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Robert L. Fink

May 1982

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A Status Report on Local Network Technology*

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ABSTRACT

The principles, terms and basic technology behind local networks are presented. Alternative forms of local network media are discussed, such as digital PBX and Broadband. Broadband's unique potential and problems are presented. An overview of the ISO Reference Model for Open Systems Interconnection is given, along with its relationship to local network systems. Finally, the current status of IEEE Project 802, for Local Network Standards, is presented and discussed.

INTRODUCTION

The advent of very dense (LSI and VLSI) integrated circuits, and the ability to produce them in large quantities at very cheap prices, has led to a total revolution in the data processing industry. Computer systems, in the form of microprocessor chips, are now so small and cheaply available that new applications and market areas are opening up at a frenetic pace. There is no longer just a data processing industry, but thousands of old industries that are computerizing old and new products.

In many of the newer applications of computer technology, distributed computer systems abound that need to communicate between one another over short distances (local areas). High speed communication between two or

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more parts of a larger system has become essential. Two relevant and diverse examples are office automation systems, where work stations and shared resource server stations need to communicate, and industrial automation systems, where master control processors and distributed process control subsystems need to communicate.

Traditional forms of computer to computer digital communications were optimized around the common carrier (wide area) networks. Thus high error rates and low speeds are typical. Also, most communication of this type is point to point; the multipoint (polled) type of communications for wide area networks have been mostly based on adaptations of the point to point type.

High speed local area networks have thus become one of the most active areas of computer and electronics development. A survey of this technology, and where it is headed, is given in this paper. It is not intended here to draw conclusions, but rather to paint a picture of a highly active and controversial technology.

DEFINITION OF LOCAL NETWORK TERMS

Many aspects of local area networks, also called LANs, are difficult to precisely define. This is due to the rapid growth, hence changing nature of LAN technology. However, a definition of an LAN is important. An LAN may be defined as:

- Allowing a number of independent devices (i.e. typically more than two) to communicate. Direct physical interconnection of all devices is a typical characteristic of an LAN, but not necessary to

the definition of it, however.

- Confining itself to a moderate size geographic area (e.g. building, plant or campus).
- Providing moderate to high data rates with a consistently low error rate (e.g. exceeding typical wide area low data rates of 9600 BPS with less than wide area bit error rates of one in 10,000.

It could also be said that an LAN is operated by the user, as opposed to a common carrier, but this is not essential to the definition.

This definition above is neither complete or entirely agreed upon. Such is the nature of the LAN business. Agreement among LAN proponents is certainly not guaranteed, or even possible at this time. To now go beyond this definition of an LAN, to become more exact about specific characteristics of LANs, it is required that many jargon words be defined.

BASEBAND and BROADBAND

These two words refer to two basically different modes of use of any communication media, whether it is wire pair, coax, fibre optic, microwave, satellite, etc.

Baseband is a transmission technique allowing only one transmission (or information) signal to be present on the medium at a time. Most direct computer cabling falls into this category, as does existing forms of ETHERNET. (ETHERNET is generally the best known form of LAN and was developed by XEROX Corp.).

Broadband is a transmission technique allowing more than one information

signal to be present on the medium at a time. Existing cable TV services (CATV) and long distance telephone circuits fall into this category, as does the advertised form of WANGNET (WANGNET is the recent LAN offering of WANG Corp.).

Broadband and baseband should not be confused as implying the ways in which the one or more information signals will be used. TV and telephones can and sometimes are supported on baseband. Similarly, some forms of computer cabling can rely on broadband though this is very rare at this time. Baseband and broadband are very limited generic terms and only become useful as an LAN description when combined with other terms.

BROADCAST and SEQUENTIAL, BUS and RING

Broadcast implies a single transmission reaching all systems connected to the LAN. Typically a bus topology, where all systems connected to the LAN receive all signals transmitted by any system, is used for broadcast types of protocols. Thus broadcast can often be confused as either a statement of topology type (i.e. bus) or a statement of protocol type (e.g. ETHERNET).

Sequential implies a topology that allows systems to relay signals across point to point circuits, and typically refers to ring topology where each system is connected (for the LAN) in a ring or loop. Signals can theoretically circle the ring forever though protocols preclude this in practice. As with broadcast, sequential can be used as a description of protocol but generally is not. Again we have two words often used to imply several different things, depending on context.

CSMA/CD and TOKEN ACCESS

CSMA/CD stands for carrier sense multiple access with collision detection. This is a generic term for protocols that: allow multiple systems to access the medium without explicit coordination; avoid collision, or contention, by sensing the carrier of the signal on the medium; use some form of collision detection to resolve contention. Though ETHERNET is a well known CSMA/CD LAN, it is not the only CSMA/CD network. Also, CSMA/CD does not imply the retransmission technique used after collision detection. Also note that an LAN could use CSMA without explicit collision detection.

Token access is a generic term for protocols that coordinate transmission between two systems on a LAN by some form of authority called a token. This term had been used more specifically to imply specific types of authority passing on ring topologies, but has now passed into broader use (as a term) with the advent of the IEEE Project 802 (Project 802 is discussed later in this paper). Token access protocols can be utilized on broadcast buses or rings.

Thus we now have a hierarchical set of terms that partially define an LAN, at least its major characteristics. For example a broadband, broadcast, token access LAN. However, one must stay cognizant of the possible multiple interpretations and always keep such naming in a relevant context.

PHYSICAL MEDIA FOR AN LAN

Many different physical media are possible for an LAN. At the moment, coaxial cable (a concentric cable with a center conductor, a dielectric and a shield) is the most commonly used medium for both baseband and broadband. This is due to the excellent electrical properties of coax for high

transmission rates (greater than 1M bits per second) and multiple (bus) access.

Shielded twisted pairs of wire are used by some systems, especially prototype ring topology LANs. However, twisted pair is not used commonly for high speed bus topologies as the transmission line characteristics of coaxial cable are better.

Though not specifically a different medium, the upcoming availability of multi-drop differential line driver chips (the work of EIA TR30.1, based on RS422) will make it practical to use twisted pairs for more specific forms of local networks. Medium speeds (100K to 1M bits/sec) over shorter (1KM) distances are practical for small LANs of very cheap semi-intelligent terminals.

Fibre optic cable utilizes various forms of glass fibres (single or multiple) to transmit light along the length of the fibre optic cable. This medium has excellent isolation, security, error and data rate characteristics, thus making it the "wave of the future". However, low production demand, high connector costs and the need for more than two accesses make fibre optics more of a future technology. Nevertheless fibre optic can be used now for specific LAN solutions such as point to point (non-bus topology), isolation of broadband systems, or for high speed gateway links (interconnection paths) between multiple LANs.

Radio is also a "medium" that will come into use in the future. The ARPA (US Dept. of Defense) funded ALOHA network of the University of Hawaii was the prototype of such systems. By the very nature of electromagnetic radio transmission and reception, an LAN using radio is a broadcast bus-like

topology. However, in practice much more complicated multi-transmitter approaches (called cellular radio) are used. Though these radio "media" approaches may ultimately be widespread in use, the current state of LAN technology does not normally include them.

TRADITIONAL WIDE AREA NETWORK TECHNOLOGIES THAT ALSO FIT LANs

Several modern forms of wide area network medium, topologies and protocols can be utilized to solve LAN problems. This becomes more the case as common carriers strive for higher speeds for the computer user, and computer system network vendors strive to include the LAN into existing wide area network systems.

The advent of DTS (Digital Termination Services) in the common carrier market will soon be providing digitally interfaced point to point circuits at speeds of 56K bits/sec and higher. These DTS connections have been given a big boost in the United States by the FCC (Federal Communications Commission) April 17, 1981 authorization of DTS microwave radio in the 10.55 GHz to 10.68 GHz band. By the late 1980s, DTS service will be quite common and many local networks may find it practical to extend themselves beyond local confines. Certainly high speed inter-LAN gateway connections will become very practical.

These potential developments highlight one important reason vendors are concerned about LAN standards established now. That is, how will todays LAN evolve into the future with newer capabilities, such as DTS, becoming available. Obviously topology and speed related LAN criteria are affected.

The digital PBX is another major impact on the future of the LAN. Soon

most new PBX equipment will be digital. PBX switching stands for private branch exchange phone switching. Traditional PBX switching has been analog, which is convenient for voice but not data (though MODEMS do mask this, at high cost, for the digital user). Now it is cost effective to digitally encode phone conversations (typically a format called PCM, for pulse code modulation, is used) and then transmit and switch the phone call in a digital fashion, decoding at the destination end. Thus cheap digital interfacing to commonly available phone circuits around a site, building or campus will be possible. Speeds will typically be 56K to 64K bits/sec as a 64K bits/sec link is the standardly accepted PCM encoding speed. In the heart of the PBX PCM switching speeds are very much higher as thousands of simultaneous "phone calls" may be in progress. Thus one can envision a highly cost effective form of local network that allows systems to create a path, through a digital PBX switch, to other systems as needed. This approach should by no means be construed to be limited to traditional dumb terminal to central computer switching. Intelligent work stations (small personal computer systems) could use such a technique when inter-system communication is required.

Several existing network systems supplied by computer system vendors (e.g. DEC, IBM) may be very well suited for adaptability to LAN technology, or at least appear to be an LAN. One example is the DECNET network product of Digital Equipment Corp. DECNET even now is capable of 1M bits/sec speeds and transparent packet switching at the network system software level. This gives DECNET a strong appearance of being a high speed, fully interconnected LAN. Other vendors share, or soon will, similar characteristics. Of course, such vendor systems lack the hoped for open nature of a modern

LAN. This will be discussed later in this paper.

This section on traditional wide area approaches and their impact on LANs is by no means exhaustive. It does serve to point out that the LAN does not exist entirely unto itself. Future traditional approaches will impact the LAN.

BROADBAND AND ITS UNIQUE CHARACTERISTICS

Broadband, as a basic approach for an LAN, has excited the user, vendor and press communities. This is, to a large extent, because of its potential for multiple modes of use. Also, to a lesser extent, the physical distance capabilities of broadband are viewed as greater than with baseband. As to distance, it is not at all true that broadband can go farther than baseband, at least theoretically. However, from a practical point of view, most baseband systems discussed are of the CSMA/CD type and the retransmission strategies require strict timing control, hence fixed maximum distances. Also, most CSMA/CD baseband designs have line driving and signal isolation limitations. Obviously these are design limitations not necessarily inherent in or unique to baseband. On the other hand, broadband typically utilizes CATV technology that is viewed as not having distance or isolation problems (i.e. vulnerability to power and ground problems between buildings). Such a view is not necessarily well founded as will be discussed later in this section.

First, however, a short description of typical broadband and its capabilities is necessary. Broadband typically utilizes CATV (Community Antenna TV) technology. Radio frequency transmitters and receivers are used to "talk" and "listen" on a coax cable through directional couplers that keep

radiation, reflections and cable damage to a minimum. Depending on distance and isolation environments, amplifiers may be used inline with the cable. Most broadband networks operate from 5 to 300 MHz with the lower half (5 to 108 MHz) being reverse (i.e. towards the center or "head-end" point) cable frequencies and the upper half (162 to 300 MHz) being forward cable frequencies. Frequencies from 180 MHz to 216 MHz are reserved for regular TV transmission. This so called "mid-split" approach requires a "head-end" receiver/translator/retransmitter, sometimes called a remodulator. This allows a single cable to be used to each drop point with no open loop amplification problems as signals in a given range (receive or transmit) travel in only one direction through the cable amplifier band pass filters.

An alternative to mid-split systems is the WANG dual-cable configuration where all transmit signals go "up" the first cable, to the "head-end" point, and come back "down" the second cable, at the same frequency. This approach is not compatible with traditional mid-split CATV equipment as signals are transmitted and received at the same frequencies in the WANG system.

By the above it should not be construed that all mid-split broadband systems are compatible. The EIA (Electronic Industries Association) TR40.1 committee has recommended a standard for mid-split frequencies that much equipment will match, but it is not a given that all combination of equipment will work together. Broadband systems need to be competently "engineered" by professionals familiar with these issues.

Broadband's major feature is the ability to use it for multiple purposes.

Thus a site, building, plant, campus or industrial area can be "wired" once with coax and taps, providing outlets for future long term use. At this point in time the broadband vendor offerings are limited, and it is generally assumed that the user will hire (on contract) a CATV installation specialist to take care of the installation of the broadband plant. Products currently offered will provide for:

- TV channels
- Voice channels
- One or more (i.e. multiplexed) point to point "virtual" data circuits
- Switched point to point "virtual terminal" circuits
- CSMA/CD LAN
- Switched (frequency agile modem) point to point data circuits

The frequency agile modem is an interesting device as it can dynamically switch to a control station specified frequency to make a "virtual data circuit" between any two points (equipped with the frequency agile modem, of course).

The switched virtual terminal capability is interesting as it is actually provided, in one vendor's case, by a CSMA/CD LAN hidden from view by virtual terminal interfacing software in the intelligent modem station.

It is the multiplicity of services which a broadband system can offer that is key to the long term potential and problems of broadband. Traditional CATV systems, in most typical installations, are for TV antenna purposes, as that was their intended design purpose. This means one (or few) transmitters and a large number of receivers, unlike the newer use (of

broadband) where there are essentially equal numbers of transmitters and receivers. Also, the types of equipment used are more limited in traditional CATV as TV is the primary function. Modern broadband may have very wide functional differences between types of equipment. Unlike the well established TV industry, the emerging broadband industry will have many wheels to reinvent.

The above modes of use for traditional CATV technology will eventually be successful. However a learning curve for this technology does exist and currently we are not very far along it. Some issues unique to broadband which remain to be completely understood are:

- impact of widely distributed transmitters and diverse frequency assignments on amplifiers and signal strength.
- impact of cable plant outages on data systems (as opposed to TV systems).
- management and maintenance of one broadband system by users of highly diverse interests and use.
- engineering of cable plant to avoid casualties (of equipment and personnel) during lightning and power problems. This is a different issue in plant/campus high voltage distribution environments [1] than in traditional low voltage grounded grid home environments.

As stressed earlier, broadband installations must be very well engineered. Management and maintenance are key problems as well, and careful thought must be given to post installation difficulties caused by different use modes, learning curve, etc. The broadband network is a "common carrier" in all but the smallest user environments, thus it should be treated as a

common carrier.

Pricing of broadband systems vary with the installation environment. Obviously a campus or multi-building plant is a more difficult and costly problem than a single building. However, a well published example from Brown University [2] shows a 110 building campus backbone cost of $317,000. This includes engineering and wiring up to the buildings, the head-end, amplifier and maintenance equipment and spare-parts. The cost of internal building wiring, including labor and outlet hardware, is averaging $46 per outlet over 1600 outlets. Then the expensive part remains: the RF modems (one for each outlet to be used) and the actual network interface hardware. RF (radio frequency) modems can be as cheap as $600 but the interface hardware, if it is more than a simple RS232 (V.24) interface, can be very expensive. For example a CSMA/CD network controller with a microprocessor interface might cost $5,000 to $10,000. The need for the RF modem is unique to broadband networks, but the controller is needed in other cases as well.

ISO OPEN SYSTEMS INTERCONNECTION REFERENCE MODEL AND THE LAN

No discussion of networking, local or wide area, ever escapes involvement with the ISO (International Standards Organization) OSI (Open Systems Interconnection) Reference Model [3]. The OSI Reference Model, or OSI/RM in short, is not a standard at all but rather a conceptualization (a model) of the typical protocol layers envisioned to be present in typical modern network systems. The OSI/RM is broken into seven layers. Very approximately the following describes the function of each layer:

- Application - to provide the user the services of the OSI network

environment.

- Presentation - to provide structure of data and control for an application.
- Session - to establish and maintain the connection for an application.
- Transport - to provide ordered and reliable transmission for the connection.
- Network - to provide the physical path for the connection.
- Data Link - to provide for information flow and error control on the physical path.
- Physical - to provide the mechanical, electrical functional and procedural interface to the physical medium.

The fond hope is that future designs will use OSI/RM as a model for layering of network systems to maximize the standardization potential of the different layers. Thus a standard at the network layer to transport layer (e.g. CCTTT X.25) could allow vendor and product substitution both above and below this point. This is a fine concept and most of the network community worldwide is hard at work to develop such standards. At the moment most emphasis on wide area networks appears to be on standardization of protocols at the transport layer upwards to the application layer.

Emphasis in local area networks is on the standard for the network layer and below due to the rapid emergence of LAN communication media and related techniques. This work is being focused in the IEEE Project 802 which is covered in the following section.

Of interest here is that the OSI/RM does have a relationship to the LAN but

it is changing as rapidly as the LAN media. This is not the place for an exhaustive OSI/RM discussion, but it is appropriate to explain just enough to see how it relates to a possible LAN Reference Model, LAN/RM in short.

The IEEE Project 802 has evolved an LAN/RM which is not the same as the OSI/RM. In particular the two OSI/RM layers of data link and physical are broken into three layers in the LAN/RM:

Logical Link Control (LLC)

Media Access Control (MAC)

Physical

The MAC layer is a new layer that handles some OSI/RM data link layer and some OSI/RM Physical layer functions. Thus the LLC and Physical layers handle less than they might in an OSI/RM environment. This is due to the greater differences between physical media approaches for LANs than presently exist for wide area networks. Note that this view of an LAN/RM is hardly a fixed or final one. Others than IEEE Project 802 may yet significantly affect the LAN/RM, and how it relates to the OSI/RM.

At the higher layers there is equal room for new interpretations. The significance of separating session and transport is not clear. Also the entire issue of internetworking is emerging rapidly. This is the ability for applications on different networks to interconnect. The IEEE Project 802 has defined an internetworking model where the network layer has been divided into a global network sublayer (GNS) and a communications services sublayer (CSS). The X.25 protocol, normally an OSI/RM network layer protocol, could be interpreted as an LAN/RM CSS layer protocol. Two major internetwork activities, outside of IEEE, are by ARPA and XEROX.

The XEROX internetworking protocols are broken into five or more levels that correspond to the OSI/RM in the following way:

- level 0 (Transmission media protocols) corresponds to physical, data link and lower network layers
- level 1 (Transport protocols for packet format, address and routing) corresponds to upper network layer
- level 2 (Transport protocols for interprocess communication) corresponds to transport layer
- level 3 (Control protocols) corresponds to presentation and part of the application layer
- level 4 and above (Application protocols) corresponds to application layer

There is no session layer equivalent in the XEROX protocols. The ARPA protocols are structured in a similar way to XEROX, though there are some philosophical differences that will not be elaborated here.

The entire issue of protocols, and their relationship to the various models, is not going to be clear for a long time. Yet, this issue may be a more significant one than either choice of LAN media, or the specific protocols. No single network approach is likely to prevail in the near (or even far?) future, making the interconnection of different networks essential. This will only be possible by wide agreement and implementation of conceptual models into practical systems.

IEEE PROJECT 802, STANDARD OR STANDARDS

Nothing is more difficult to comprehend than all the activities of IEEE

Project 802 [4]. These activities are more understandable when related to the rapid fire emergence of LAN technology because of the perceived user need for distributed computer based products interconnected by an LAN. Every serious vendor in the computer system area recognizes that the stakes are high. Thus when the IEEE Computer Society established Project 802, to hopefully reach early agreement on LAN media standards, the Pandora's box was open, and everyone jumped in.

The most written about LAN technology to date is XEROX ETHERNET, which is a CSMA/CD, baseband, broadcast bus LAN. Its use dates to the early 1970s, at XEROX, and was seen as both a threat and a promise. Vendors and users wanting to quickly reach agreement hoped ETHERNET was the answer. Other vendors and users seeing the problems of baseband, bus topology and CSMA/CD arbitration wanted something else other than ETHERNET. So in Project 802 we have the unusual situation of watching a public technology fight which, in previous times, might have been waged either privately by the academic community or in the competitive product marketplace.

The LAN approach of Project 802, and soon to be enhanced by the Draft C report based on the most recent 802 meeting, is to approve multiple types of LANs. Both baseband and broadband will be supported. Both bus and ring topology will be supported. Both CSMA/CD and token access will be supported. Both connectionless (datagram) and connection (virtual circuit) services will be supported. Thus the current full systems that could result are:

- BASEBAND BUS CSMA/CD 10M bits/sec
- BASEBAND BUS TOKEN ACCESS ("Token Bus") 1,5,10,20M bits/sec
- BASEBAND SEQUENTIAL TOKEN ACCESS ("Token Ring")

- twisted pair 1,4M bits/sec
- coax 4,10M bits/sec
- fibre optic is being considered

- BROADBAND BUS CSMA/CD 1,5,10M bits/sec
- BROADBAND BUS TOKEN ACCESS 1,5,10,20M bits/sec

There are several interesting facts about the choice of MAC protocols. The CSMA/CD protocol was based originally on ETHERNET, then diverged during the course of the project and has now returned to being almost pure ETHERNET. XEROX must now choose to make a few key changes to bring ETHERNET fully in line with 802. Proposed changes to ETHERNET include:

- multipoint grounding
- frame format
- error detection capability

Whether XEROX will make these changes is unknown. It may not matter, as the LSI chips to implement Project 802 CSMA/CD can be produced from earlier ETHERNET LSI chip efforts at INTEL. Therefore the Project 802 standard could simply overwhelm ETHERNET use in delvered products.

The token ring protocol is, for the moment, identically the new IBM token ring specification. If it stays IBM, token rings may become very widely used, simply because it is IBM. The August 1982 IEEE Project 802 meeting is expected to decide this.

Currently, the broadband specifications are not complete. However, as mentioned earlier, the EIA TR40.1 work on broadband frequency assignments has been adopted by IEEE Project 802.

IEEE Project 802 may be unique in actually setting standards before LAN products reach the marketplace. If so, the work of Project 802 will be of great significance. If not, just the massive information sharing between vendors and users will make Project 802 important.

The resulting multiple LAN standards of Project 802 is in itself a significant outcome. Just the general recognition that there are not single absolute answers for choices of LAN is important. This is not likely to change, and IEEE Project 802 recognition of this will greatly help to shield higher level products and services from these lower level differences.

CONCLUSION

It is hoped that an even and fair representation of the current state of local networking has been presented here. If there is any single point the author would like to make here, it is that the user must resist the great fascination with local network hardware in favor of the harder world of real products that work.

There will be no single LAN choice possible for large user environments, as most LANs will come highly packaged with end user products, such as word processing systems, scientific personal work stations, etc. Thus interconnection of LANs, or more importantly the systems using LANs, is the key and future issue to successful LAN use.

REFERENCES

[1] Art Turney, UC LBL, "Data Communications and the Inter-Building Ground Loop", LBL internal report, 1982.

[2] William S. Shipp and Harold H. Webber, Brown University, "Wiring a University", ICC '82 IEEE Communications Society.

[3] ISO/TC97/SC16/N537 "Data Processing Open Systems Interconnection Basic Reference Model".

[4] IEEE Project 802 "A status report", Draft B, October 19, 1981.

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