LOCAL AREA NETWORKS

P. Zafiropulo
IBM, Zurich

Pitro Zafiropulo is a staff member at the IBM Research Laboratories at Zurich. He joined IBM in 1968 and has worked on protocol validation, synthesis, integrated networks, network reliability, PABX's and speech recognition.

Local Area Networks are intended to provide improved communication capabilities such as high data throughput rates, low error rates and ease of connection among terminal stations and computers. These new types of networks operate within a limited geographical range like an establishment, campus or building and are owned by a single organization.

The presentation introduces these networks and the main techniques are described. It then proceeds to evaluate the main switching techniques as they apply to LAN ring and bus configurations. The preferred technique of token-ring distributed switching is identified.

(Paper not received)

The contents of Mr. Zafiropoulos's talk was somewhat similar to the paper of Mr. Kummerle, which is therefore included in these Proceedings.

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LOCAL-AREA COMMUNICATION NETWORKS — AN OVERVIEW

K. Kümmerle

IBM Zurich Research Laboratory, 8803 Rüschlikon, Switzerland

Abstract: Local-area communication networks represent a new field of activity. In this paper we first describe three scenarios for the use of these networks, and then discuss various technical approaches. Particular emphasis is put on bus and ring systems with various media access control mechanisms. Specifically, we compare the delay-throughput characteristic of two access methods, carrier-sense multiple access with collision detection and token passing, and discuss some significant differences of bus and ring systems concerning wiring, media, transmission, and reliability.
1. Introduction

In the seventies, major activities in networking were focused on private and public data networks using either circuit and packet-switching technology or integrating both switching methods into a single network. In this time frame, also most manufacturers of main frames defined and implemented network architectures, e.g., [1-3], ISO started work on the reference model of the Open-System Interconnect Architecture [4], and CCITT recommended the X-series of interfaces [5].

Local-area communication networks represent a new field of activity which can be viewed as an extension to data networks for making packet-switching technology widely available to the in-house domain. Currently, much research and development work is being pursued in this field, both at universities and in industry. The term local refers to communication on the users premises, i.e., within a building or among a cluster of buildings.

A typical example of a system widely used today for local data communication is depicted in Fig. 1: sets of terminals are attached to control units and these are tightly coupled to a processor via I/O channels. The terminals are not intelligent and the necessary control functions are provided in the control unit and shared among a set of terminals. This leads to low attachment costs per station. There are, however, three shortcomings/problems with systems of this category: i) since the control units are channel-attached, they have to be physically located in the computer center for transmission reasons; ii) the star-type system structure requires an individual coaxial cable for each terminal. This and the previous fact may lead to the well-known problems of crowded cable ducts and difficult

Fig. 1. Star system for local data communication
system expansion, particularly for large installations, and iii) terminal switching is usually not available. This implies that if a user wants to work with software systems residing in different host machines, he has to be connected to more than one controller where each one is associated with a different host.

Switching would have to take place manually at the station. The undesirable features of the approach are the number of control units required and the cabling problem.

Another possibility to provide the flexibility referred to in iii) above is the remote attachment of stations. This means to make use of system architectures and network technologies as developed for TP applications. Fig. 2 is an example of such a network.

Long-haul or TP networks can be characterized by the following technical facts which, as we shall see later, give them different characteristics compared to local-area networks. First, communication lines represent an expensive commodity and therefore we have the design objective to optimize utilization of the transmission capacity. Second, the data rate of TP lines is in the range of 2400 bps to 50 Kbps. This means that the speed of processors either attached to the network or used in switching nodes is high compared to the data rate on transmission lines; the consequence being that processors in network switching nodes have time to perform functions which ensure error-free transmission and message integrity. These functions are performed in each switching node in the path between end points, i.e., hop-by-hop.
From the point of view of a system, irrespective of whether we have a network topology according to Figs. 1 or 2, current systems have a structure as shown in Fig. 3. Communication between terminal and host computer is provided by the front-end network, whereas communication between the host computer and its associated mass storage devices takes place through the backend network which in current installations degenerates to an I/O channel.

Transmission lines in the local domain, on the other hand, do not represent an expensive commodity and data rates in the range of 1 - 10 Mbps are readily available. The implication is that processors are no longer fast compared to rates on transmission lines. A potential consequence is that functions executed hop-by-hop in teleprocessing networks should be moved to the end points and executed end-to-end.

The availability of low-cost LSI/VLSI components is another driving force behind local-area networks from various points of view:

i) Network adapters can be provided at reasonably low cost, i.e., the cost advantage of using shared-logic controllers diminishes.

ii) Workstations/personal computers will have substantial amounts of processing capacity due to powerful microprocessors. However, it is unreasonable to expect the availability of sufficient mass storage, files, or high quality and powerful printers, e.g., laser printers, for each workstation for cost reasons. In the case of cost-effective hard disks
which could be afforded for each workstation, one might like to have them geographically separated from the workstation since they are noisy.

In Section 2, three scenarios will be discussed of how local-area networks can be used. Section 3 shows various possibilities of technical approaches. It also contains a description of several access methods for systems with either bus or ring topology. Finally, in Section 4, we provide some arguments for a system comparison.

2. Local-area network usage scenarios

The intent of this section is to illustrate how local-area networks are already being used or might be used in the future prior to discussing technical approaches. In the subsequent considerations, we deliberately do not address the question of whether these scenarios physically use the same or separate networks. It should be noted, however, that all scenarios represent a departure from the systems outlined in the previous section.

2.1. Terminal-to-Host Communication — Frontend Network

A first possibility to use a local-area network is for terminal-to-host communication. In this case, Fig. 4, the most important function provided by the network is allowing terminals to select a host machine, i.e., a capability generally not available in systems according to Fig. 1. Furthermore, the local network solves the problems of additional control units and of additional cabling between control units and stations. It should be pointed out that in this scenario, emphasis is on system flexibility rather than on exploitation of the high-speed communication facility. In this sense, the scenario of Fig. 4 can also be viewed as the migration of current equipment and applications to a
new network whose full functions can only be exploited by new equipment and new applications.

There is a problem which needs careful consideration: Should a terminal be attached direct to the network or through a control unit which it shares with other terminals? Apart from cost considerations, the answer will also be determined by whether one has the concept of a general wall plug in mind associated with the capability to readily move stations from office to office, i.e., to dynamically change the configuration during operation of the system.

2.2. Backend Network

Direct-access storage devices (DASD) are unintelligent in current systems, Fig. 3, and are tightly coupled to the I/O channels of their respective processors. Given a local-area network of adequate bandwidth, processors can be attached through serial I/O channels and communicate with DASD's through the network and also share them, Fig. 5. This implies some intelligence at the DASD for network-access purposes and for the execution of protection mechanisms. Besides the communication between processors and DASD's, a backend network can also carry channel-to-channel traffic. The system described in [6] is an example of a local-area network supporting the latter.

![Local-area network as backend network](image)

Fig. 5. Local-area network as backend network

2.3. Client-Server Network

The two preceding scenarios are powerful generalizations of today's system structures. The client-server network [7] shown in Fig. 6 represents the scenario currently being most discussed, particularly in the context of
office communication. The stations attached to the network are assumed to be intelligent workstations. Compared with the configuration described in Fig. 1, the attachment costs per station — as already mentioned — will only be slightly higher and be fully justified by the additional functions made available through the network.

These workstations, called clients, communicate through the network with functions, called servers, which can be implemented in a centralized or distributed way. Some examples of servers follow. For many workstations it will not be cost-justified to have a private data base. In this case, they will have to share the file system with other workstations. Key element of the file system is the file server which on behalf of the workstations stores and retrieves information. The transport of information between workstation and file server is achieved through a file-transfer protocol. Compared with the structure of current systems, Fig. 3, this scenario has remarkable, new features. Previously, the station had its application resident in the host computer where it was executed in a time-sharing mode, and the host computer communicated with the unintelligent direct-access storage devices. Now,
these functions are split. Application processing is performed in the intelligent workstation, and the intelligence in the host computer, required for controlling and communicating with the DASD's, got moved to the file server. The scenario shown in Fig. 6, in this sense, represents a step away from the world of time-sharing, potentially just as significant as the step from batch processing to time-sharing. We should like to point out, however, that in our opinion, this new scenario will not decrease the importance of the big data-processing machines.

Similarly, workstations will share high-quality printers, e.g., laser printers, which are attached to the local-area network via a printer server. Communication takes place only between workstation and printer server, most likely using the same file-transfer protocol. The printer server then has files printed on behalf of workstations. Other examples of servers are an electronic-mail server which allows workstations to exchange mail, and a name server with whom all stations have to register when they join the network. The name server allocates addresses to stations which register, and resolves names into addresses upon request.

We conclude the discussion of the client-server network with another functional capability it can support, Fig. 6. We assume that there are workstations with a common architecture but for cost reasons be optionally equipped with different amounts of RAM, diskettes and/or hard disks. Based on their actual configuration, they will depend on a central processing facility which will: i) download the appropriate software packages into the workstation through the network, or in other words customize the workstation, and ii) perform functions on behalf of the workstation.

Networks for process-control applications [8] or for use in the production-floor environment also fall into the category of local-area networks. Their special requirements and characteristics and how they relate to the scenarios discussed above will not be addressed here.
3. Approaches and classification

3.1. Technical Approaches

In this section, we shall briefly discuss possible approaches to local-area communication without making an attempt to predict which one will prevail in the future.

The best-known local communications system is the private automatic branch exchange (PBX). Most of the PBX's installed today are optimized for real-time voice, and use analog technology. The advent of computer-controlled private branch exchanges (CBX), implemented in digital technology and providing channels with the standardized speed of 64 kbps, paves the way for one approach to local-area networks.

CBX's have the potential to handle data, text, and videotex in addition to real-time voice. In this sense, it is an interesting idea to view them as an extension of the Integrated Services Digital Networks (ISDN) [9], currently being defined and studied for the public domain, into the local area. On the other hand, CBX's cannot be expected to cover the whole range of local-area communication since they are not suited to handle bursty computer traffic.

CBX's employ centralized switching with central control; the switching technology is circuit switching and from a topological point of view, they represent star systems. System proposals not based on CBX's but also using centralized switches are discussed in [10] and [11]. These switches use packet-switching technology instead of circuit switching, and therefore have the capability to handle bursty traffic.

Conceptually, the disadvantage of any centralized approach is the entry cost for small installations due to the use of centralized switching and control facilities. The alternative to centralized switching/control is to use a distributed control structure to regulate access to the transmission system. Topologies which inherently provide broadcasting, such as busses and rings, lend themselves readily to implement distributed access control,
see Fig. 7 and [12-14]. For both topologies, the functions provided in the set of network adapters A over which stations are attached, represent this distributed access-control system. It should be noted that all adapters are peer partners and that there does not exist a master adapter or a master station controlling access of the others.

This approach has important architectural consequences which become clear when we compare a multipoint system currently used for TP applications with data-link control procedures such as HDLC or SDLC [15,16] and a bus or ring system for local-area networks as being standardized by the IEEE Committee 802 [17]. These differences are represented in Fig. 8. In a multipoint system, the primary station has to poll the secondary stations before they can transmit a frame to the primary. From an architectural point of view, this clearly means that access to the transmission system is controlled with commands and responses of the elements of procedure of HDLC or SDLC. In local-area networks, on the other hand, the current data-link layer, level 2 in the ISO reference model [4], is split into two independent sublayers:
media-access control and data-link control. Media-access control is part of the distributed control structure mentioned above and determines, as the name suggests, when a station can transmit.

![Diagram showing primary-to-secondary communication](image)

**Fig. 8. Primary-to-secondary versus peer-to-peer communication**

It also allows peer-to-peer communication among all stations attached to the network and not only between primary and secondaries as before. The data-link control layer can contain any data-link control procedure and is no longer responsible for controlling access to the transmission medium.

The IEEE 802 standard activities on local-area networks in relationship to the complete ISO reference model is shown in Fig. 9.

![Diagram showing ISO and IEEE 802 standards](image)

**Fig. 9. IEEE 802 project and OSI**
A single bus or ring system will not be able to serve establishments with a large number of attachments. Therefore, the capability to interconnect bus or ring systems, called subsystems in this context, is an important requirement, Fig. 10. Subsystems are connected to the high-level network via elements called bridges. The high-level network can degenerate to a few bridges interconnecting systems direct in case only a few subsystems have to be linked. Otherwise, the high-level network may be again of the bus or ring variety or it may consist of a star network. An important feature of a bridge is that it only performs a simple routing function and buffering, but does not execute higher-level protocols for performance reasons. Access to other local-area networks or to the public domain is provided via gateways.

In the remaining part of this paper, we shall confine the discussion to bus and ring systems with distributed access control.

3.2. Classification of Local-Area Networks

This section provides a classification of subsystems and a brief discussion of several access-control mechanisms. An obvious differentiation is according to topology where we distinguish between bus and ring systems, Fig. 7. Within these categories, we can distinguish according to access methods, see Table I.

Basically, the access can be either controlled, in which case no collisions will occur, or random, which implies that collisions of transmission attempts may happen. As a consequence, mechanisms are required to recover from collisions.
Table I. Classification according to access method

<table>
<thead>
<tr>
<th>BUS</th>
<th>Controlled Access</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Token</td>
</tr>
<tr>
<td></td>
<td>- Multilevel multiple access (MLMA)</td>
</tr>
<tr>
<td></td>
<td>Random Access</td>
</tr>
<tr>
<td></td>
<td>- Carrier-sense multiple access with</td>
</tr>
<tr>
<td></td>
<td>collision detection (CSMA/CD)</td>
</tr>
<tr>
<td>RING</td>
<td>Controlled Access</td>
</tr>
<tr>
<td></td>
<td>- Token</td>
</tr>
<tr>
<td></td>
<td>- Slotted</td>
</tr>
<tr>
<td></td>
<td>- Buffer/register insertion</td>
</tr>
</tbody>
</table>

3.2.1. Token ring

In a token ring [13,14,18], access to the transmission channel is controlled by passing a permission token around the ring. When the system is initialized, a designated station generates the first free token which is passed around the ring until a station ready to transmit changes it to busy and puts its information onto the ring. In principle, the information block can be of arbitrary length. The sending station is responsible for removing its own frame from the ring. At the end of its transmission, it passes the access permission to the next station by generating a new free token.

3.2.2. Slotted ring

In a slotted ring [18-20], a constant number of fixed-length slots circulates continuously around the ring. A full/empty indicator within the slot header is used to signal the state of a slot. Any station ready to transmit occupies the first empty slot by setting the full/empty indicator to "full", and places its information in the slot. When the sender receives back the busy slot, it changes the full/empty indicator to "free". This prevents hogging of the ring and guarantees fair sharing of the bandwidth among all stations.
3.2.3. Buffer insertion ring

In buffer insertion rings, the contention between the traffic to be transmitted by a station and the data stream already flowing on the ring is resolved by dynamically inserting sufficient buffer space into the ring at each ring adapter [21,22]. In contrast to the token ring where the sender is responsible for removal of the frame it transmitted, this function is performed by the receiver.

With regard to the point in time when a station is allowed to transmit one of its pending messages, we can distinguish between two operational modes: station priority and ring priority.

In the case of station priority, a station having a transmit request pending is allowed to transmit its information blocks immediately, if there is no block in transit at that moment. Otherwise, it must defer its transmission until the end of the transit block being currently transmitted. With ring priority, a station cannot begin transmission of one of its information blocks prior to the state when the insertion buffer is empty, i.e., all traffic already on the ring passed the station.

3.2.4. CSMA collision detection bus

The best-known random-access scheme for bus systems is carrier-sense multiple access with collision detection (CSMA/CD) as described in [12,18,23]. Under a CSMA protocol, every station ready to send must listen before transmitting an information frame in order to detect transmissions already in progress. If another transmission is already in progress, the station defers its sending until the end of the current transmission. Due to the non-zero propagation delay on the bus, carrier sensing cannot completely avoid the collision of information frames. A sending station can detect a collision by comparing transmitted with received data. In case of a collision, the transmission is aborted and the station reschedules its packet by determining a random re-transmission interval.
3.2.5. MLMA ordered-access bus

One possibility for ordered access control on a bus is the multilevel multiple access (MLMA) introduced in [24]. In its simplest version, the method works as follows. Information transmission occurs in variable-length frames with a structure as shown in Fig. 11. A controller generates start flags at appropriate time intervals indicating the beginning of a frame. A frame is divided into two parts: a request slot and an arbitrary number of information blocks. Every station attached to the bus owns one bit within the request slot. By setting its bit, a station indicates a request for transmission within this frame. At the end of the request cycle, all stations know which other stations are going to transmit within this frame. The actual transmission sequence is determined by a priority assignment known to all stations.

3.2.6. Token bus

Another controlled-access scheme on a bus uses a permission token in a similar way to that described for a ring system. This scheme is currently being studied by the IEEE 802 group [17]. Token access on a bus means that the station ready to transmit and which received the free token can send an information frame. At the end of the transmission, the station frees the token and passes an addressed token to the next station which should have an opportunity to transmit. It is important to note that in contrast to a token-ring system, the token has to be addressed since a bus system does not provide sequential ordering of the stations attached.

In addition to topology and access method, we can classify subsystems according to the transmission technique. We can differentiate between baseband and broadband systems. The term baseband is self-explanatory. In a broadband system, the available frequency spectrum is subdivided into different frequency bands where frequency multiplexing techniques are required to separ-
ate the bands. Ref. [25] provides an example of such a system. Fig. 12 schematically shows the principle. The bands can be used independently of one another, e.g., one band for CSMA/CD or token access, a band for voice, and other bands for video. The economic viability of these systems is determined by the modem cost incurred on top of the cost for implementing the access scheme.

![Diagram of broadband system](image)

**Fig. 12. Principle of broadband system**

4. Subsystem comparison

The important and difficult question which arises here is to compare subsystems. Obviously, it cannot be expected that a particular subsystem with a particular access method can be proven inferior for all conditions and applications. Comparing, rather means to understand the relative merits of various systems for a broad spectrum of parameters. The following parameters must be considered in such a comparison: Performance, transmission, wiring, reliability, availability and serviceability. For the sake of conciseness, we subsequently use the two most widely discussed subsystems, i.e., token access on a ring and CSMA/CD on a bus.

4.1. Performance

Two performance aspects are of primary interest: The delay-throughput characteristic of the media-access control schemes discussed in Section 3.2 and system behavior when the load approaches the saturation point. A fairly com-
prehensive performance comparison was recently published [18]. In the fol-
lowing, we use some of the results reported in the paper referenced.
Figs. 13a, b, and c show the performance of token ring and CSMA/CD bus for
two data rates: 1 Mbps and 10 Mbps. The general conclusions we can draw from
these results are: i) at a data rate of 1 Mbps, both systems perform equal-
ly well; ii) if the data rate is increased to 10 Mbps, the token ring clearly
has the better performance characteristic over a wide range of parameters.
In Fig. 13a, the frame-length distribution is negative exponential with an
average value of 1000 bits. A frame represents the entity transmitted by a
station if it has access to the medium. The critical parameter which de-
termines the performance of the CSMA/CD bus is the ratio of propagation de-
lay and mean frame transmission time. Since the propagation delay is inde-
pendent of the data rate, this ratio increases with the data rate. Theory
shows [18] that a CSMA/CD bus behaves ideally as long as this ratio is suf-
Ficently low. If for reasonable
traffic loads it exceeds 2-5 percent,
the increasing collision frequency
causes significant performance de-
gradation.

Apart from the early saturation
point, the CSMA/CD bus has another
undesirable property. In case of a
collision, transmission is aborted
and the station reschedules its
frame by selecting a random retrans-
mission interval the length of which
is dynamically adjusted to the ac-
tual traffic load in order to avoid
an accumulation of retransmissions.
The high collision frequency at high
load levels together with the re-
transmission policy causes the vari-
ation of the transfer delay to grow.

The practical consequence is the danger of stations becoming locked-out for
an unpredictable period of time.
The general validity of the conclusions drawn above is supported by Figs. 13b and c. In Fig. 13b, all parameters are the same as before except for the length of the cable which is now 10 km instead of 2 km. The curve for the CSMA/CD bus at 10 Mbps illustrates the impact of the propagation delay, and confirms the importance of the ratio propagation delay and average frame transmission time. As a practical consequence, all CSMA/CD systems being discussed specify a maximum distance which is less than 10 km. Finally, Fig. 13c further demonstrates the robustness of the results. There, the frame-length distribution has a coefficient of variation of 2.

4.2. Other Considerations

The other parameters previously mentioned, transmission, wiring, reliability, availability, and serviceability are equally important but cannot be discussed in detail in this paper. Subsequently, we shall concentrate on several general properties and again limit the discussion to token ring and CSMA/CD bus.

In the design of a ring system, basically three problems have to be solved which are sometimes claimed to be weak points when compared against a bus: i) Each ring adapter contains a repeater and, therefore, the entire ring consists of a string of repeaters. The basic problem here is that a failure in any one repeater can disrupt the whole ring. ii) Clock coordination. Here the problem is that the set of repeaters has to agree on a common clock rate, and that this rate must result in an integral number of bit times of delay when going around the ring. iii) Initialization of the ring and recovery from errors without resorting to centralized control.

These three problems have solutions which work well in practice. Therefore, they are no longer considered as exposures of ring systems. Some key aspects follow. Problem i): Instead of trying to build very reliable repeaters, the basic idea is to bypass malfunctioning repeaters or inactive stations through bypass relays. These relays can be located either directly behind the wall plug or, more favorably, in distribution panels. In the latter case, the ring consists of several interconnected distribution panels, Fig. 14, which
can be placed at strategic and protected places in the building. Wiring from each panel to its stations is radial and the powering of the relays from the station is through the local lobe, see [13,26]. The solution with distribution panels not only solves the problem, but buys some advantages rings have over busses. Distribution panels represent several centralized locations for maintenance and reconfiguration and provide the potential to automate these functions. Trouble isolation and repair in a bus system, on the other hand, cannot be easily centralized. Also, they allow cutting out of the local lobes of inactive stations, a property which helps to gain distance. Furthermore, the concept of distribution panels with bypass relays facilitates the systematic prewiring of a building including the installation of wall plugs in all offices. CSMA/CD busses, on the other hand, require transceivers for each attachment which have to be installed very close to the bus for transmission reasons. Since transceivers do not represent low-cost elements, they make the prewiring of buildings and the installation of wall plugs in all offices fairly expensive.

Problem ii): A robust solution to this problem is described in [26]. Each repeater has a phase-locked loop which tracks the next active repeater upstream. The PLL filters are designed such that operation of the whole cascade of PLL's is stable and also that the accumulated clocking jitter is minimized to allow for the number of stations desired. In [27], further solutions are indicated.
Problem iii): As shown in [14], ring initialization and recovery from errors can be solved by introducing a monitor function which is available in each ring adapter. At any given point in time, only one monitor function is active and protects the circulating token against loss, permanent busy condition, or duplication. The monitor functions in other adapters are passive and supervise the health of the active monitor function. In case of a monitor failure, the passive monitor functions activate themselves, compete for the role of the active monitor, and after the competition has been resolved, one monitor function is again the active one.

In ring systems, transmission is unidirectional and point-to-point. This has several consequences, two of which will be explained briefly. First, rings allow media to be mixed easily, i.e., to use different media in different sections of the ring, e.g., twisted pair, coaxial cable, low-cap cable, see Fig. 14. This also means that rings can easily migrate to new transmission technologies, e.g., optical fibers. Bus systems do not have such flexibility. Moreover, the use of higher-speed transmission media, such as optical fibers, would create difficult problems. The first one is the performance problem CSMA/CD has at high data rates, the other the lack of a satisfactory technique for tapping an optical fiber and detecting a signal without diverting too much optical energy. Secondly, the analog engineering component in a ring system is small. The solutions to the ring engineering problems mentioned above can all be implemented in digital technology, and therefore can benefit from technological improvements in VLSI. The major problems for a CSMA/CD bus, on the other hand, are in the analog engineering domain. Some examples follow. i) A transmitter's signal must be receivable by all receivers on the cable. Similarly, each receiver must be able to hear every transmitter. The design must be such that under worst-case echo buildup and attenuation, any transmitter-receiver pair can communicate. Also, collision detection requires that a transceiver must be capable of detecting the weakest other transmitter during its own transmissions and of distinguishing the signals from the other transmitter from its own transmitter's echoes. To meet these requirements, transceivers have to be carefully designed. They have a significant analog engineering component. ii) Other
engineering problems are concerned with ground reference and power supply, the use of an unbalanced transmission medium, and the need of bidirectional repeaters to obtain the required physical distance. Details on these items can be found in [27].

5. Summary

The following key ideas have been highlighted in this paper:

i) Computer-controlled private branch exchanges and ring and bus systems with various access methods represent feasible approaches to solve the problem of local-area communication.

ii) The most likely application scenarios will encompass terminal-to-host communication, channel-to-channel and CPU-to-DASD communication, and the case where intelligent workstations operate in a distributed processing environment and access-shared resources through the network via servers.

iii) Ring and bus systems can employ a broad spectrum of access methods; the particular choice will have a significant impact on performance. The comparison of token ring and CSMA/CD bus shows that for data rates of 1 Mbps, they have the same delay-throughput characteristic, whereas for data rates of 10 Mbps, the token ring clearly shows the better performance over a wide range of parameters.

iv) Significant differences of ring and bus systems are in the areas of wiring and of providing centralized maintenance and reconfiguration facilities. The ring has a considerable amount of flexibility to mix media and to migrate to newly emerging transmission technologies, due to the point-to-point nature of its transmission system. Bus systems do not have this flexibility. Also, since rings do not require transceivers located adjacent to the transmission medium, prewiring of buildings and the installation of wall plugs in all offices can be cost justified. Furthermore, the use of distribution panels in ring
systems provides points for centralized maintenance and reconfiguration. To have the same capability in CSMA/CD bus systems seems to be fairly difficult.

v) In CSMA/CD bus systems, difficult analog engineering problems have to be overcome. In ring systems, on the other hand, the difficult problems have solutions which can be implemented in digital technology and thus have the potential to benefit more from advances in VLSI technologies.

vi) Based on technical arguments, one cannot rule out either one approach. Therefore, it might well be that issues such as ease of installation, maintenance, automatic fault isolation and system reconfiguration, capability of migrating to new transmission technologies, and the way these systems are going to be used will dominate the technical arguments.

Acknowledgment

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References


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QUESTIONS

MR. R. PIKE - BELL TELEPHONE LAB. MURRAY HILL, N.J.

• Q --> With hardware doing some of the protocol features, are you able to write software protocols that can use the hardware features? Protocol specification is difficult, and it would be nice not to duplicate features in protocols which will just be connected back-to-back.

• A --> The hardware protocol can do collision detection and error detection but not error recovery. A software protocol is required for that. I do not see any good solution yet to avoid duplication of protocol design and implementation effort until there is a protocol standard.

MR. D.R. MYERS CERN

• Q --> How do you see the market developing between BM & Texas Instruments versus Intel, Zerox & DEC?

• A --> I cannot comment on this question.
MR. J. AUDI - AEROSPATIALE, AVIONS, PARIS

• Q ---> Considering the continuously changing industrial environment, is it not a practical problem to add new workstations in places where, unfortunately, distribution panels have not been placed when the ring was installed?

• A ---> There are several ways to deal with this problem, and it has been anticipated as shown in these figures (transparencies re-displayed).

MR. P. VANN BINIST - UNIVERSITE LIBRE DE BRUXELLES

• Q ---> Can you explain the significance of the horizontal axis on your "systems evaluation" graphs of ring versus bus systems?

• A ---> The scale shown is a properly normalized scale for this comparison. The detailed analysis was published in the Proceedings of the IEEE towards the end of last year.

MR. D. WILLIAMS CERN

• COMMENT ---> Users want to connect terminals, minicomputers, and microcomputers together soon, and independently of the company which supplies the equipment. IBM has a duty to make its position clear on this question quickly (i.e. by the end of 1982).

MR. C. CURRAN CERN

• COMMENT ---> I am delighted to see that IBM is moving towards a simpler physical interconnection system. We have enough difficulty at present connecting even IBM devices to IBM devices, but even CERN might manage to plug in a coaxial connector correctly! More strength to your elbow....!

MR. J. GAMBLE CERN

• Q ---> Could you comment on the use of the token ring technology in high-noise environments? One point that is disturbing is that if the token is "HIT", then the whole ring is disabled for the timeout period, whereas, for a bus, it is only the passing message. This may be important for applications to Large Area Networks in experiments or control systems.

• A ---> The only solution for ring systems is to incorporate redundancy or to use shielded cable.