TOWARDS INTEGRATED, COMPUTER-BASED MANAGEMENT COMMUNICATIONS

Vladimir Teremetsky

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

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I. INTRODUCTION

Communication is of fundamental importance in organizations. Mintzberg, for example, observed that the managers he studied spent more than 75% of their time communicating (Mintzberg 1973).

Presently, new, computer-based technologies are emerging which offer new alternatives for communication.

One of these is so-called electronic mail--i.e., passing informal messages to other users on a time shared network.

Another is of course text processing. This is not so much an alternative technology as it is an efficiency improvement in conventional hard copy correspondence and reports.

Another technology is also developing which serves to confuse the issue from a communication standpoint--namely the growing appeal of personal computing. Small microcomputers are often within reach of a departments discretionary budget and often they find it easier to do certain text processing and decision aiding applications locally than coordinate with a centralized computer department.

While personalized computing brings control of applications closer to the people having those problems, it does have the disadvantage of discouraging use of the computer for passing of messages to other offices.

A potential follow-up phase to the spread of localized computing in offices is, we believe, a move towards interconnecting these on a local communication network.

However, to date, computer-based intra-office communications have only considered typed text--what we call "typographic" data.

To support communications in other forms--e.g., voice, free hand graphics--other technologies have developed separately and make use of separate communication network: for instance, telephone, cable TV, thermo fax.

Looking beyond the use of computers for typographic communications, we would like to consider a single intra-office network for managing all the above mentioned forms of communication. We call this proposed system an Integrated-services Intra-Organizational Communication Network (IICN).

II. NEED FOR BETTER COMMUNICATIONS

Our specific attention to the problems of managers is intentional. It seems (Infotech International 1979, 1980b) that existing intra-organizational information systems somehow have missed a manager. They have not been aimed at the executive but have concentrated rather on secretarial and clerical functions (e.g., text and word processing). Nevertheless, managers and professionals are a major part in distribution of office workers by number and even larger part in the distribution by cost (see Figure 1 (Infotech International 1979), and 2). Besides, the number of this most expensive group of office workers--managers and professionals--increased more quickly in comparison with the clerical groups (Figure 3)(Infotech International 1980b).

Also, a number of recent researchers (e.g., Hiltz 1978, Dudorin 1980, Infotech International 1980b) have emphasized the growing need for improving the efficiency of information systems for managers. But to improve manager's effectiveness means to a great extent improving their ability to communicate (Figure 3) (Infotech International 1979).

In order to defend this statement let us consider a manager's working role in an organization. First, consider the following passage from H. Mintzberg (1973):

> Much of the manager's power derives from his information. With access to many sources of information, some of them opened to no one else in the organizational unit, the manager develops a data base that enables him to make more effective decisions than his employees. Unfortunately, the manager receives much information verbally, and lacking effective means to disseminate it to others, he has difficulty delegating responsibility for decision-making (emphasis ours).

Mintzberg also gives the following classification of managerial functions:

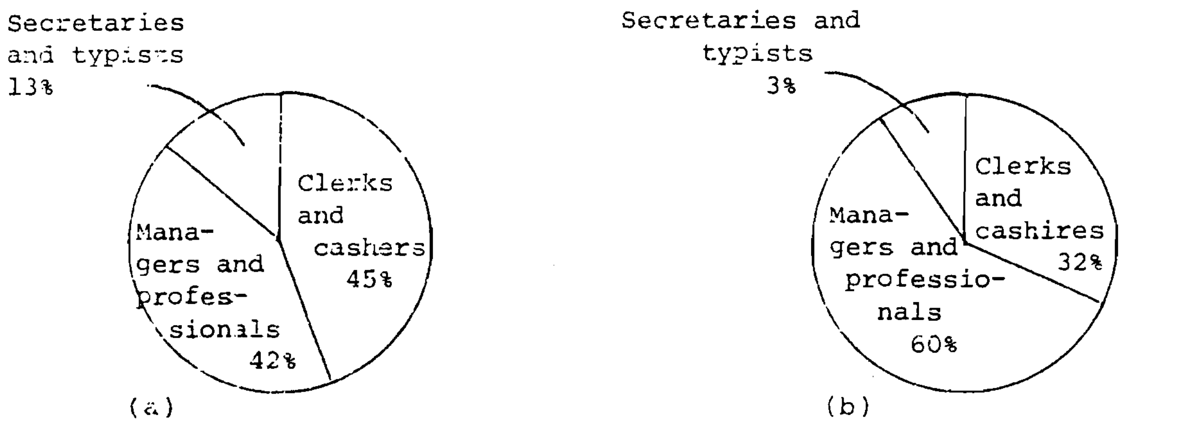

Figure 1. Distribution of Office Workers (a: by Number and b: by Cost) in the U.K. (Source: Infotech International 1980b)

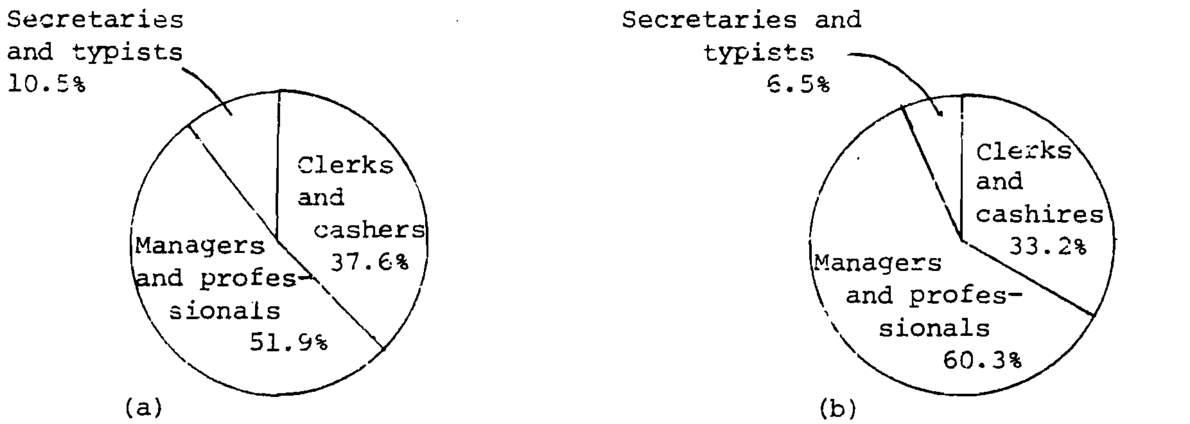

Figure 2. Distribution of Office Workers (a: by Number and b: by Cost) in the U.S.A. in 1978 (Source: Statistical Abstracts of the United States 1979).

	1966	1971	1976
Managers and professionals	1681 (7.0%)	1961 (8.6%)	2609 (11.6%)
Clerks and cashirs	2521 (10.5%)	2651 (11.3%)	2812 (12.5%)
Secretaries and typists	789 (3.3%)	767 (3.3%)	832 (3.7%)

Figure 3. Civil Employment Figures for UK Offices (in thousands and as percentage of workforce) (Source: 1966 and 1971: Department of Employment British Labor Statistics, 1976: Analysis of recent information in CSO publications)

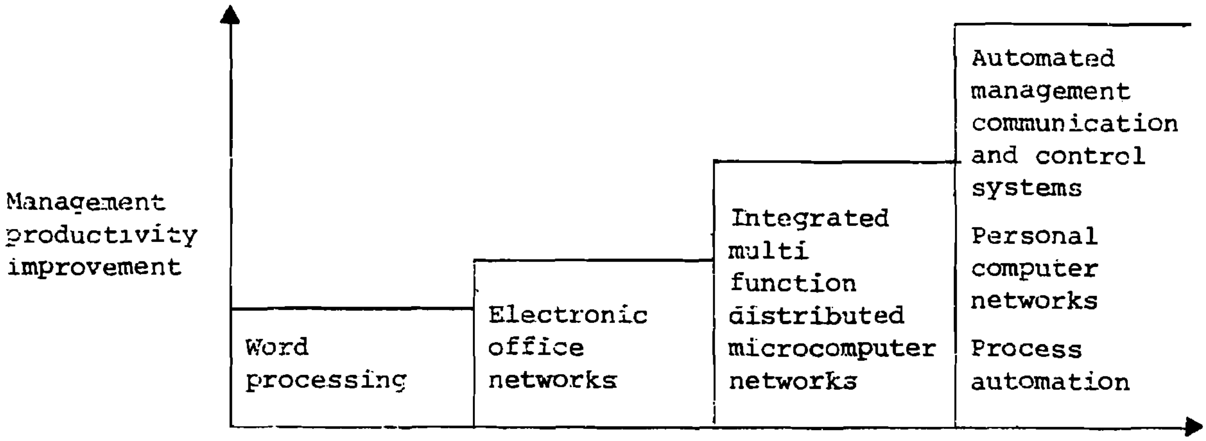

Figure 4. Amount of Change in Management Communication and Control

I. Interpersonal roles

1. figurehead -- representing organization
*2. liaison role -- interaction with peers and other people outside his organization
*3. leader -- relationship with his subordinates, i.e., motivating staffing, etc.

II. Informational roles (see Figure 5)

*4. monitor -- receiver and collector of information
*5. disseminator -- transmission of special information into his organization
*6. spokesman -- dissemination of organizational information into his environment

III. Decisional roles

7. entrepreneur -- initiation of changes
*8. disturbance handler
9. resource allocator -- decides where his organization will expend it's efforts

10. negotiator

(* indicates this role includes communication)

Even ignoring the informational roles, which also depend on communications, one can find at least three areas (namely, liaison, leader, disturbance handler roles) where improved communication is likely to improve a manager's effectiveness. For example, crisis management often requires the following sort of things (Hiltz 1978):

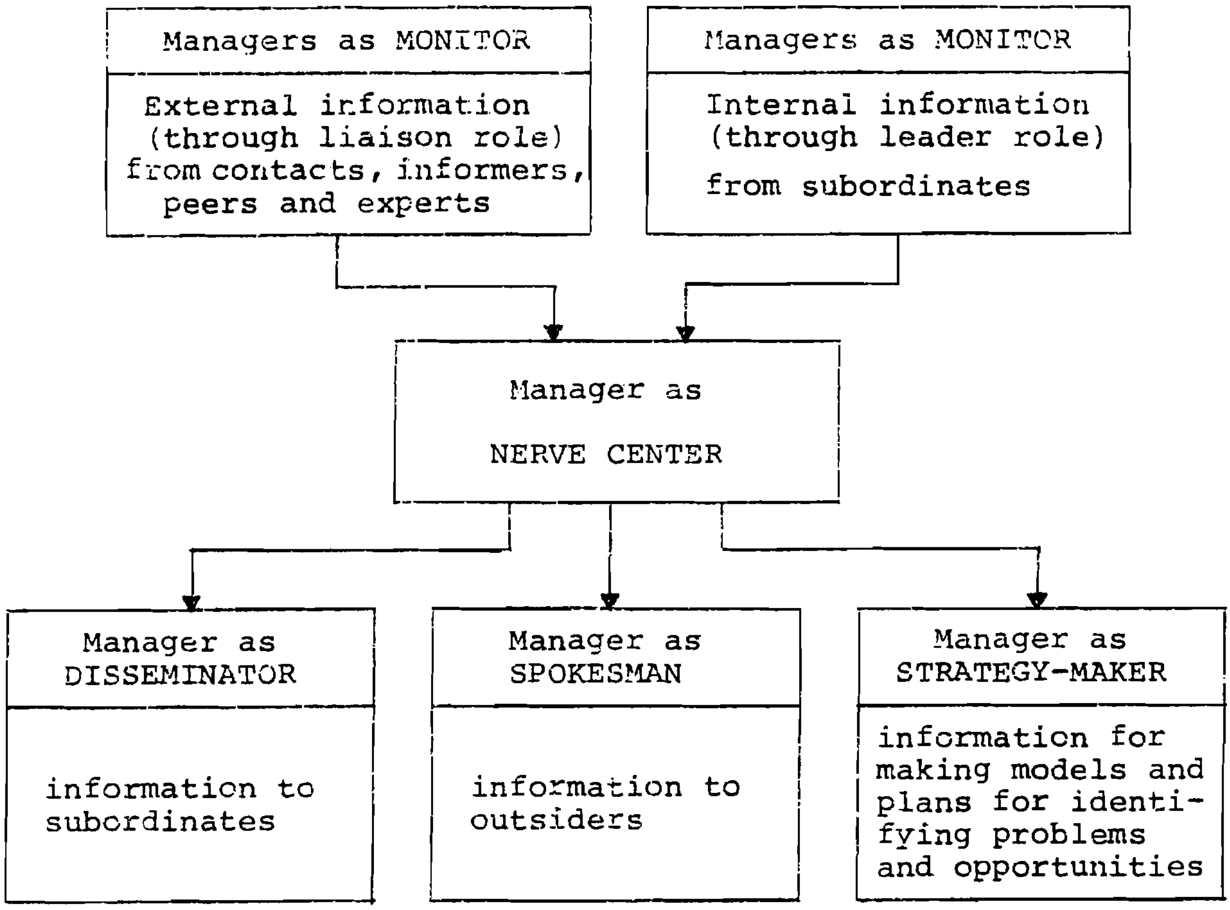

Figure 5. The Manager as Information Processing System

1. Factual information from many sources;
2. Value judgments from key individuals;
3. Discussion on proposed alternatives and their ramifications;
4. Anonymity in voting or discussing such issues, so that middle managers do not feel inhibited about criticizing the ideas of their superiors;
5. A way to determine a general consensus within a short period of time, when a decision must be reached.

An intra-organizational communication system might help to fill the above needs, by providing means to structure and categorize the communications flow.

Let us be more specific about our use of the term "communication."

In Figure 6 we present a simple taxonomy of communications (suggested by R. Lee, personal conversation). Here there are two major parts of information communication, namely verbal and non-verbal (which includes facial expressions, voice intonations, etc. and comprises 50% of the communication in face-to-face interaction (Uhlig et al. 1979)).

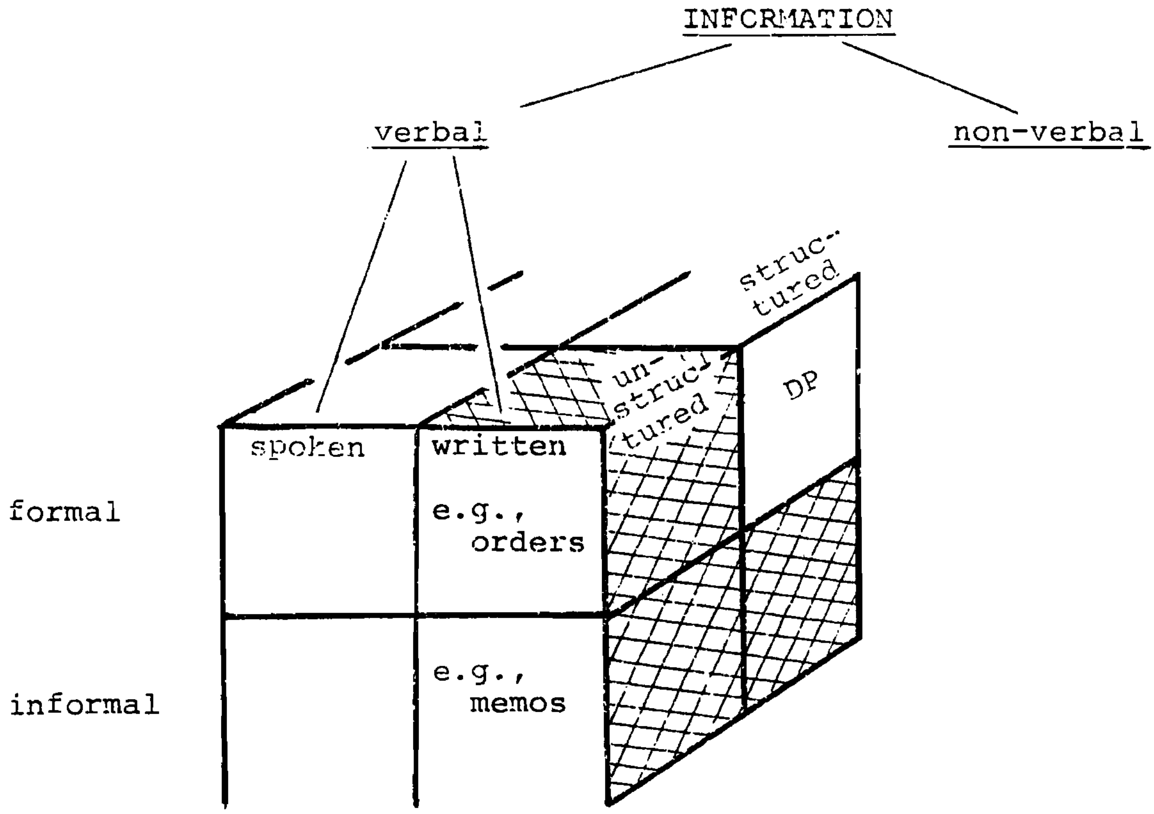

Figure 6. Types of Communications

The former can be further subdivided into spoken and written communications which, in turn, may be formal (e.g., orders, reports, etc.) and informal (e.g., memos, messages, comments). Again, written communications may be given another dimension which categorize it on unstructured and structured communications.

Conventional data processing (DP) concentrates mainly on structured formal communications, e.g., sales and purchase transactions. Communication of non-verbal information is unlikely to be affected by the IICN. Its focus in this taxonomy lies in the verbal part. In other words, the aim of the IICN is to help a manager in his unstructured verbal communications (written and to a certain extent, spoken).

To show that conventional DP has difficulties in helping the unstructured managerial communications refer to Table 1 below.

The table shows the information flows (measured by the numbers of computerized summaries on different items) provided by the USSR Information system "APPARAT" in different levels of management (Dudorin et al. 1980).

It can be seen that this system based on DP is best suited for the low-level management. However, higher in the organizational hierarchy, where managerial communication activity

Table 1.

Subdivisions	Number of computerized summaries		
	Sections, Offices	Shops, Departments	High-level management, Directorate
Short-term planning	22	3	--
Materials and equipment supply	41	11	4
Technical and economical planning	9	4	5
Bookkeeping	21	--	--
Technological support	21	14	2

becomes less structured and more heterogeneous, less support is provided by this system.

An interesting study was made by J.H. Carlisle (Infotech International 1979), who interviewed 34 senior managers and experts in three departments of a European multinational corporation to find out their attitude towards the office automation systems (as part of broader IICN). The conclusions were as follows:

-- desire and expectations on the part of management to find ways of improving their effectiveness were high.
-- there were 21 applications areas identified in which office automation was expected to make a significant and cost-effective contribution to managers and professionals.
-- interest in the prospects of office automation seemed to be high although the awareness of technological options was low (emphasis ours).

When referring to the above table, reference (Dudorin et al. 1980) also stresses that the awareness of the urgent needs and appropriate tools for helping a high-level manager in his unstructured communications is now becoming stronger in the USSR.

So, the general statement seems to be that managers consider their communications needs to be serious, and are actively interested in technological assistance to these problems. However, by and large, they are rather uninformed about the options available.

In the balance of this paper, we hope to remedy this somewhat.

III. THE MANAGER'S NODE IN AN IICN

Before getting to the discussion of the design of integrated-services intraorganizational communication network let us speculate on what manager's work station as an IICN node will look like in the near future.

Nowadays a manager might have an intelligent microcomputer and stand-alone terminal to retrieve his personal files and to help him in decision-making. The terminal might even be connected to a host-computer providing access to organizational data bank. For example, in the Institute for Systems Studies (Moscow, USSR) the head of a department can call a computer program "PLAN" and see at his display each of the personnel assignments at the present moment: who is to submit a scientific report, who is to start preparing to a conference, etc. Upon calling another program "ISKRA" he is able to place orders in a standard format and have it disseminated within the department.

Still next to these intelligent devices you are sure to see at a manager's desk a telephone connected to a separate switched public telephone circuit, where approximately two thirds (Infotech International 1980b) of all phone calls fail to reach the desired person. And though various PTT's now offer a number of advanced telephone services, e.g., store-and-forward calls, automatic dialing of voice calls, automatic answering, etc. the usage of these features is very low (Infotech International 1980b) perhaps because they often require complicated operating procedures--the result of attempting to handle sophisticated things with too simple a device. Consider, for instance, the following example (quoted in Infotech International 1980b):

> <u>To transfer outside call to another extension:</u>
>
> If you wish to transfer an outside call to someone else in the building, advise the caller that you are going to transfer him. Press the recall button of your telephone and when you hear a dialing tone, dial the internal extension required.
>
> When the called extension answers, advise him that you are transferring an outside call. The called extension must then press his recall button to connect himself to the outside caller. When you hear an engaged tone, the call has been transferred satisfactorily.
>
> Only then replace your receiver.
>
> NOTE:
>
> You CANNOT transfer an outside call until the required internal extension has been answered.

When receiving an outside call from an internal extension, remember to press the recall button to connect yourself.

If you are in difficulty, you can ask the Switchboard Operator to transfer the call by pressing the recall button and dialing "Ø". Advise the Operator of the name of the person OR the extension number that the caller requires. Then replace your receiver.

We recommend a more general approach to such problems: incorporate in a manager's work station a device converting analogue voice signals to a digital form (with the possibility to store and retrieve it as conventional digital data) and transmit it through the same communication line together with the data from the terminal or computer. (Due to the limited distances of intraorganizational network it is reasonable to have the special communication channels, say fiber-optics or coaxial TV-cable, which are more expensive than usual ones, but have better quality and capacity.) Then to build special communication software which would handle these "integrated" messages. Adding here a device for digital coding of images, those messages would also be able to carry graphical information.

Now, what would a manager like his future office work station to look like? As we suggested, it ought to be able to send, receive and store communications in any of text, voice, active video and static graphics forms. A schematic of such a work station is shown in Figure 7 (from IEEE 1978).

The system capable of transmitting voice, data and images in a digital form in one circuit will offer new services to a manager:

1. A manager will be able to handle a new kind of message--one consisting of text, graphics, and voice information.
2. A new possibilities will arise in sending diagram tables or written messages with a manager's spoken comments or refer to the video presentation, which can be accessed by the receiver.
3. The ability to associate text, graphics, and voice in a file will substantially benefit the area of computer-assisted briefings. It will be possible to have an ordinary "telephone" conversation and at the same time look into stored text. A manager will be able to see who is calling him by "phone" and maybe also the subject of the conversation on the screen, before he answers the "call." During the conversation he can make notes or bring up background material, or even store the whole conversation by the stroke of the key.
4. All incoming mail can be scanned into the system before being distributed physically. Thus, a manager won't need to send the copies around. Documents can

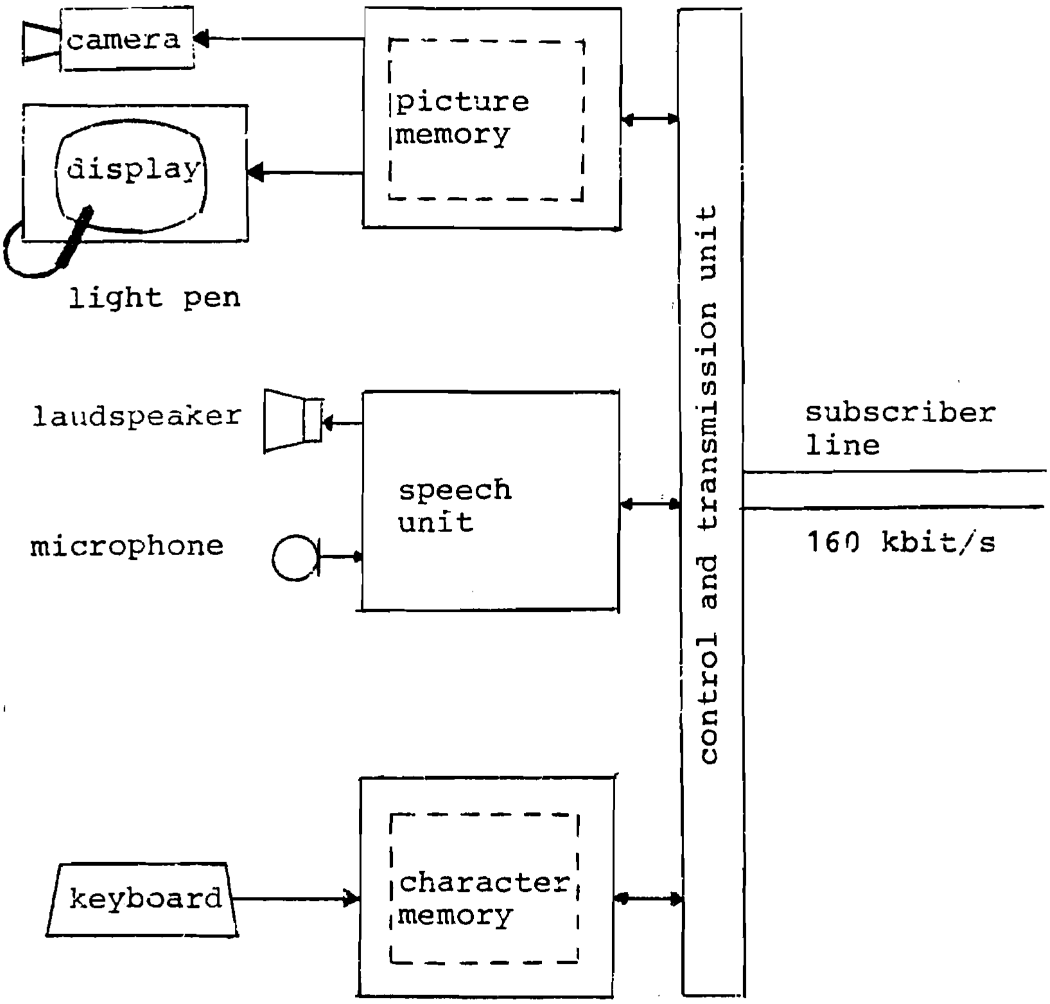

Figure 7. Block Diagram of IICN Manager's Work Station

always be referred to and brought up in a discussion without carrying them around.

5. It would be possible for a manager to use a voice input to the computer, or to the data retrieval device, store and retrieve the voice information, send a copy of conversation (store-and-forward calls).

Other advantages are likely to appear when a manager starts using IICN. But before it becomes possible the problem must be solved of how to interconnect all such work stations within the organization and to build software which will handle "integrated" messages in the IICN.

In the following chapters we shall discuss some technological problems of IICN design which might be of interest and concern to a manager.

IV. INTEGRATED-SERVICES INTRAORGANIZATIONAL COMMUNICATION NETWORK (IICN)

Integrated-services intraorganizational communication network interconnecting large numbers of very different types of devices including computers, manager's work stations, word processing facilities, etc.--must satisfy communication requirements in a very flexible way over a limited geographic area (typically less than two kilometers in diameter).

To be effective, it must be:

-- an integrated services network with increased mixing of voice, data and image communications;
-- a high speed network offering each of the possible hundreds of individual users sharing it relatively high information rates;
-- a network with simplified and standardized interfaces for an easy connection of new devices;
-- a network with imperceptibly small error rate supported by error-correcting procedures;
-- a network satisfying the requirements of confidentiality demanded by many of today's business environment.

V. IICN TOPOLOGY AND INFORMATION FLOW CONTROL

One of the major considerations in designing of IICN for a particular situation is the choice of its topological structure. Depended on this issue is the type of information flow control technique.

When discussing this problem we shall try to illustrate each case by the appropriate example. It should be noted, though, that there have been no known examples of implementing in full the IICN concept proposed here. However in those described below there are some features that can be used in the IICN design.

For any local communications network, there are basically four basic architectures (see Figure 8).

1. A star network built around the central controller as a message-switching system providing an intelligent interface to the changing applications, services and networks. The star is the most suitable topology for a system using one processor and several work stations. The links in a star network could be cables such as telephone lines, or fiber optics. In this case, each of the devices connected to the star can transmit whenever it has information. The data are stored by the central switch until the intended destination is able to accept the traffic.

As an example of applying a star topology in an integrated local network let us consider Kyoto University information-processing network (Kuipnet) (Kitazawa and Sakai 1978). The traffic in the network consists of:

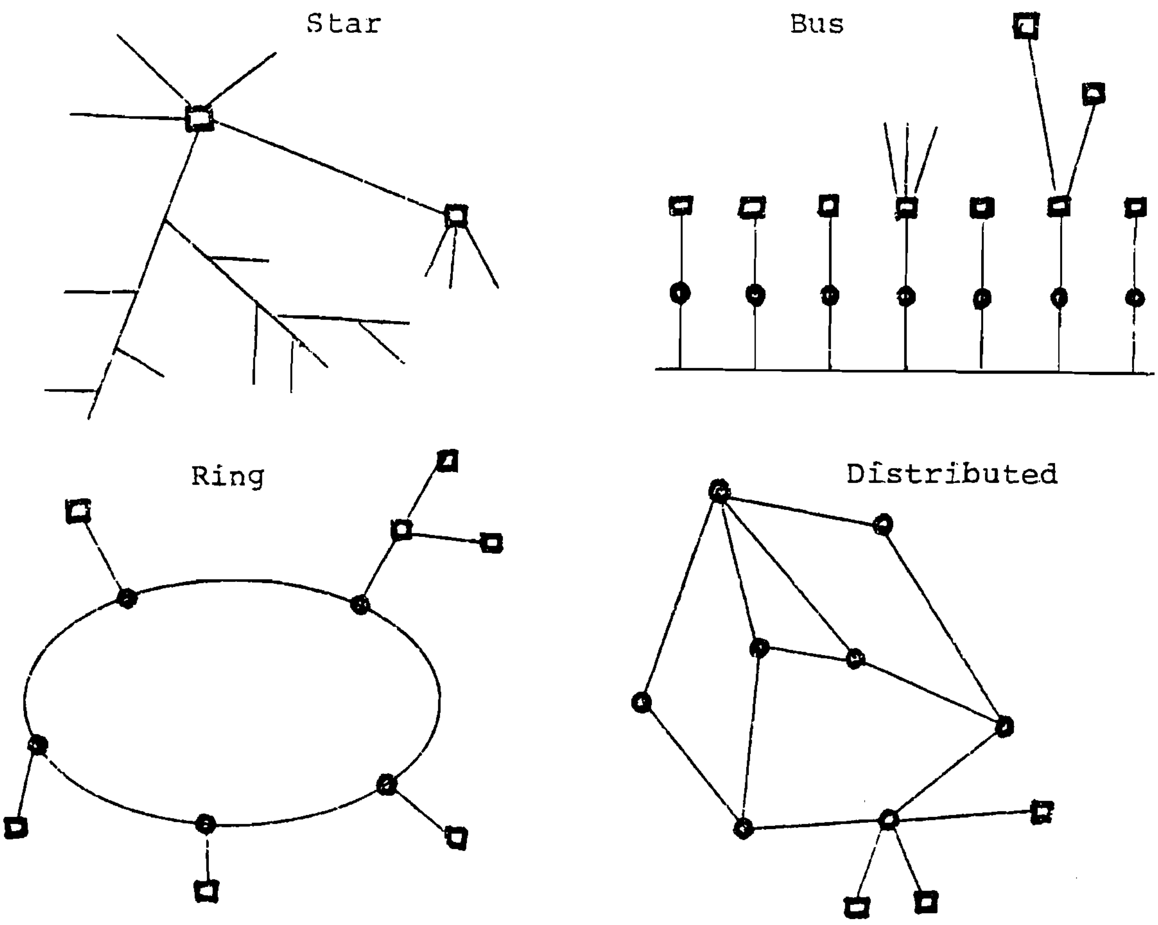

Figure 8. IICN Topology

-- data, program in digital form;
-- speech signals;
-- line drawings, figures, and gray-scale or color photographs.

Figure 9 shows the 1977 Kuipnet configuration, including six local heterogeneous computers with peripherals connected to a switching computer (interface message processor--IMP) through high-speed (1,6 Mbit/sec) lines.

IMP handles two different types of messages: characters and raw data. The first include source programs, object machine codes, line printer output, etc. A message of raw data is data of video sampling or speech. Since the continuous speech data should be transmitted at more than 200 Kilobits per second (Kbps) average rate they are given a higher priority than the ordinary data character.

Kuipnet is using a customized IMP, but for the wide spread of IICN an off-the-shelf, standardized message-switching device is needed. A good step to it is the introduction of computer-controlled private branch exchanges (PBX), which employ standardized pulse-code modulated time-division multiplexed (PCM

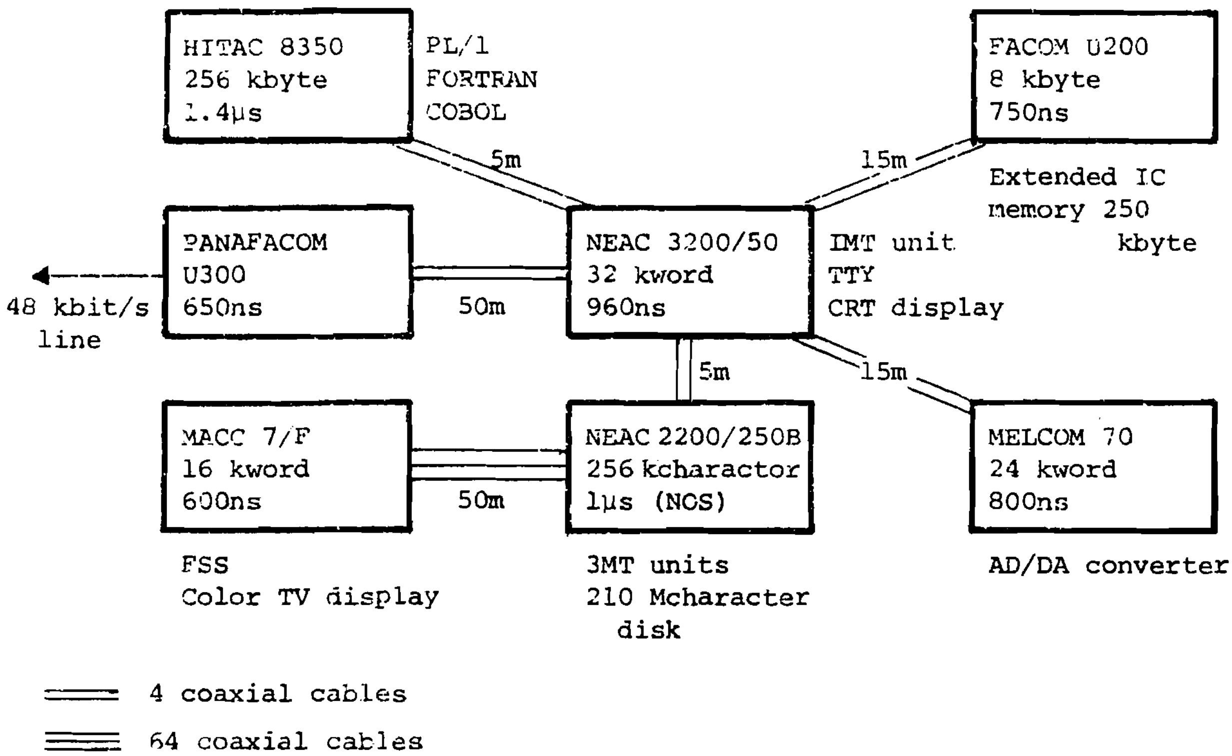

Figure 9. Kuipnet Configuration (December 1977)
(W=16 bit, B=8 bit, character=6 bit, FSS--flying spot scanner, TTY--teletypewriter)

TDM) techniques, affording a compact and rapid switching infrastructure for bit stream of typically 64 Kbit/sec. It is a sampling technique, in which the analogue signal is sampled at discrete time intervals, the measured analogue signal's ampitude is digitized into a binary number and the result is transmitted as part of a bit stream through the circuit. At the receiving end the reverse process takes place, where the coded data creates a voltage ampiitudes to reconstruct the original signal. Because of the wide bandwidth of a usual cable pair it is possible to time multiplex in one line a number of 64 kbit/sec voice channels (typically 30) (Infotech International 1980b). The modern PS&X is transparent to the information that flows through it--i.e., it can handle both voice, data and images in a digital form.

One of the recent implementations of such a device is ITT 1240 digital exchange for voice and data in its integrated services Network 2000 (Cotton and Lawson 1980). A distributed control structure, incorporation of special purpose LSI (large-scale integration circuits) and commercially available microprocessors, a modular approach provide simple implementation of design changes for technology and for the offering of new services.

The core of the digital exchange is the switch element (constructed from 16 identical LSI chips), which implements time and space switching functions. And when, for instance, A wants to connect to C, and B wants to connect to D, this element knows that C must sample A's time slot, and D must sample B's. The structure of each of the chips which form a switch element is illustrated in Figure 10.

ITT 1240 software has been designed to cover the full traffic range and telecommunications needs that include voice, data, rural, local transit and toll applications.

Software is written in the CCITT high level language called CHILL derived from concurrent PASCAL and is executed as concurrent processes by the operating system. In addition a finite state machine language (FSML) has been developed for control programs.

ITT 1240 switching processor operating system (Figure 11) supports concurrent communication processes. The primary functions of the operating system are to

- -- provide a dedicated virtual processor for each process;
- -- provide communications between processes by passing messages;
- -- provide timing when necessary;

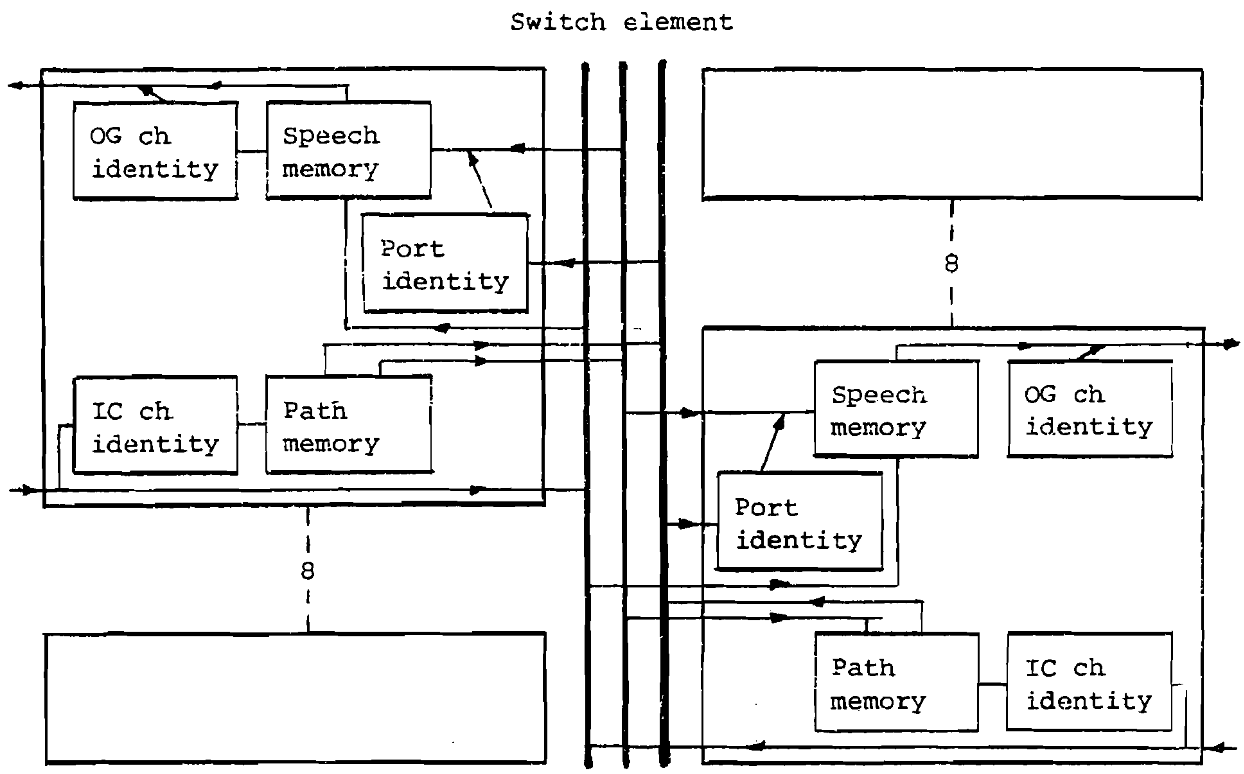

Figure 10. One of the 16 Inlet or Outlet Port LSI Chips that Together Form a Switch Element

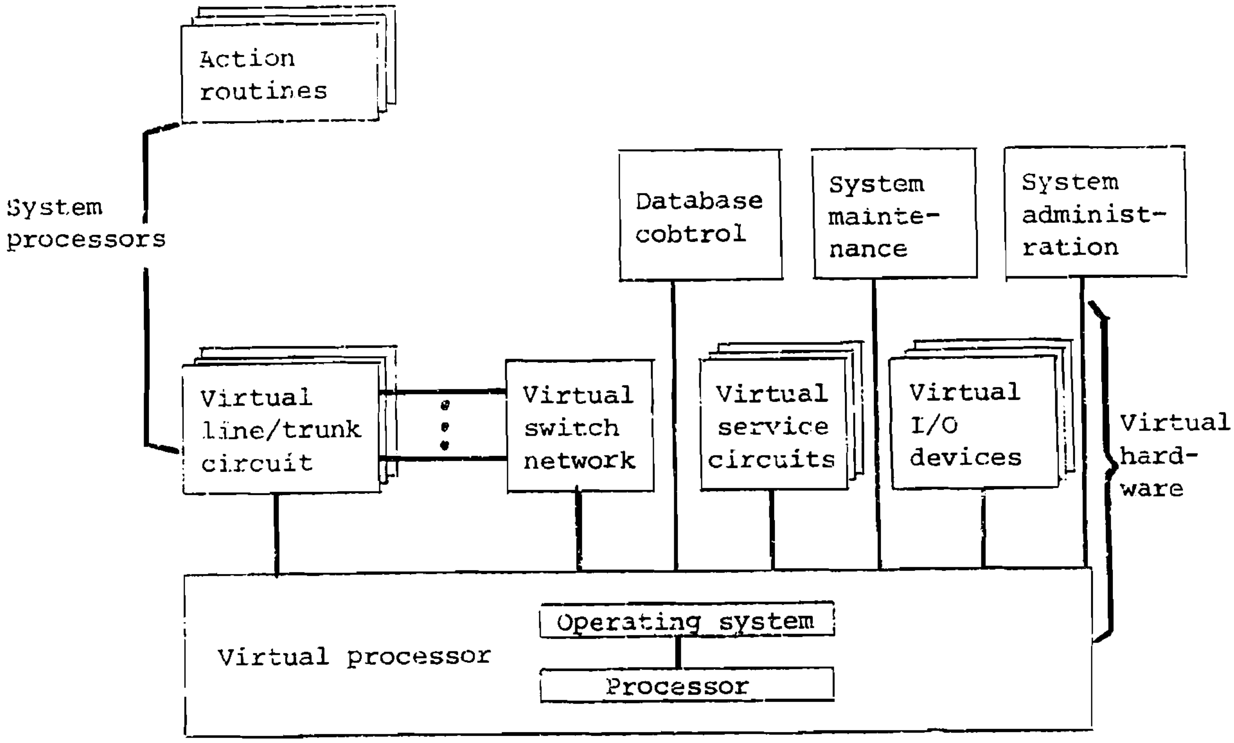

Figure 11. Block Schematic of the Basic Switching Processor System

-- provide for the creation and destruction of processes;
-- allocate system resources such as memory and processor time.

Figure 12 shows the block schematic of the ITT 1240 exchange.

2. A ring (loop) network (Figure 13) which interconnects all devices on one circuit. In this case data flows sequently around a single transmission loop connecting the communicating facilities.

The main advantage of such systems is that the highest volume of traffic between nodes goes purely on the local system--without requiring the use of any common carrier facilities.

The ring system is capable of high-speed communications, and allows an easy attachment of the new devices if only the proper and highly reliable interface is developed. Ring interface must have some means of disconnecting itself from the ring in case of failure not to break all the communications in the network.

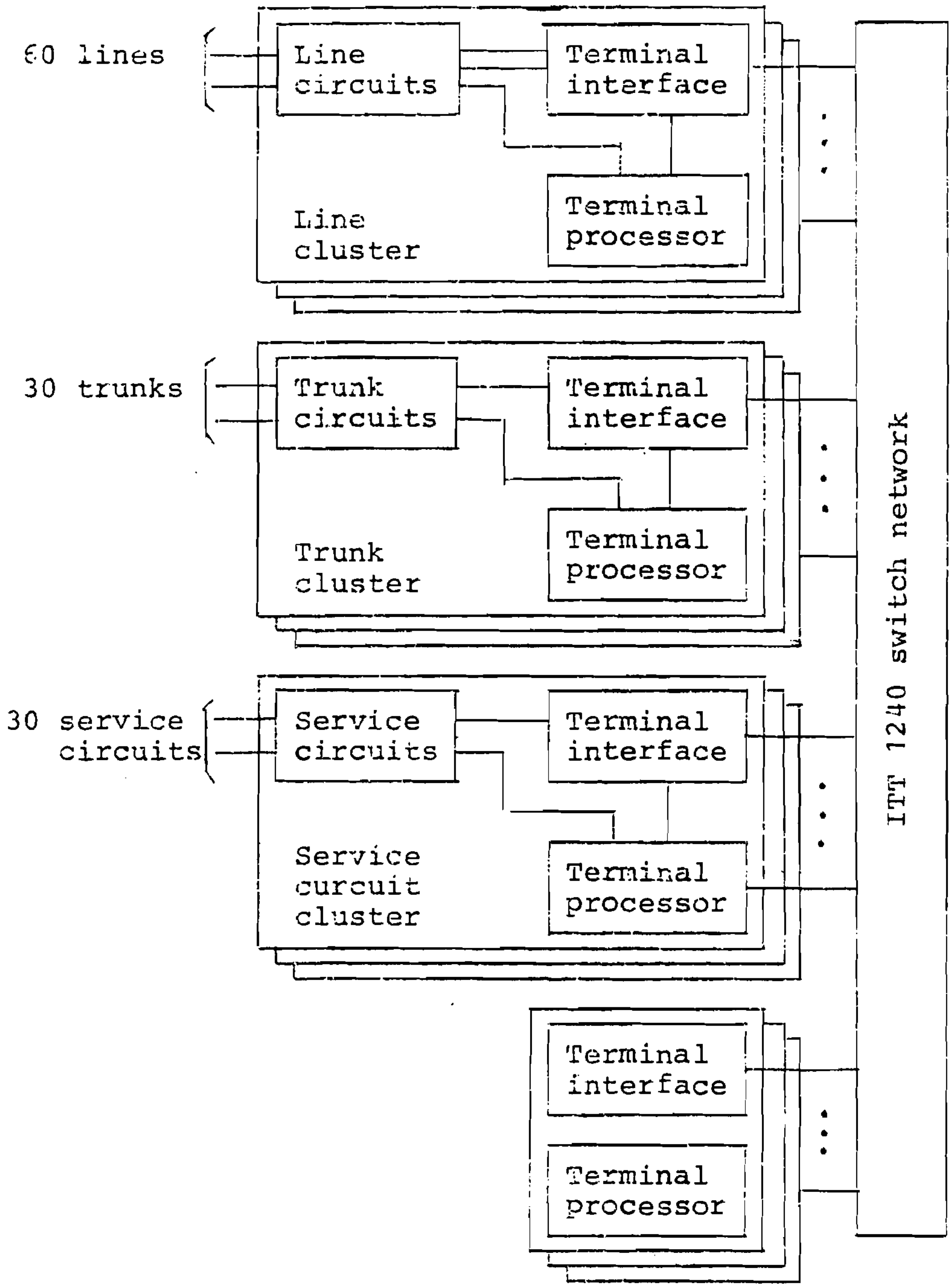

Figure 12. Block Schematic of the ITT 1240 Exchange

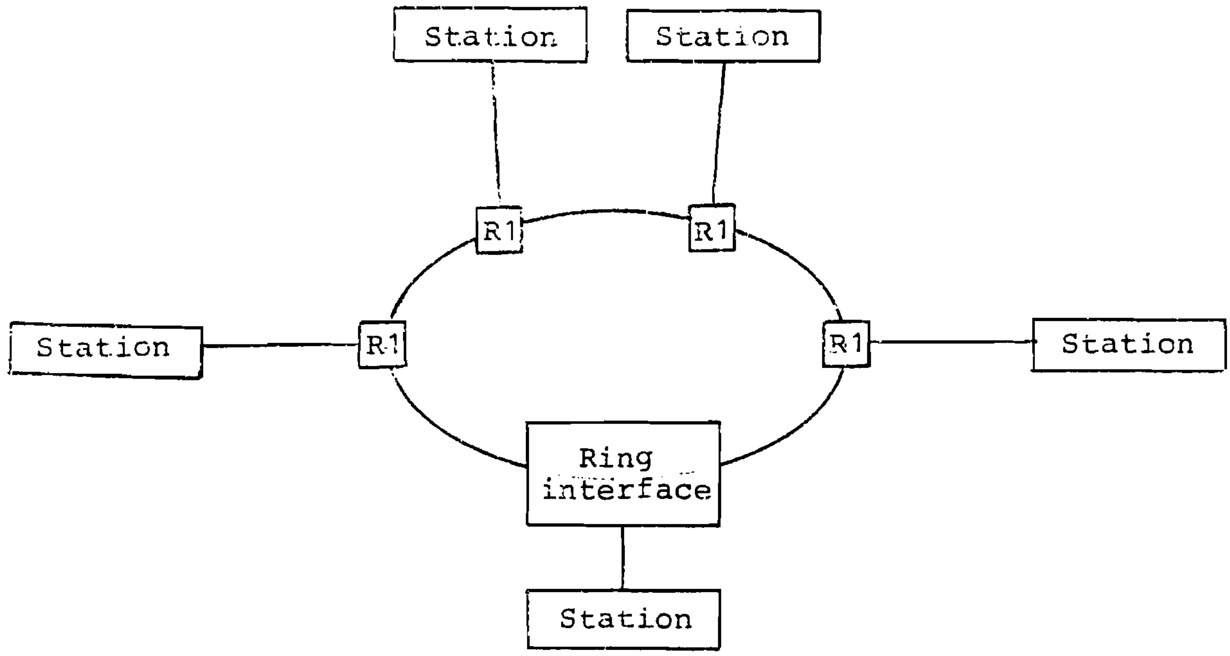

Figure 13. Ring Network

The most common control strategy in such systems involves message "trains" traveling round the ring at high speed, with the ring interface examining the address on each of these messages to determine if it is subscribed for the station attached to that particular ring interface. If so, the interface then copies those messages off and marks them as having been read. At the end of the string of messages there is a control token indicating the end, and at that point the ring interface can append a new message to the "train." When the message gets back to the originator, the originator removes it from the stream.

Similar technique is applied in the integrated communication system which has been built at the University of Ljubljana (Yugoslavia) (Figure 14) (Denning 1979). This integrated digital loop system (IDLS) controlled by microprocessor connects up to 225 user terminals (T) with the help of (digital) exchange E through the two-wire symmetrical line in the closed loop. Each terminal has its own A/D or D/A converter using delta modulation technique at 64 Kbit/sec.

The message "train" is circulating around the loop at 2048 Kbit/sec, bearing the control information necessary to establish junctions between the terminals (30 junctions are possible at the same time according to the number of translators (TR) used) and connect the terminal to a certain information channel. The format of transmitted information in IDLS is shown in Figure 15.

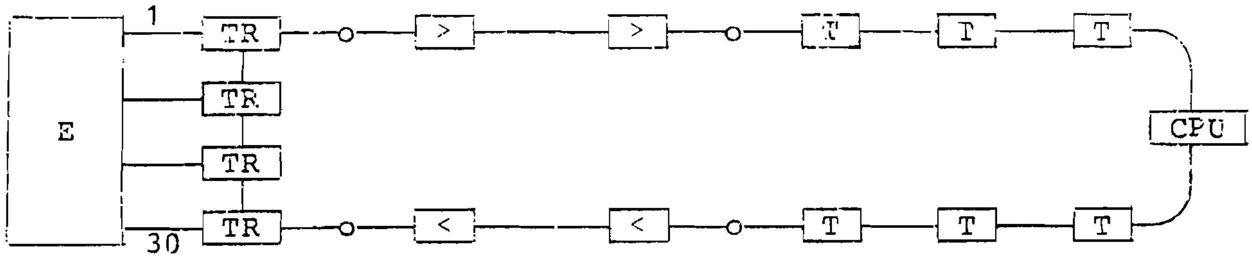

Figure 14. Connection of Terminals to the Exchange E with Integrated Digital Loop System (IDLS)

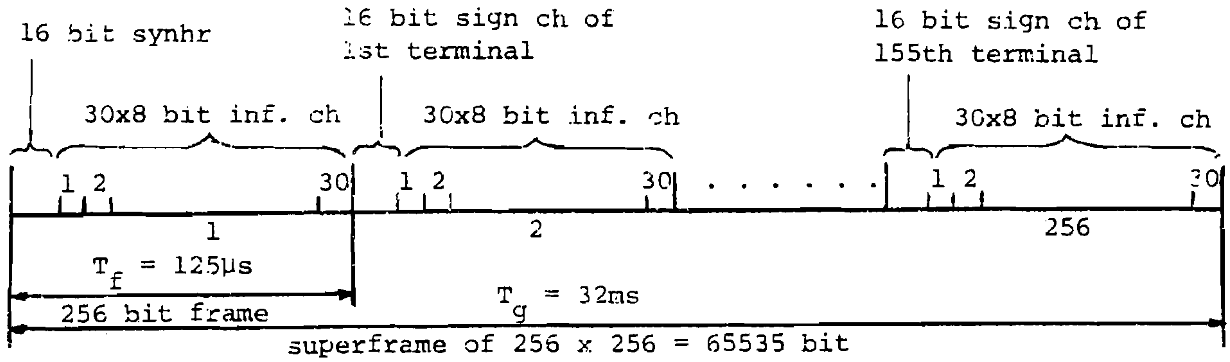

Figure 15. Format of Transmitted Information in IDLS

It consists of one superframe with 256 frames, each divided into 32 eight-bit channels. The first two channels in the frame are used for synchronization and signaling and the rest (3-32) are the information channels. Each terminal gets the control signals every 32 ms and is able to receive or transmit data every 125 μs.

The most attractive features of the IDLS are as follows:

-- the possibility to integrate the transmission of voice and data;
-- intensive usage of commercially available LSI's;
-- the calculated cost per subscriber is smaller than in conventional star networks, also because only the broad-band digital line of PCM system is needed (IEEE 1978).
-- easy expandability.

Still one of the drawbacks of the IDLS is the usage of delta modulation (DM) in analog digital coding which makes it difficult to solve the problem of its compatibility to existing digital systems since DM is not internationally standardized.

3. A bus network, in which data is broadcast to all devices with no closed loop in the transmission facilities.

The most common way of controlling the information flow in bus networks is to use a contention technique (though it may also be applied in other topologies), which allows the devices to be free to transmit whenever they have information to send. Should some of the terminals transmit simultaneously and their messages destructively interfere ("collision")--this can be detected by e.g., the central station when analyzing the checksum at the end of the transmission block--they fail to receive the transmission acknowledgment within a given period and would try to retransmit. In order to reduce the number of collisions special provisions can be made in the protocol (Figure 16, Infotech International 1979). One is called "listen before talk," or "corrier sense multiple access" where the device looks at the circuit to see if another station is transmitting before trying to transmit. Because of a propagation delay there is still can be collisions but efficiencies in the range of 80% to 90% can be achieved. If you can provide the detection of collisions after the transmission has begun in order both devices could immediately cease transmissions and retransmit at a later time ("listen while talk"), the efficiency may be raised to above 90%.

The first system that fully implemented the improved contention technique was the Ethernet developed at the Xerox Palo Alto Research Center (Metcalfe and Boggs 1976). Though this network is not actually an integrated-services information system because it was designed to carry only digital data packets among personal minicomputers, printing facilities, large file storage devices, etc., its example can be further applied to the future-integrated services intraorganizational networks.

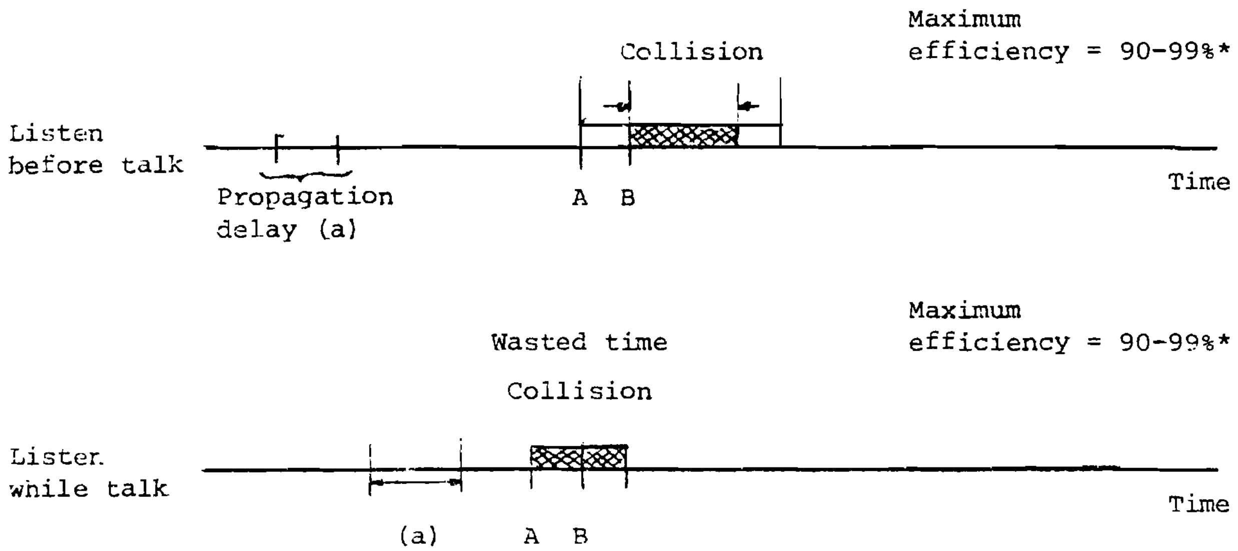

Figure 16. Contention Techniques

Ethernet is a system for local communications among computing stations (Figure 17) connected through the transceiver to the tapped coaxial cable that typically operates at transmission rates between 1 and 3 Mbit/sec. Information flow control is completely distributed among stations, with packet transmissions coordinated through statistical arbitration.

The Xerox Corp. has implemented some 30 of these local networks with hundreds of stations connected to the cable. When the cable distances get too long or the number of stations on a single cable gets so large that collisions are taking too much bandwidth away an extra piece of cable can be added with a repeater (see Figure 17). Adding the filtering capabilities to the repeater allows to reduce greatly the traffic on each cable segment by passing through messages not subscribed to this segment thus practically removing the limit on network expandability.

4. Generally distributed network, in which several paths exist between communicating nodes but not all nodes are connected directly to each other. Among the advantages of such a network is the possibility of paralleling the physical topology of large organization, averaging of traffic, high reliability, but it requires all the sophisticated routing, addressing, and control structures of a long-distance network.

It is difficult to predict the result of applying this type of architecture and corresponding control procedures in the IICN, and at the first state this complex communications architecture may be not the best way to go.

However, this architechture might be favored at the certain stage of IICN maturity solving the problem of a high traffic and sophisticated communication structure of the organization.

VI. IICN PROTOCOLS AND INTERFACES

Data communications within the network are controlled by several layers of protocols, i.e., that sequence of commands used for governing the actual transmission of data. The layered architecture model (Accarno et al. 1979) which can be applied in the IICN organizes in hierarchical levels all possible functions necessary for the correct exchange of information between two entities wishing to communicate by means of a communication network. The model comprises seven layers (that are not necessarily all present), which are subdivided into two sets (Accarno et al. 1979) (Figure 18):

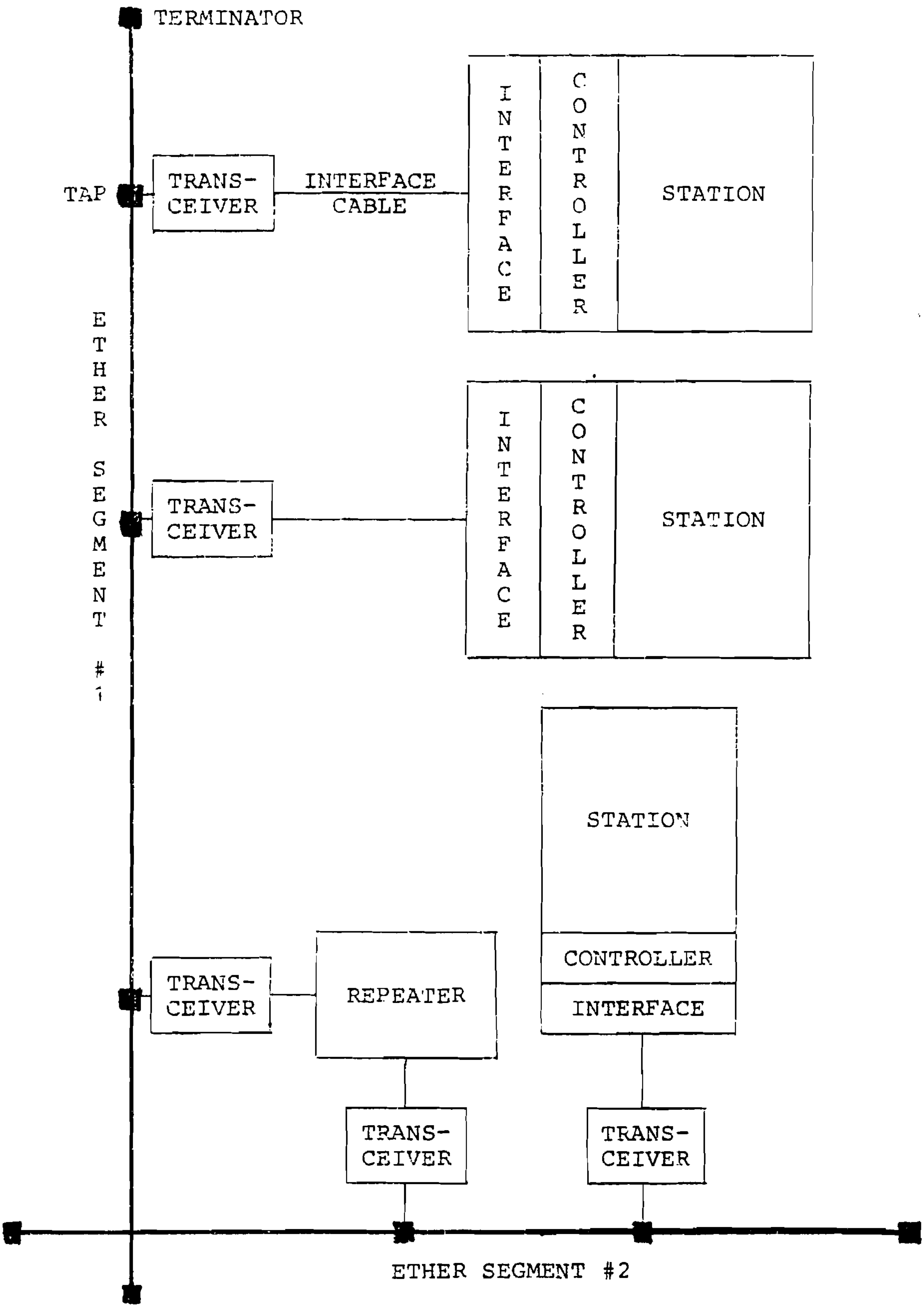

Figure 17. A Two-Segment Ethernet

Level number	Function	Examples	Responsibility
7	Application	Database Timesharing Electronic funds transfer Order entry	ISO
6	Presentation control	Data structure formats Virtual terminal progocol File transfer protocol	ISO
5	Session control	Session management	ISO
4	Transport End-to-end	Network independent interface	ISO
3	Network control	X25 level 3	CCITT
2	Link control	X25 level 2	CCITT
1	Physical control	X25 level 1	CCITT

Higher level protocols (levels 7–4)

Note 2 (levels 7–4)

Note 1 (levels 3–1)

Standard transport service (between levels 5 and 4)

Notes: 1. ISO for private networks
2. CCITT for network services (ISO collaboration)

Figure 18. Data Communications Model Showing Procedural Levels

-- the user set, including
  - application layer
  - presentation layer
  - session control layer
-- the transference set comprises
  - transport layer
  - network control layer
  - link control layer
  - physical control layer.

Any layer (or level) is formed by a group of functions constituting a protocol at that layer. The layered architecture implies that the i-th level offers a service to the (i+1)-th level only and uses the services offered by the (i-1)-th level only. Thus, each of these layers is transparent to the layers above it.

The user levels allows the remote job or terminal user to exchange messages with his applications software, to access teletext databases or to store-and-delivery services, etc.

The transference levels refer to the signaling procedures to be used for customer access and interexchange control in communication networks. Transport (Level 4) comprises information offered by the three lower levels. Particularly, Level 3 refers to the protocol needed to route each call through the network, while Level 2 concerns the protocol necessary to employ any link (between users and network or between exchanges) within the network serving a group of calls. Finally, Level 1 specifies the electrical and functional characteristics, which guarantee the physical availability of links. All the protocols required are implemented by communications control software.

To successfully provide IICN users with increased services and to solve the problem of compatibility further development of internationally standardized protocols is required, as well as the adoption of a new "all digital" telecommunications network interface. One of the proposed approaches towards the construction of such an interface is shown in Figure 19 (Infotech International 1980a).

VII. CONFIDENTIALITY

Here we come to the most delicate problem of all those concerning the introduction of IICN which is to help and to a certain extent replace traditional ways of retrieving and disseminating information within organizations. A certain amount of confidentiality (depending on the organization) must be provided in any IICN if it is to be viable, to assure him that no "unauthorized" access to his message put into electronic transmission media is possible. Moreover, the user must be assured that his personal electronic file is at least as secure as the traditional paper one.

This degree of confidentiality is not always easy to achieve because, first, there are plenty of ways to compromise information in the IICN--from the erroneous address data output

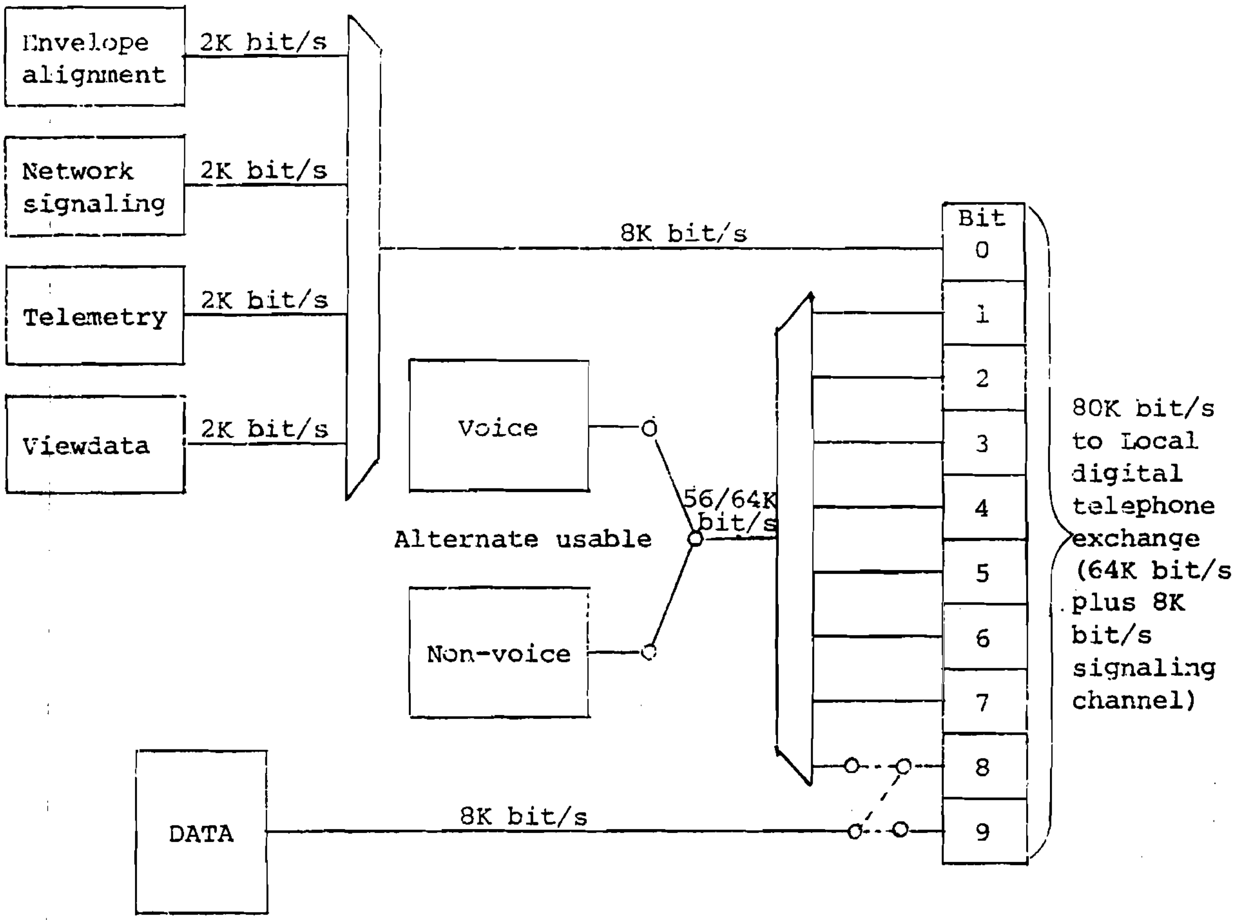

Figure 19. Integrated Services Digital Network--Possible User Interface

up to intentional tapping of the communication line,--and second, all security measures to some extent decrease the efficiency of the IICN and increase its cost.

Still one must think of confidentiality when designing an office IICN or else a manager will tend to distort data before it is fed into the system (Fick 1979).

So, to cope with the problem let us divide it into two parts: first, the IICN designer's problem of building a mechanism for information flow control and confidentiality within the IICN; and second, the user's own safeguards that make him responsible for his data security.

1. A Model

A fruitful approach towards the analysis of information flows in computer systems can be found in (Denning 1976). Applying it to the IICN case we will have the following.

Supposing we have a set N of logical storage objects capable of accumulating information within the IICN

$$N = \{a, b, \dots\}$$

Elements of N may be IICN users, terminals, I/O devices, files, etc. depending on the level of detail under consideration.

Supposing further that a set P of processes exists in this IICN resulted from (sequences of) operations that cause information to be transferred from one object to another

$$P = \{p, q, \dots\}$$

Copying, assignment, i/o, message sending are the examples of such operations.

Each IICN object a may be assigned to one of the classes C, denoted by $\underline{a}$, depending on the category of information stored in a:

$$C = \{I, II, \dots\}$$

For instance, different level managers may be assigned to different classes. Each process may also be bound to a class $\underline{p}$ according to the class of user owing p, or the history of classes for which p has had access.

To form a flow model the class-combining operator "$\oplus$" is defined which specifies the class of the result of any operation. If, for example, a new object C is created by combining information from objects a and b with classes $\underline{a}$ and $\underline{b}$ respectively, the class of C will be

$$\underline{C} = \underline{a} \oplus \underline{b}$$

Finally, a flow relation "->" between two classes, e.g., $\underline{a}$ -> $\underline{b}$, means that information in class $\underline{a}$ is permitted to flow into class $\underline{b}$.

A flow model

$$FM = \langle N, P, C, \oplus, \rightarrow \rangle$$

defines the confidential IICN if execution of a sequence of operations within the system cannot give rise to an information flow that violates the relation "->". For instance, if information from objects $a_1, \dots, a_n$ whose classes are $\underline{a}_1, \dots, \underline{a}_n$ respectively, is sent to object b with class $\underline{b}$, then

$$\underline{a}_1 \oplus \ldots \oplus \underline{a}_n \rightarrow \underline{b}$$

must hold.

Incorporated in the controller which checks all information flows within the system and cancels those not satisfying the relation "->", this mechanism allows to maintain confidentiality in the IICN.

2. Encryption

The second part of a problem deals with providing an IICN user with a certain mechanism, so as he should not have to rely on facilities or the communication links of the IICN for the safety of his data and be responsible for the security of his electronic possessions.

It is possible to do with the help of an encryption device and hardware keys (Denning 1979, Matyas 1979). The encryption device implements public-key encryption schema (Denning 1979), where for a given plaintext (usual clear message) message M, the corresponding ciphertext C (encrypted message) is related to M by the relations

$$C = M^P \text{ and } P = C^S,$$

where

P denotes a public key, and
S stands for the private key.

Each private key pair is recorded on a pair of ROM (read-only memory) chips. So, to safeguard personal data, a user sets the switch of his encrypton device to his public P-key to automatically encipher all transmitted information. And after that it is computationally infeasible for anyone to decipher his information without acquiring his private S-key, which is engraved in a memory chip.

This concepts also allows to implement the digital signatures procedure which can be used by the message recipient to prove not only the identity of the message's originator but also the message's true content. Such signatures are computed function of (1) the message, (2) private information known to the originator, and possibly, (3) public information known to all parties.

In the IICN the most suitable way of validating digital signatures is through a third party, where every signed message communicated between sender and receiver is sent to an arbiter (Figure 20) (Matyas 1979).

Each user's signature-generation information must be snared with the arbiter to allow message and signature validation. The arbiter authenticates each message and signature, and communicates the result to the intended recipient.

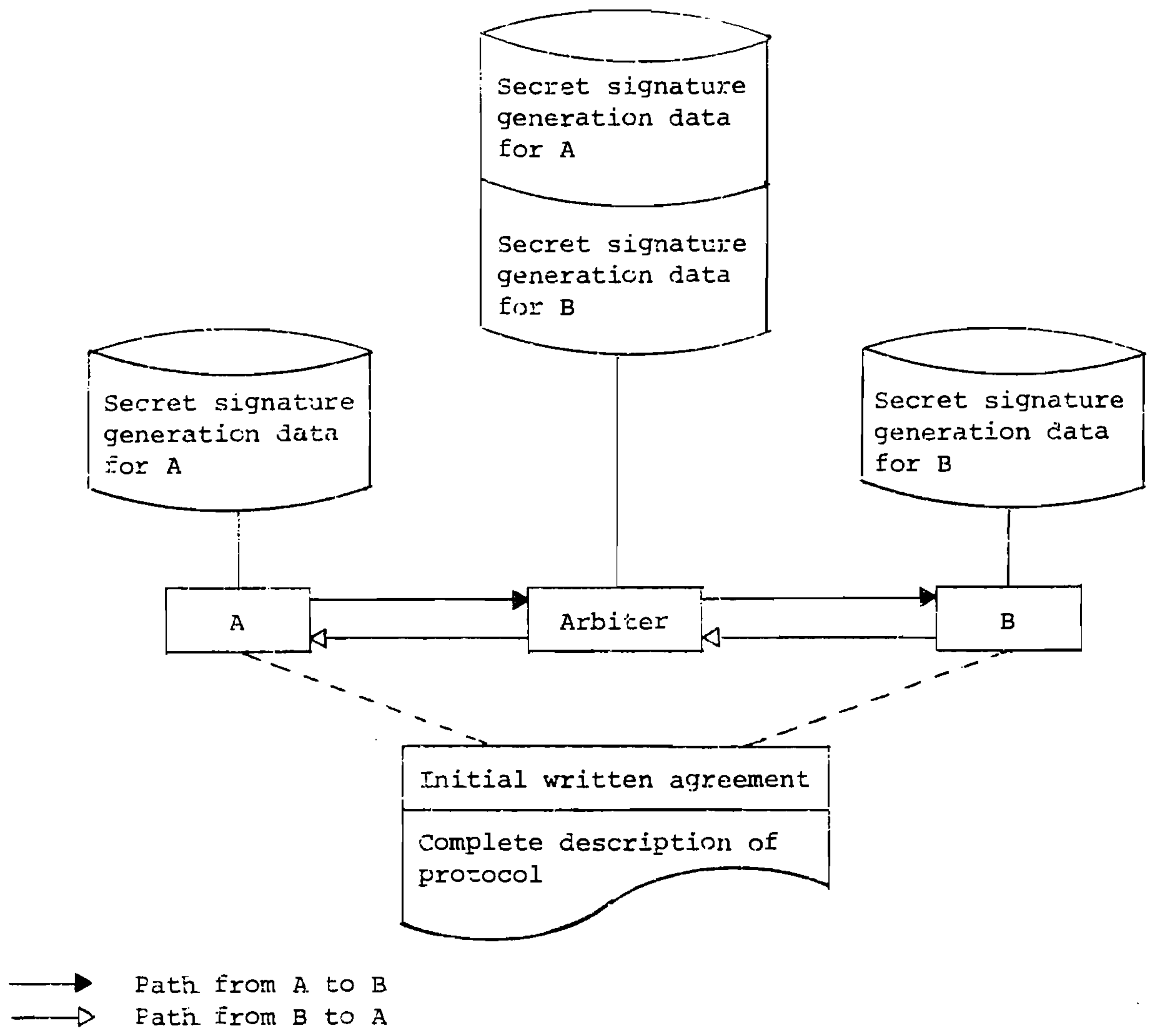

Figure 20. Digital Signatures via an Aubiter

With the recent advances in the field of LSI technology it becomes possible to get off-the-shelf encryption devices at reasonable prices, that meet the high speed requirements. Such devices are manufactured by Western Digital Corp., Texas Instruments, Motorola and some others.

VIII. CONCLUSIONS

Several software architecture design strategies to support management communications within an integrated-services intraorganizatonal communication network have been reviewed. The main results of the survey can be stated as follows.

1. Special attention must be paid to the communication problem when considering the convergence of computers, communications, and office automation in the design of the future electronic offices, since a lot depends on establishing effective communication paths within the organizations which help to integrate electronic as well as human resources.

   The aim of the IICN approach is to help a manager in his unstructured verbal communications. IICN will connect all manager's work stations in one circuit integrating voice, data and image communications.

2. All communications must be supported by the appropriate software providing a number of special features in comparison to the long-distance networks software:
   -- increased mixing of voice, data and images
   -- higher transmission rates
   -- lower delay
   -- lower error rates
   -- greater use of multi-address communications
   -- simplified and standardized interfaces for easy connection of new devices.

3. The most probable topological structure on the first stage of IICN development will be that of a ring or bus types depending on the particular situation.

4. A certain degree of confidentiality must be provided in an IICN and the best way of achieving it seems to be through supplying a user with an encryption device to safeguard his own data and leave the problem of monitoring all information flows to the IICN administration by means of special controller.

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