IEEE 802 Standards for Local Area Networking

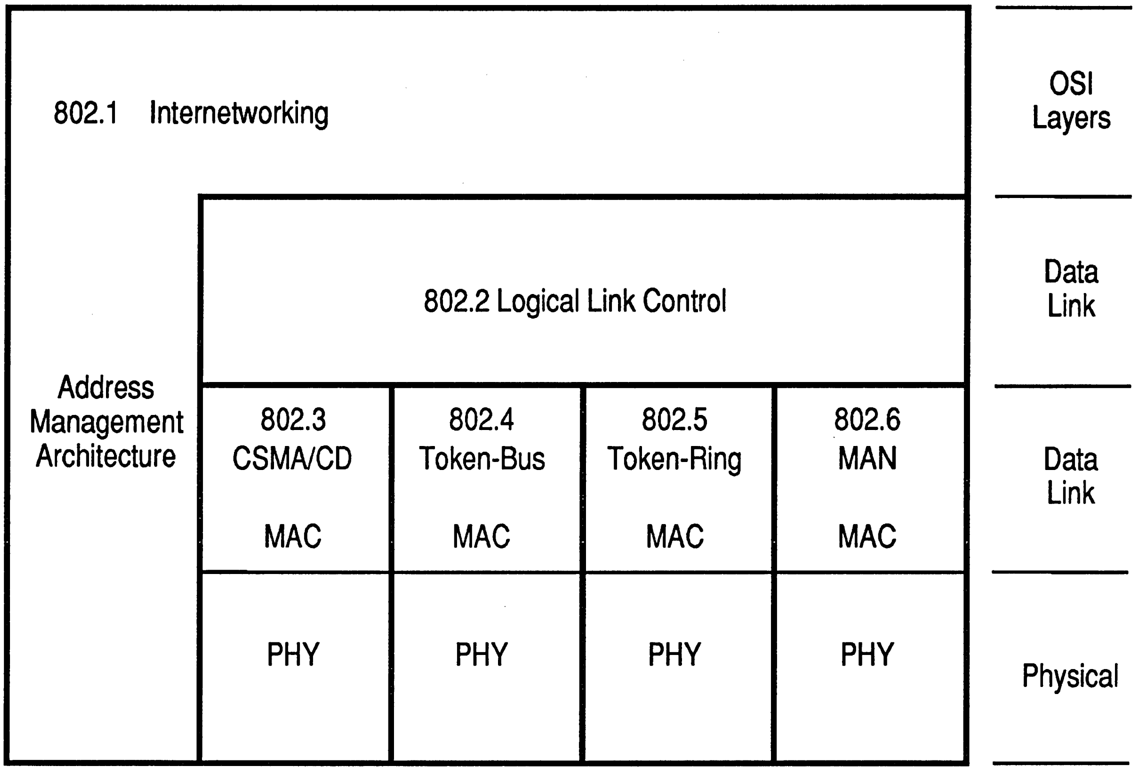
In this report:

Synopsis

Editor's Note
The local area network market is one of the fastest-growing segments of the computer and communications industry. Developing standards have helped to fuel the growth of this market. The IEEE 802 standards body is chartered to define the standards for local area networking, and this report provides an overview of the IEEE 802 LAN standards, some of which are not yet final.

Report Highlights
The Institute of Electrical and Electronics Engineers (IEEE) began Project 802 in February 1980 in an attempt to establish standards in advance of the local area network (LAN) market. The IEEE 802 Committee has defined interface and protocol specifications for logical link control and access methods for various LAN topologies. The project has maintained an open-door policy, and from 20 to 300 people have participated in any one working group. Most of the participants work for a computer or network components vendor, and many have a communications or marketing background. Since the project's commencement, it has been under intense scrutiny by the computer industry, because the resulting set of standards has—and will continue to have—a significant impact on the growing LAN market. This report will help you to understand the IEEE/ISO LAN standards; compare the differences among the various options and alternatives; recognize how the standards evolved from inception to the present; and understand standard approaches to interconnecting LANs.

Figure 1.
IEEE Project 802 Working Groups



The IEEE 802 standards address the two lower layers (Physical, Data Link) of the OSI Reference Model.

Introduction (A Little History)

During the mid-to-late 1970s, a small company in Texas developed a capability to provide access to shared direct access storage devices (DASDs) from microprocessor workstations located within a reasonable distance from the DASD. The company was Datapoint Corp. and the technology was Arcnet—Attached Resource Computer Network. At about the same time, Xerox Corp. was developing its experimental Ethernet. These were the first local area networks (LANs) to be offered as commercial products.

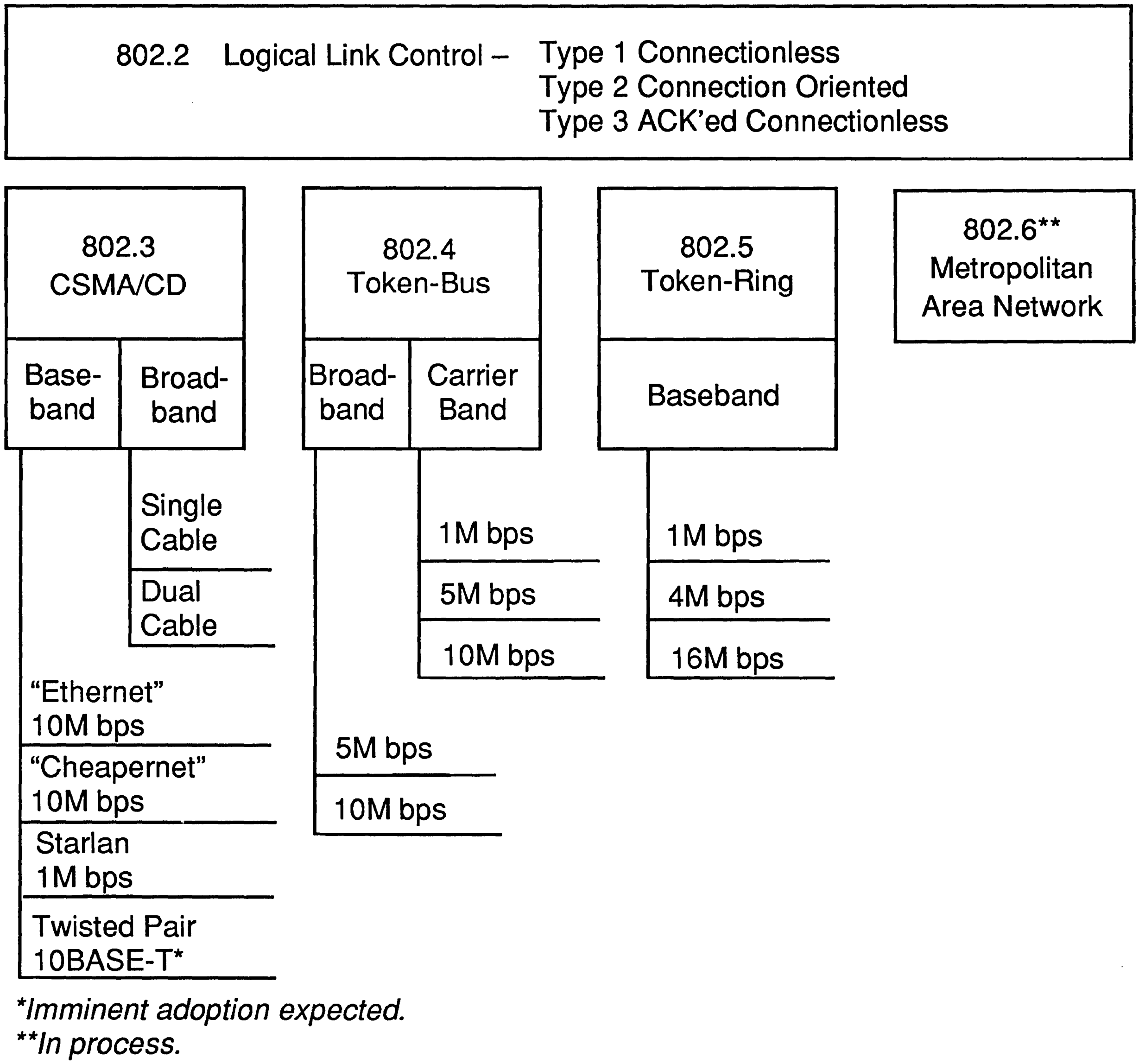
In the 1980s, with the near demise of Datapoint, and Xerox' alliance with Digital and Intel, the IEEE had little choice when it adopted an "Ethernet-like" approach for its local network standard. Other organizations such as General Motors and IBM had their own ideas about what the "ideal" LAN should look like. The result was a family of LAN standards to be known as the IEEE Project 802 LAN standards.

Despite these developments, Arcnet did not disappear. Vendors that had acquired the licenses continued to make Arcnet interfaces, but now focused on the PC as the workstation. Arcnet continues to enjoy a useful life as a mature and highly functional proprietary LAN implementation.

With the ever-increasing popularity of LANs, new requirements have developed for higher speed networks of greater geographic range. In response, vendors have developed alternatives to the standard implementations, and standards bodies such as ANSI have produced the Fiber Distributed Data Interface (FDDI), among others.

The bottom line is that while there are currently a fair number of standard LAN implementations, there are also proprietary implementations from leading vendors, which, while not "standard," may suit one's needs very well. As long as technology continues to improve, entrepreneurs will continue to come up with "better ways." Some of these better ways will fade quickly after initial flurries of excitement, while others will pave the way for new and better standards.

Figure 2.
IEEE Standards Variations



There are variations within each of the IEEE 802 standards.

Standards are not static, and the network architect must realize that there will always be a better solution tomorrow. Of course, if one continues to wait for the better solution, no solution will ever be implemented.

It is also essential to realize that a variety of forces competes in the standards development world—each with its own agenda (whether hidden or unhidden). The result is often a less than perfect compromise. It is often said that "the two things you really don't want to watch being made [if you're going to be involved with them] are sausages and computer network standards."

Overview of the IEEE 802 Standards

The IEEE 802 standards essentially address only the two lower layers of the Open Systems Interconnection (OSI) Reference Model.

The Physical Layer corresponds to the OSI Physical Layer, while the OSI Data Link Layer is divided into two sublayers: Medium Access Control (MAC) and Logical Link Control (LLC). The

Medium Access Control sublayer addresses the specific procedural issues associated with distributed arbitration of access to the channel. The Logical Link Control sublayer provides a mechanism accommodating those functions of wide area network Data Link protocols that pertain to LAN link management. Unlike the wide area Data Link protocols such as High-level Data Link Control (HDLC), which addresses specific nodes, LLC frames contain only service access points or internal memory addresses of software entities. Physical node addresses are handled by the MAC sublayer.

There are four basic access methods with published standards, as well as a subset of higher Data Link Layer functions. In addition, there are several working groups whose activities are focused on specific technologies which are applicable across a broad range of the access methods.

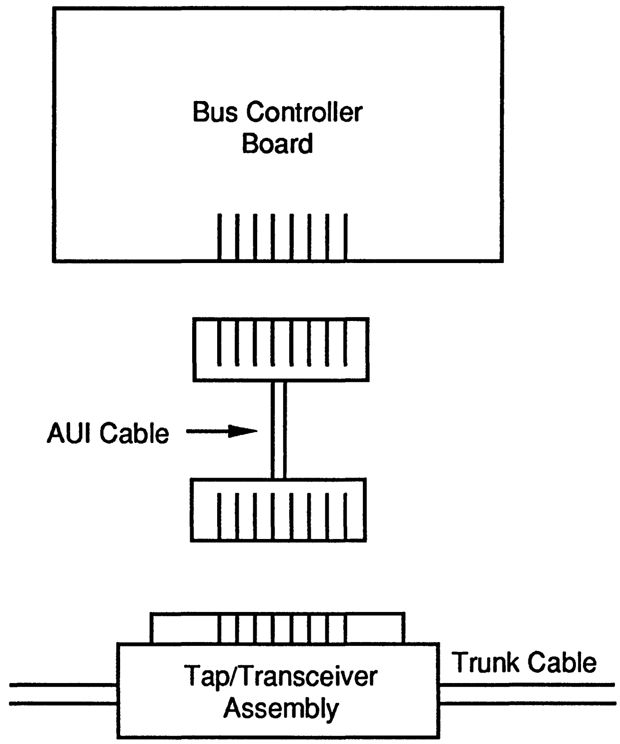
The carrier sense multiple access with collision detection (CSMA/CD) method was the first to be developed by the IEEE and was modeled after the Digital/Intel/Xerox (DIX) Ethernet. Although there are differences between the Ethernet and 802.3, manufacturers now typically produce hardware that can support both, so that effectively the two are compatible. Differences in the packet format are resolved in firmware for a particular implementation. We will continue to use the terms Ethernet and IEEE 802.3 interchangeably. Table 1 defines the differences between Ethernet and IEEE 802.3 implementations.

The 802.4 specifications were developed primarily in response to requirements for the deterministic performance of token passing, coupled with the facility of bus-oriented cabling. The use of broadband technology provided the additional benefits of increased bandwidth, geographic coverage, and numbers of terminations.

The 802.5 token-ring specification was developed under the "guidance" of IBM and reflected the emerging "blue" perspective on local area networking. While the initial versions of the network provided less capacity than Ethernet, the expected improvements due to deterministic performance and priority mechanisms yielded other benefits.

With time, however, we have seen a wide variety of implementations emerge—each reflecting a specific application arena. Some of these have been standardized, while others will likely become standards in the near future.

Figure 3.
10BASE5 Termination Hardware



The 10BASE5 version of IEEE 802.3 uses thick Ethernet coaxial cable and various termination hardware.

Work began recently in several new technology areas including integrated voice and data (IEEE 802.9—IVD), security standards for interoperable LANs (IEEE 802.10—SILS), and wireless LANs (IEEE 802.11—WLAN). Preliminary work continues on the use of fiber optics by the Fiber Optic Technical Advisory Group (IEEE 802.8—FOTAG).

With this backdrop, we will explore the specific 802 LAN standards.

IEEE 802.3 (CSMA/CD)

IEEE 802.3 standards are characterized by a shorthand notation which facilitates their description in as few words as possible. The notation (e.g., 10BASE5) is composed of three elements:

- 10—megabits per second
- BASE—baseband (or BROAD for broadband)
- 5—meters per segment divided by 106

With standards adopted more recently, such as 10BASE-T, IEEE has tried to be more descriptive

Table 1. Ethernet/IEEE 802.3 Differences

Feature	Ethernet Version 1	Ethernet Version 2	IEEE 802.3
Specification	1980 Blue Book	1982 Blue Book	1983, 1985
Transceiver cable	2 Pairs AWG 22	4 Pairs AWG 20	4 Pairs AWG 20
Grounding at host	Inner/Outer shield common at backshell & pin 1	Same as Version 1	Inner shield to backshell; outer to pin 4
Electrical signal	0 v to negative	+ & - signal	+ & - signal
Signal Quality Error (SQE)	None No hearbeat	Yes Heartbeat	Yes Heartbeat
Repeater specification	None	None	Multiple collision protection
Jabber control	None	Yes	Yes
Type/length field	Type (>1500)	Type (>1500)	Length (<1500)
Coaxial cable	50Ω Double shield	Same	Same

with its notation. For example, the "T" in the 10BASE-T standard is short for "twisted-pair wiring."

10BASE5

Using the formula, 10BASE5 means 10M bps, baseband, 500-meter segments. This was the first version of the specification to be developed, and it most closely resembled the earlier Ethernet Versions 1 and 2 (1980 and 1982, respectively). The 10BASE5 LAN employed the "thick Ethernet" 50-ohm coaxial cable. While this cable is difficult and relatively expensive to install, it provides significant advantages over other implementations in terms of distance and the number of terminations permitted for each segment.

The workstation contains an adapter board, called the "bus controller" in Ethernet parlance. Attached to the bus controller is a multiconductor cable known as the Attachment Unit Interface (AUI) cable. This, in turn, is connected to a transceiver/tap assembly called the Medium Attachment Unit (MAU), which is connected to the Ethernet trunk cable employing a "vampire" tap.

When Ethernet products were first developed, this assemblage of components normally cost $1,500 to $2,000. Since LAN implementations are very sensitive to workstation termination costs, less expensive alternatives were required. This problem was resolved in two ways. First, vendors developed less expensive implementations (the old "better way" trick), which we will explore in a moment; and second, the natural momentum in declining semiconductor costs reduced these implementations to a fraction of their former costs.

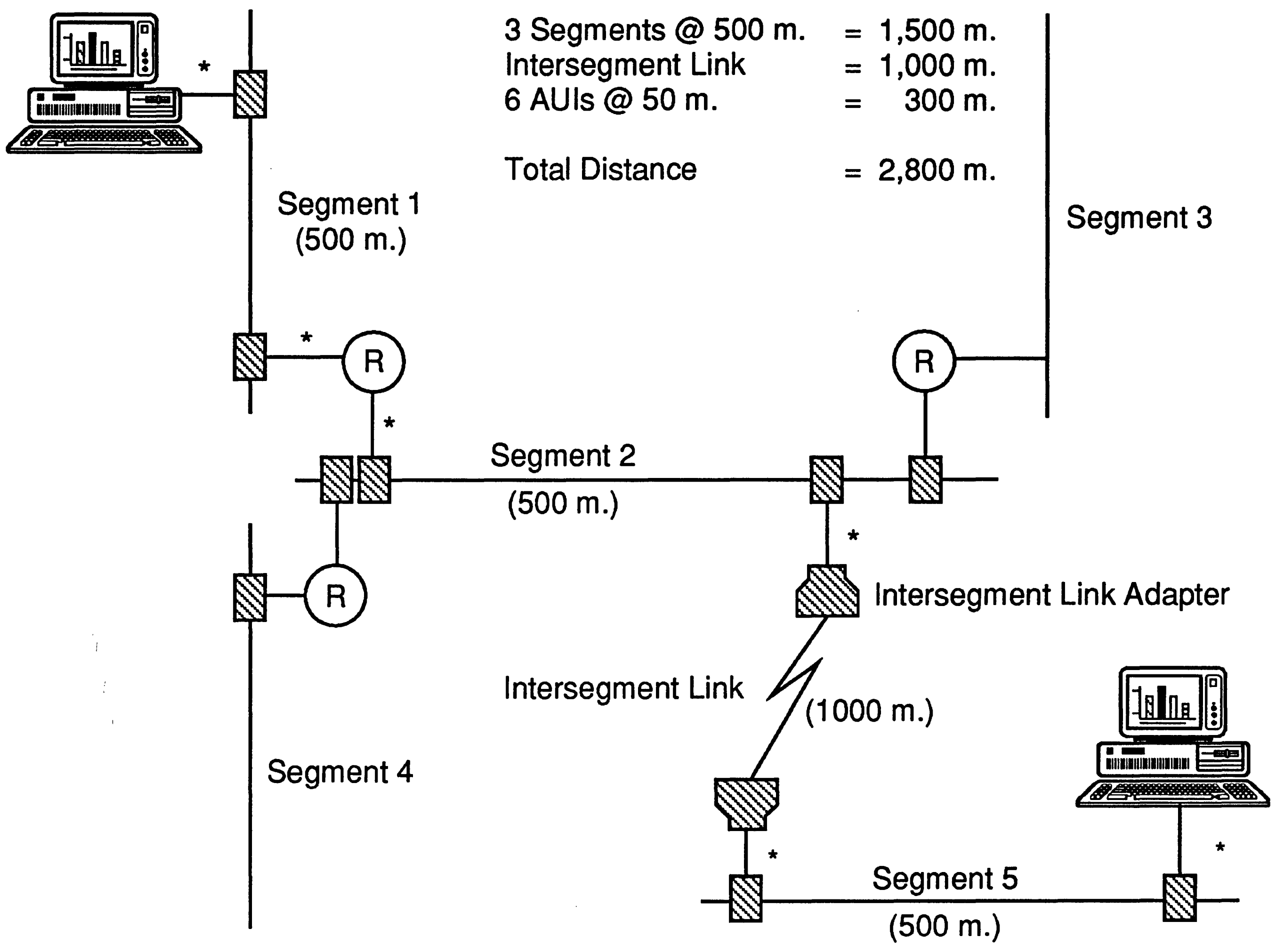
Due to the sensitive timing issues associated with the performance of the CSMA/CD protocols, limits were imposed upon the overall length of a multisegment LAN, as well as the maximum signaling rate. A typical large-scale CSMA/CD LAN is limited to a distance of 3,000 meters between any two communicating stations. This is often implemented by using three 500-meter segments, two 500-meter link segments, and up to ten 50-meter AUI cables. An important distinction between a link and a segment should be noted. Segments can have workstations attached, while links are simply media used to extend the overall distance of the LAN.

Figure 4 illustrates a 10BASE5 LAN with the maximum distance between two workstations. Other constraints associated with 10BASE5 LANs concern the number of devices that can be terminated on the trunk cable. Up to 100 devices can be placed on a 500-meter segment, with a maximum of 1,024 devices on the entire network. This limitation can be circumvented through the use of bridges, which partition a LAN into several connected, but independent LANs—thus yielding the maximum length and number of workstations for each.

10BASE2

10BASE2 (also known as "thin Ethernet or "Cheapernet") employs a thin flexible coaxial cable (RG-58) that connects to the bus controller board in the workstation by means of a BNC "T" connector. In earlier implementations, the transceiver functions were onboard, but in the interests

Figure 4.
Multisegment CSMA/CD LAN



**50 m. each AUI.*

For a multisegment 802.3 LAN, the maximum distances between segments can vary; however, the maximum distance between any two communicating stations is limited to 3,000 meters.

of using the bus controller for either implementation, MAUs and bus controllers have been developed which provide options for both 10BASE5 "vampire" taps and 10BASE2 BNC connectors. More recently, board manufacturers commonly provide boards with built-in transceivers that can be switched on or off by the component manufacturer for a particular application.

The standard 10BASE2 LAN can support only 30 terminations on each coaxial cable segment of 185 meters. While this may seem like a major constraint, it is often adequate for most work area environments. Where a requirement exists for interconnecting multiple work areas, or work areas with multiple 10BASE2 segments, a backbone 10BASE5 segment can be employed to provide intersegment connectivity. Figure 5 illustrates this type of configuration.

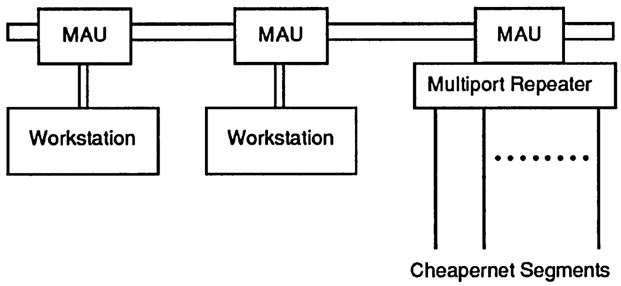
1BASE5

This standard approach was contributed by AT&T to accommodate its earlier Starlan products. It operates at 1M bps, and as such is often most useful for small work areas or low traffic environments. 1BASE5 also employs inexpensive twisted-pair wire interconnected through a hierarchical system of concentrator hubs. The hubs emulate a bus configuration by broadcasting all data and collision information on all ports.

10BASE-T

One of the most exciting developments on the local network scene has been the development of the 10M bps unshielded twisted-pair (UTP) Ethernet. This implementation has now received final approval from the IEEE. One of the best-known products to claim compliance with this standard is

Figure 5.
10BASE5/10BASE2 Interconnectivity



In environments with multiple work areas, or work areas with multiple 10BASE2 LAN segments, a backbone 10BASE5 segment can be used to provide intersegment connectivity.

SynOptics' LattisNet. There are now several major manufacturers producing products meeting this standard (including AT&T, HP, Digital, and 3Com); in fact, virtually every vendor active in the Ethernet market now offers 10BASE-T products.

It is important to note that these implementations will be limited to 100-meter segments due to the greater attenuation and signaling difficulties of twisted pair. This should not present any unusual problems since these networks' connections usually only have to reach to the "communications closet." From there, FOIRL and coax can be used to concatenate and interconnect LANs with standards such as 10BASE2.

It is imperative, however, that organizations planning these networks have their existing twisted-pair wire certified for both attenuation and capacitance before making any assumptions on its salvageability.

Like the AT&T Starlan, this system uses a hub concentrator to interconnect multiple stations and emulate the bus operation.

10BROAD36

The 10BROAD36 implementation uses much of the same hardware as the baseband implementations. The essential difference is the substitution of a broadband electronics unit and a passive broadband tap for the baseband MAU. This enables an organization to use its existing bus controller boards in the workstations for connection to either a baseband or broadband system. In recent years, this standard is being used less frequently.

The primary functions of the broadband electronics unit are to create the frequency-derived channels of 14MHz for data and 4MHz for collision consensus. It also converts the signals from the baseband-coded signal of the AUI to the analog signal necessary on the broadband channel.

Workstations can be placed up to 1,800 meters from the "head-end" of the broadband cable plant. By placing the head-end in the center of the configuration, workstations can be installed up to 3,600 meters from each other.

IEEE 802.3 Standards Status

Within the IEEE 802.3 group, the following standards have been completed as of this date:

- CSMA/CD Medium Access Control Layer
- 10BASE5 Medium
- 10BASE2 Medium
- 10BROAD36 Medium
- Repeater Specifications
- Fiber Optic Inter Repeater Link (supports distances up to one kilometer)
- Layer Management
- 10BASE-T
- ATS for AUI Conformance Testing

Several projects remain open, with adoption expected imminently on some:

- Conformance Testing
- Maintenance
- 10BASE-F (Fiber Optics Task Force)
- Hub Management

IEEE 802.4 (Token Bus)

The 802.4 Token Bus working group wrestled with the issues of coordinating both IEEE and ISO standards development activities. Although the initial broadband implementations of the token bus appeared to be highly flexible and desirable in terms of the generic manufacturing requirements, a number of difficulties arose.

First, the industry found that migration from the early versions of the Manufacturing Automation Protocol (MAP) suite (Version 2.1) to current specifications (Version 3.0) is less than facile. It has become a manager's nightmare for a number of reasons.

For instance, fewer and fewer people are interested in broadband implementations primarily due to the difficulty in design, installation, and maintenance. Additionally, the apparent benefits of broadband networks, in terms of the number of terminations, geographic range, and bandwidth, have been overtaken and negated by the introduction of Medium Access Control bridges that provide even greater capabilities for baseband networks—nearly transparently. These bridges enable an organization to increase the traffic loading by simply partitioning the network and eliminating the concern. Couple these high-risk implementation issues with the scarcity of products, difficulty in migration from MAP 2.1 to 3.0, and soft industry support, and one will find that the token bus presents a quagmire of implementation risks that most managers would rather avoid.

There is some hope on the horizon for the medium access specification. Other broadband physical medium specifications are being developed for optical fiber. Some difficulties lie ahead here since the dominant fiber specification in the U.S. is the 62.5µm fiber specified by ANSI for the Fiber Distributed Data Interface. In Japan and Europe, 50µm fiber is a more common implementation. In the final versions of this standard, both options are permitted—62.5µm is the standard and 50µm is allowed.

The 802.4 Token Bus architecture has matured despite the uncertainties presented by the MAP protocol suite. Standards for medium access control, broadband media, carrier-band media, and optical fiber have been completed. Open projects include conformance testing.

IEEE 802.5 (Token-Ring)

The token-ring implementation, which has received so much attention since it was first approved in 1985, has undergone a variety of modifications, and completion of essential specifications.

Media Issues

The initial version of the ring was a 4M bps implementation which ran on shielded twisted-pair wire. The issues surrounding shielded twisted pair have always been controversial. Telephony carriers avoid shielded wire to the extent possible, since the shielding introduces capacitance changes and ultimately increases attenuation, thus requiring more frequent repeater placement. The LAN proponents, such as IBM, feel differently. They contend that the shielding protects the media from unwanted EMI/RFI and that the distance between repeaters is not an issue since each station is its own repeater. The company using shielded wiring must decide if lower attentuation is worth the extra cost associated with a thicker (i.e., harder to install) and more expensive wire.

Considering the context of their respective positions, both contenders are correct. In the case of LANs, however, the shielding does buy some value. One thing we can be sure of is that where there is a requirement, someone will stand up to fill the niche. Thus, when IBM introduced the 16M bps token-ring network, running only on shielded wire, it was not surprising that other vendors immediately introduced unshielded wire 16M bps implementations. It is reasonably certain that in due time, the IEEE 802.5 working group will introduce a specification for unshielded twisted-pair wire. Considering the work that the Electronic Industries Association (EIA) has done concerning intrabuilding wiring (PN-1907), it is likely that the EIA specifications for unshielded wire will be candidates for the 16M bps ring.

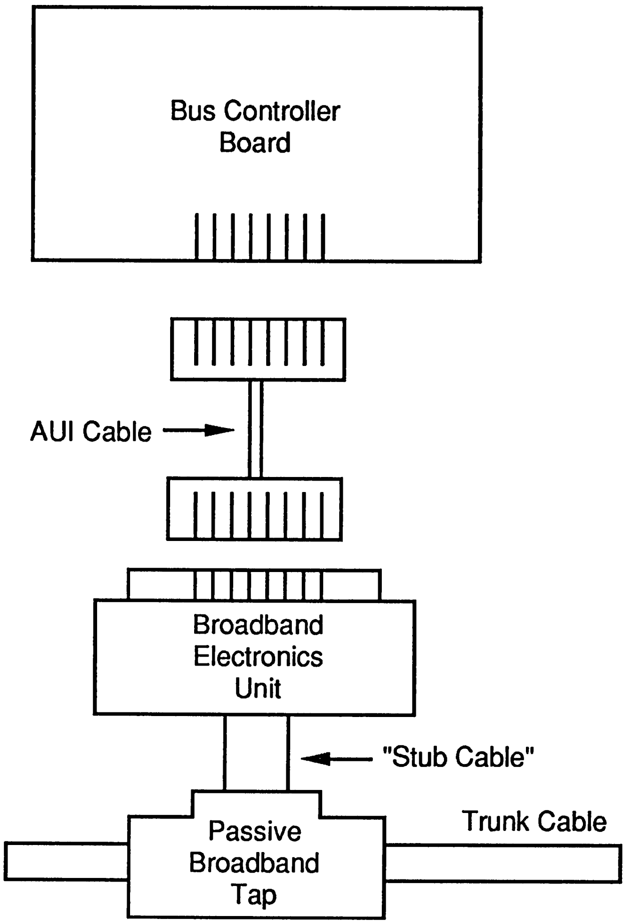
Other media-related issues being explored by the 802.5 group are the use of Optical Fiber Station Attachment equipment and redundant media for backup (reconfiguring dual rings).

Token-Passing and Multi-Ring Protocol Issues

Recently, IBM introduced a new version of the token-passing protocol called "Early Token Release." This new protocol is intended to make more efficient use of the available bandwidth on physically large rings operating with particularly small packets. In earlier versions of the token-passing protocol, a new free token could not be released by the sending station until it recognized the address in its own packet coming back around the ring to itself. If the packet was small, and the ring was large, there was a great deal of wasted time on the medium.

Using Early Token Release, a sending station can release the free token immediately upon completing its transmission. The empty time slots on the ring can now be used by other parties. When coupled with the 16M bps ring, this new protocol appears to have significant advantages in terms of performance.

Figure 6.
10BROAD36 Model



A 10BROAD36 broadband 802.3 implementation uses much of the same hardware as baseband 802.3 LANs.

Another area of interest in the token-passing world is the controversy on Medium Access Control Bridges. While Ethernet proponents prefer a minimum spanning-tree approach, many token-ring developers prefer source routing bridges. The 802 spanning tree bridge is an approved standard.

A discussion of Medium Access Control Bridges can be found in the Data Link Layer Repeaters section.

802.5 Standards Status

Presently, the following completed standards are available from the 802.5 working group:

- ANSI/IEEE 802.5 Token-Passing Ring (1985)
- 802.5A Station Management Functions Revision
- 802.5E Management Entity Specification
- 802.5F 16M bps Operation
- 802.5H Acknowledged Connectionless Logical Link Control
- 802.5I Early Token Release
- ANSI/IEEE 802.5 (1989)
- 802.5B Unshielded Twisted-Pair (being published)
- 802.5C Reconfiguring Dual Ring Specifications (being published) (redundant media)

The list of ongoing open projects includes:

- 802.5D Multi-Ring Configurations
- 802.5G Conformance Testing
- 802.5J Optical Fiber Station Attachment
- UTP 4/16 megabits per second

IEEE 802.6 (Metropolitan Area Network)

The IEEE 802.6 Metropolitan Area Network is a fourth MAC alternative that has been defined by the IEEE. Early plans for this moderate geographic area service focused on CATV-type networks, while later proposals revolved around a slotted ring concept. Current specifications call for a Queued Packet Synchronous Switch, which is a hybrid approach. It has been developed under the auspices of the Australian Postal, Telephone, and Telegraph administration and appears to be gaining general acceptance. The standard is approved.

IEEE 802.9 (Integrated Voice & Data LAN)

Topics under consideration by this working group include MAC frame delimiting, TDM frame formats, 20M bps PMD, and Layer Management. Both medium (4M bps) and higher speed Physical Layer standards are being investigated. Voting on a relatively "mature" specification is expected this summer.

IEEE 802.10 (Standard for Interoperable LAN Security)

This group is making progress on defining an architectural model for implementing interoperable LAN security. Licensing terms for the use of patented public key technology are being studied. Group 802.10B is working on secure data exchange. Group 802.10C is studying Key Management. The group is not predicting a standards ballot in the immediate future.

Table 2. 802.3 10BASE5/10BASE2 Differences

Feature	10BASE5	10BASE2
Name	802.3 "Ethernet"	Cheapernet, THIN Ethernet, THINWIRE Ethernet, etc.
Type of cable	50Ω Thick dual shield	50Ω RG-58
Maximum segment length	500 m.	185 m.
Spacing of devices on cable	2.5 m. minimum	0.5 m. minimum
Maximum number of taps for a segment	100	30
Maximum number of full repeaters in a path between two stations	2	2
Type of taps	Vampire	BNC "T" connector for "daisy chaining"

IEEE 802.11 (Wireless Local Area Network)

Interest in this standard comes from all over the world including Japan, Canada, and Europe. The group has started on specifications for MAC and the Physical Layer, though a ballotable draft standard is still at least a year away. The work done by this group will be applicable to other MAC standards including 802.3, 802.4, and 802.5. Interest includes radio frequency and the infrared spectrum. The group hopes to have a standard in place by the end of 1992. The group is keeping other standards bodies, including T1P1, ETSI, and ECMA, informed of its progress.

Local Area Network Interconnection

As LANs proliferate, it is becoming more important that standard techniques for interconnection be adopted.

IEEE 802.1 Higher Layer Interface

Data Link Layer Repeaters

Interconnection of similar but separate LANs has resulted in the need for specifications on Medium Access Control bridges. MAC bridges are hardware/software implementations that are limited to resolving the MAC sublayer differences between two or more interconnected LANs. No further higher layer protocol translation is required, and they are often transparent to the user in terms of delay and performance.

MAC bridge specifications have been addressed by the IEEE 802 working groups. The 802.10, 802.1, and 802.5 teams have developed significantly different approaches, but even these are beginning to converge. It is likely that within the next year, we will see more mature guidance in this area.

The current approaches are the Minimum Spanning Tree for bus implementations and the Source Routing bridge for interconnected rings.

The essential difference is that in the bus environment, only one path between any two devices exists. The bridges learn the LAN segment and node addresses and filter packets accordingly as required. Provision for multiple alternative paths is provided in the interconnected ring environment, which, in turn, yields a requirement for a routing protocol. This routing protocol is facilitated by adding "routing information" (RI) fields to the packet header. The RI field contains all of the source node routing information necessary for the bridge to determine which path is to be adopted for a specific packet.

There are certainly advantages and disadvantages to both of these approaches, but the common goals are to provide global, transparent interconnection. Global in the sense that any device on any LAN can share resources with any device on any other LAN; transparent in the sense that performance must be adequate to ensure that access to remote resources is provided rapidly and accurately. This guarantees that users do not perceive a difference between local and global objects.

IEEE 802.3 Physical Layer Repeaters

In the case of the IEEE 802.3 CSMA/CD LANs, intra-LAN segment connection standards are well developed and mature. These physical layer relays

Table 3. Logical Link Control Alternatives

Service	Type 1	Type 2	Type 3
Basic Service	Connectionless	Connection	ACKed connectionless
Acknowledgements	No	Yes	Yes
Error Recovery	No	Yes	Yes
Flow Control	No	Yes	No

are implemented in the form of repeaters that regenerate the signals from one segment for retransmission to the next. The unique aspect of these repeaters is that they must be capable of retransmitting collisions as well as data frames. Unlike Data Link Layer relays (or MAC bridges), these repeaters are not addressable. Since all segments are part of a unified LAN, the nature of the shared channel must be preserved by broadcasting all information to all terminated devices.

The latest specifications for repeaters are contained in the IEEE 802.3C supplement (1989). Unlike the earlier version of this supplement (1988), this specification provides rich detail on coaxial cable, AUI, and optical fiber repeater interfaces. Repeater specifications now pertain to all 10BASE implementations.

In addition to the functions described above, repeaters as specified in the 802.3C supplement can provide "partitioning" between segments. Thus, if conditions on a given segment are causing the extensive proliferation of collisions, the rest of the LAN can be protected from this anomaly. The repeater will count the number of collisions from the source segment and interrupt these from transmission to the next segment. This function is designed to address an abnormal situation such as a cable break or network card failure.

IEEE 802.4 Physical Layer Repeaters

The issues of signal attenuation in a broadband LAN are normally resolved in two ways. First, the maximum placement of a device from the head-end provides a maximum bound on signal loss in the context of attenuation. Second, since many stations can be connected to the bus, each resulting in a specific "insertion loss," amplifiers are often required to ensure that the total loss does not exceed specifications.

The IEEE 802.4 broadband bus specifications define a Regenerative Repeater Machine (RRM) as an optional component that is present only in special repeater stations such as the head-end. Since broadband systems are analog, amplifiers are usually used to boost signal strength. Regenerative repeaters actually re-create a new signal in accordance with amplitude and time specifications.

A regenerative repeater is also defined for the single-channel carrier-band system. Since the latter is not a multichannel broadband bus (a medium supporting multiple frequency-derived channels such as a Community Antenna Television [CATV] system), a head-end is not required to facilitate this function. Physical placement of these devices is a function of the number and placement of user devices on the network. There are no explicit maximum terminations defined in the specification, but the standard suggests that 30 may be an appropriate user limitation.

IEEE 802.5 Physical Layer Repeaters

The nature of a token-passing ring obviates the necessity for repeaters, since each station's ring interface performs repeater functions. The maximum attenuation of a signal is thus guaranteed by limiting the distance between any two devices in the ring. As with 802.3, the issues of overall length of the ring impact protocol performance as opposed to signal attenuation.

IEEE 802.2 Logical Link Control

The IEEE 802.2 Logical Link Control (LLC) specifications include those Data Link Layer functions that are common to all 802 LAN MAC sublayer alternatives. Three basic service types are provided.

Type 1 (Connectionless)

This service provides a best-effort delivery mechanism between origin and destination nodes. No call or logical circuit establishment procedures are invoked. Each packet is treated as an independent entity by the network. There are no flow control mechanisms or acknowledgments. If the packet arrives at the destination—all well and good. If not, it is the responsibility of the higher layers to resolve the problem through time-outs and retransmission.

Type 2 (Connection Oriented)

Like many wide area network protocols, this service requires that a logical circuit or call be established for the duration of the exchange between the origin and destination nodes. Packets usually travel in sequence and are not routed as independent entities. Positive acknowledgments and flow control mechanisms are an integral part of this service.

Type 3 (ACK'ed Connectionless)

No circuit is established in this service variation, but acknowledgments are required from the destination node. This type of service adds additional reliability to Type 1, but without the potentially excessive overhead of Type 2.

Specific LAN types lend themselves to different types of service. Table 3 illustrates the LLC variations as they apply to the different MAC implementations.

Summary

The IEEE 802 local area network standards have evolved and matured significantly since their development in the early 1980s. It is essential that we not view this maturation process as an end. The standards will continue to evolve, and as new technologies and requirements develop, new standards will follow. The ideal utopian environment would be for standards development to lead product development, but it is unrealistic to believe, in an environment as volatile as local area networking, that vendors will wait patiently while users clamor for more and better products.

The IEEE will be faced with a continuing challenge to ensure that as new requirements and products evolve, the standards also evolve. This challenge will also be coupled with a requirement that migration from prior implementations is as painless as possible—both in terms of development risk and cost. ■