, Sample Cases

Two examples will be examined to see if technical economies of integration exist in various configurations of line switching and message switching systems.

Case I Message Switching and Data Processing on the Same Computer:

This situation should only arise when (i) a very limited data processing load exists which can be run in conjunction with a message switching service, or (ii) a message switching service exists with a small load, then limited data processing can absorb some of the spare time without hampering the message service. In both cases, the reliability and design criteria would severely limit the data processing load. Under the assumptions made at the beginning of this section, the economies (if any) would be the same for both the addition of data processing services to existing communications firms or the addition of message switching services to existing computer utilities. Given free entry into both services, communications firms would have no real advantage (in terms of lower social costs) over computer utilities in offering both services.[28/] Of course, under present rules, such a service on one computer

28/ If free entry were allowed into both communications and processing rather than the one way competition of allowing carriers to offer processing, the fears of the unnatural extension of monopoly power would be removed. Would the carriers attempt to engage in predatory pricing in the processing market while raising prices for communications services, processing firms could freely construct their own communications facilities. This policy of free entry is not likely to occur given the fears on creamskimming and the breakdown of the present internal subsidization scheme.

could not be offered by either the common carrier or a private company.

Case II Message Switching and Data Processing on Two Separate Interconnected Computers:

If the message switching and data processing are performed on two separate but interconnected computers, then there are two suggested configurations of equipment as shown in Figure I and Figure II. In Figure I the two computers are in the same company and located close together. This represents the most economical configuration since the communication distances are short and data might be transmitted over a dedicated cable.

Figure II represents the configuration of equipment when the computers are separated by a significant distance. In this case, the data must travel over a communication line between the message switching computer and data processing computer at least twice. The marginal economies here are represented by the difference between communication costs over a five-year period (the usual depreciation period for a computer) and the rental of the direct link represented in Figure I. These marginal economies were given in Table III.

If the two interconnected computers have a five-year depreciation period and the data processing machine initially costs a total of $4,000,000.00 then the marginal economy from advantageous interconnection would be about 2.8% ($111,000.00 approximately), if 50 kilobit transmission was used. The transmission costs in this case were calculated on an absolute minimum cost basis, the marginal economy might actually be as high as 5%.

By having the two computers located next to each other, there may be some economies associated with reliability of service. If we assume that the data processing and message switching computers are the same type, then probably only one computer needs to be available for stand-by service. If the computers are owned by separate companies, then at least one extra stand-by computer will be required for high reliability service.

Of course, there are two points to be raised here. Will the message switcher and the data processor both be the same type of computer? It is not clear that this would be an optimum design decision. Also since the message switcher is a store-and-forward system, can it retain all data processing tasks when the data processing computer is being serviced? Such a situation would obviate the need for a stand-by computer. Of course, the need for a stand-by machine is highly application-dependent and it would be difficult to discover if there are any economies here without looking at the reliability requirements of individual applications.

Computer Networks [29/]

Up to this point the paper has considered configurations of two computers. However, it is becoming apparent that distributed computer networks are likely to be a reality in the near future. For example, consider the 'simple' network of Figure III which consists of four message switching computers and two data processing computers. Here the data processing computers are part of a large computer network and data is sent to them for processing purposes as it moves through the network. Of course, some of the data in the network may be passed on as 'pure' messages while other messages may be transformed or generate special data using the data processing computers. For example, in an airline reservation system, a request such as 'Are there available seats on Flight 95' would be routed to the data processing computer, while a request such 'Has Flight 95 left Chicago' might be sent directly to a terminal in the Chicago airport.

This section of the paper discusses the reasons for a computer network and describes two networks currently under study.

A computer network is a set of autonomous independent computer systems which are interconnected together to permit sharing of resources between any pair of these computer systems. The resources that would normally be shared are programs and data and the ability to access and execute these items on any one of the computers in the network. In other words, the goal of the computer

---

29/ The technical details in this section rely on Davies [4], Roberts & Wessler [12].

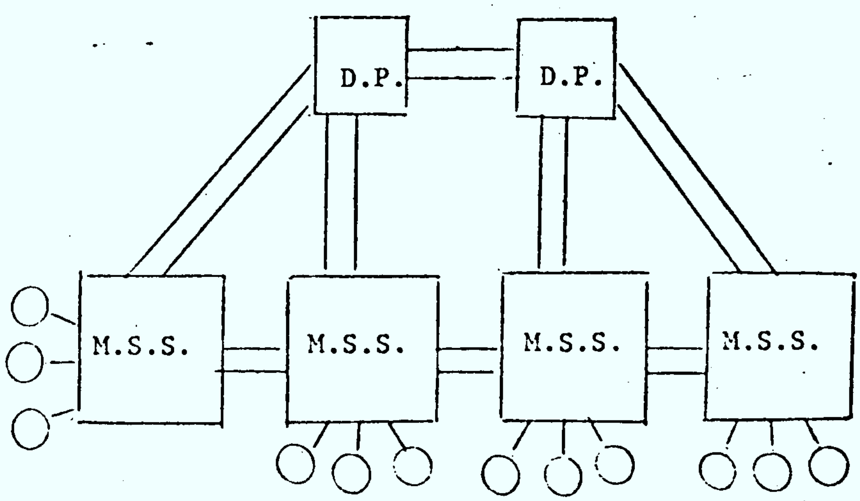


Figure III

network is for each computer to make every local resource available to any computer in the network in such a way that programs and data available to users of a local computer can be used remotely without degradation.

At the present moment, every computer centre is forced to recreate all of the software and data files it wishes to use. In many instances, this involves a complete reprogramming effort or a complete reformatting of data files. Such duplication is extremely costly and has led to very restrictive standards both on language and hardware. A successful computer network would reduce many of these problems of sharing resources.

Are computer networks likely to have widespread applicability or are they just a computing dream? One important future application is the specialized customer service computer systems already in existence or envisioned for the future. These specialized computer systems will provide many services for the general public, business and government. They will make available such services as instantaneous quotations from the stock exchange and the commodities market, automatic debit and credit of individual bank accounts from almost any location and many other services too numerous to list here.

While some of these computer services are presently available, they require a direct dial connection to the service through the public telephone network and any data that is required for this service must be transported by telecommunications circuits or other means to the site of the computer.

This set of restrictions decreases unnecessarily both the market available for any one program and the choice set of a prospective user.

If nationwide networks of computers were available, which could communicate with each other then it only becomes necessary for a company offering services to connect its computer into the network. This individual company would not supply consoles to its users and some of its data may come from other service computers in the network. Communication costs would probably be based on the length of any messages involved in a transaction over the network and not on distance. Use of broadband circuits between computers will also reduce costs significantly. Users could choose the service they require based on criteria such as reliability and ease of use rather than on proximity or unavailability of alternatives.

The philosophy of computer networks will allow a broad range of computer services to be made available. What range of services will ultimately be provided is difficult to anticipate. However, if a computer network is established the limiting factors in developing services will not be the communications system.

There are a number of networks operating or under development at the present time throughout the world. The next few paragraphs will describe two of these networks; the ARPA Network in the United States and the so-called Davies Network in Great Britain.

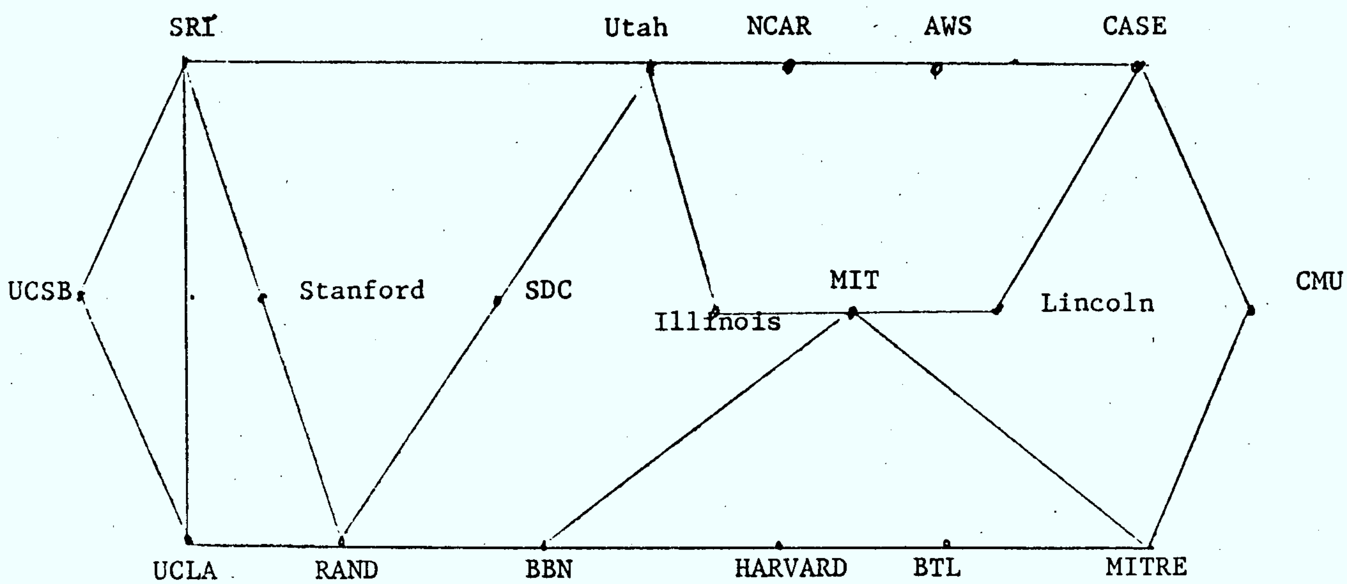
The ARPA Network is a fully distributed message switched system. At each site or node, where there are active users, there is a store and forward computer (or message switch). This computer is connected to some of the other nodes by transmission lines so that eventually there are connections from any given node to any other node.

A diagram of the initial ARPA Network is shown in Figure IV. Messages are sent from node to node until they reach their destination. When the message arrives at its destination it is sent from the switch to a host computer which analyzes the message and acts upon it. There is a host computer at every node of the network. In the ARPA Network all users of terminals are connected to a host computer which governs their use of the network.

The Davies Network which has been proposed for Great Britain is similar and yet significantly different from the ARPA Network. A partial Davies Network is shown in Figure V.

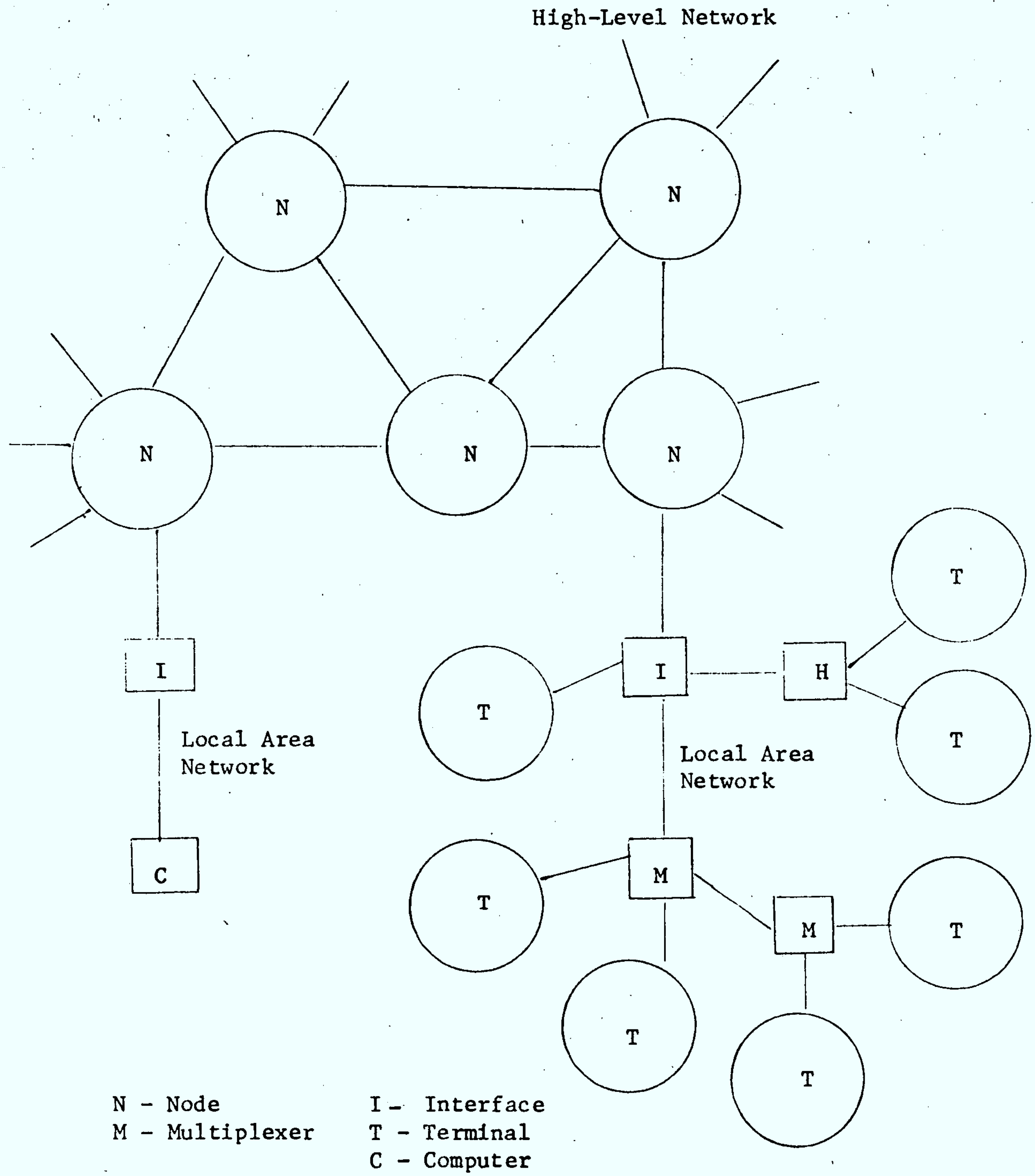
In this network the store and forward concept is used to transmit messages between the nodes of the high-level network. Messages are short and in fixed format and called packets. Messages are entered into the high-level network from either terminals or computers both of which are connected to any given node by an interface computer. Terminals are usually connected to a multiplexer to utilize the transmission lines in a more efficient manner.

These are only two of many different network designs which are under development. How these networks will evolve into actual working configurations is impossible to assess. As a result, the public policy aspects of competition and integration in both processing and communications are difficult to discuss. We therefore present a number of questions and conjectures rather than a full analytical discussion of all relevant material and issues.



INITIAL CONFIGURATION OF ARPA NETWORK

FIGURE IV



A PARTIAL DAVIES NETWORK

<u>FIGURE V</u>

Potential Economies from Technical Factors - The Future - Questions and Research Needs

What new problems will computer networks cause in the area of public policy and can these problems be anticipated far enough in advance to provide guidance in the formulation of policy? This section asks a number of questions about computer networks, it, however, leaves the answers as a subject for further study.

A computer network is a combination of computers and communications facilities. Who should construct and maintain these networks? Should these be the responsibilities of the common carriers, a consortium of the common carriers and other companies, such as manufacturers of computers? Perhaps even a new type of common carrier should be franchised, one who uses the communications network supplied by the carriers and incorporates computers into the network. Many possibilities certainly exist, in at least one country it has been suggested that a government corporation be established to build and manage a computer network. This government corporation would allow participation by the common carriers as holders of large blocks of stock.[30/]

It is likely that any organization which manages a computer network will be a regulated monopoly. (Generally, one such network will be sufficient for a country)[31/] If this monopoly is allowed into the data processing business, then a situation develops similar to the one discussed in previous sections of this paper. Should this monopoly

---

30/ This suggestion is analogous to the relationship in communications by satellite - COMSAT.

31/ The possibility of an intercountry or global network does exist.

be allowed into the data processing business, since it uses computers in its network for communications purpose? Can and should these computers also do data processing? An answer to this question is highly dependent on the design of the network. If either the ARPA or Davies Network designs were chosen, then it would appear that the node computers would be specifically designed for communications purpose (i.e. packet switching, code conversion, etc.) and would not have the time or be available for general purpose or limited data processing.

In other areas of a network, computers will likely be used as interfaces to the network and as multiplexers to utilize lines more efficiently (see the Davies Network in Figure V). It has been suggested that these computers might provide some extra intelligence [Martin, [9], [10]) and handle at least some of the transactions locally rather than send all the information into the network.

If these computers are allowed to do data processing, should they be supplied by the operator of the network? Should individual companies be allowed to connect their own equipment into the network as long as they obey reasonable standards? In the case of small businesses or individuals, there could be a local utility or utilities which supply interface units. This situation would be analogous to the distribution of electric power although one has to be careful not to carry this analogy too far. This type of scheme would at least spread and somewhat neutralize the effects of a large monopoly.

These are only some of the questions which must be considered about computer networks. It would be appropriate if many of these questions could be examined before we have committed ourselves to an unhealthy and irreversible situation.

To examine them properly requires a concerted effort by engineers, lawyers and economists. While many countries are in the process of establishing agencies to do long range research in this area, the F.C.C. has yet to do any significant research into the potential of integration economies. Public policy, if it is to maximize the efficiency of resource allocation, must rest on a complete understanding of the technology, present and future. To make decisions without this knowledge, leaves outsiders with the impression that policy is guided by political judgments or the balancing of power among various interest groups.

Conclusions

This paper has examined technical factors which influence the design and implementation of computer systems which offer both communications and data processing services. It has defined the terms associated with this subject and considered the problem areas.

In particular it has examined -

(i) reliability criteria

(ii) design criteria

and (iii) interconnection of computers

We have concluded that communication functions and data processing should probably be implemented on different interconnected computers except where the data processing functions are very limited or where the message switching load is very light. This conclusion was borne out by the actual practices of many of the communications firms.

Since these functions were to be carried out on interconnected computers, we examined the methods of interconnection in order to determine if the communications companies could realize an economic advantage because of convenient access to their message switching computers.

An investigation of two interconnected computers led us to conclude that small economies would result if the two computers were not remote from each other since communication costs would definitely increase the cost of the total message switching- data processing package.

An examination of the more general problems of the computer network indicates that there are many important questions which should be examined in order to determine what serious problems will arise in public policy. This paper has not attempted to ask nor answer all of the questions which can arise but rather to give an indication of the complexity of the problems. The authors hope that many of the questions will be examined before the answers become a fait accompli.

Our recommendations are that at the present time (now - 5 years), in a country of the size and degree of technical sophistication as in the U.S.A., the short run policy should be to maintain the competitive aspect of the data processing industry. Little real resource saving results from an integration of communications and processing while both the complexity of regulation and the threat of predatory pricing increase. The present interim policy which allows non-Bell carriers to offer data processing services only if such services are offered in arms-length subsidiaries on separate equipment is an irrational compromise. Good reasons exist to maintain a simple sphere of action for communications carriers. The use of arms-length subsidiaries ensure that <u>no</u> integration economies could result.

What purpose then does this policy serve? Carriers are not satisfied, data processing firms are unhappy, the public is better off only to the extent that there was a lack of facilities available previously.

For the long run, the regulatory agency must maintain resources which will enable it to judge whether the change in technological capabilities will lead to real social savings from offering teleprocessing rather than communications and data processing services.

APPENDIX I

Transmission Costs
Rates for Dataphone 50 Service
Interstate Usage

Fixed Monthly Charge

Access Line and Data Set $275.00

Transmission Charges in Dollars
(in one minute increments, distances used are airline distances)

Transmission Rate (kilobits/sec.) / Mileage	50
Intracity	.20
Up to 50	.50
51 - 150	.80
151 - 300	1.25
301 - 600	1.75
601 - 1200	2.25
1201 - 2000	2.75
2001 -	3.25

Transmission Costs

Rates Series 8000

Private Line Service

Interstate Usage

Fixed Monthly Charge

Access Line and Data Set $425.00

Transmission Charge in dollar/mile/month.

Transmission Rate (kilobits/sec.) / Mileage	50
0 - 250	15.00
251 - 500	10.50
501 -	7.50

Sample Calculation

Amount of data to be transmitted = 3×10^9 bits/month.

Transmission Rate = 50 kilobits/second

Number of one minute increments required

$$= \frac{3 \times 10^9}{50 \times 10^3 \times 60} = 10^3$$

Cost of Transmission over a distance of 500 miles

$= 10^3 \times 1.75 = \$1,750.00$/month.

Total Cost = Fixed Monthly Charge x 2
+ cost of Communication Adopters x 2
+ Transmission Cost

= 550 + 1,750 + 1,000

= $3,300.00

Sample Calculation

Cost of Transmission over 500 miles

= 15.00 x 250 + 10.50 x 250

= $6,375.00

Total Monthly Cost -

= Transmission Cost

+ Fixed Monthly Charge x 2

+ Cost of Communication Adapter x 2

= 6,375 + 850 + 1,000

= 8,225

REFERENCES

1. Averch H. and Johnson, L.L., "Behaviour of the Firm under Regulatory Constraint",American Economic Review, Vol. 52, (December, 1962).

2. Baumol, W.J. and Klevorick, A.K., "Input Choices and Rate-of-return Regulation: An Overview of the Discussion", Bell Journal of Economics and Management Science, Vol. 1, No. 2, (Autumn, 1970).

3. Cowan, D.D. and Waverman, L, "Economies of Integration in Communications and Data Processing", Appendix A, Department of Communications Teleprocessing-Report of Committee, Ottawa, 1971

4. Davies, D.W, "Communication Networks to Serve Rapid-Response Computers", p. 72-78, IFIP Conference Proceedings, 1968.

5. Dunn, D.A., "Policy Issues Represented by the Interdependence of Computer and Communication Services", Law and Contemporary Problems, (Duke University, Spring, 1969).

6. Knight, K.E., Datamation, September, 1966.

7. Knight, K.E., Datamation, January, 1968.

8. Matheson S.L. and Walker, P.M., Computing and Telecommunications: Issues in Public Policy: Prentice Hall.

9. Martin, J., Telecommunications and the Computer: Prentice Hall.

10. Martin, J., Teleprocessing Network Organization: Prentice Hall.

11. President's Task Force in Communications Policy, Staff Paper I - A Survey of Telecommunications Technology, PB184412, Clearinghouse for Federal Scientific and Technical Information, U.S.A.

12. Roberts, L.G. and Wessler, B.D., "Computer Network Development to Achieve Resource Sharing, " p. 543-549, AFIPS Conference Proceedings, May, 1970.

13. Watson, R.W., "Time-Sharing Design Concepts" McGraw-Hill, 1970.