ABSTRACT

IsoEthernet is an integrated services LAN directed at multimedia applications. It enables the carrying of 6.144 Mb/s of isochronous data (96 B-channels at 64 kb/s each) in addition to 10 Mb/s of 10Base-T traffic using the existing 10Base-T wiring infrastructure. A 10Base-T mode of operation accommodates existing 10Base-T equipment. Interoperability with 10Base-T networks is provided for packet traffic. IsoEthernet is being standardized by the IEEE 802.9 standards committee.

IsoEthernet: An integrated Services LAN

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IsoEthernet is the first multimedia-capable network that offers an attractive solution for the desktop. It brings to the desktop a standards-based melding of circuit-mode and packet-mode data, supplying the full functionality of both a private branch exchange (PBX) network and a local area network (LAN) with video data services. IsoEthernet is being specified by the IEEE 802.9 standards committee.

IsoEthernet is an enhancement of Ethernet (10Base-T) that includes a 6.144 Mb/s isochronous data service in addition to the 10 Mb/s Ethernet packet service. It uses the same physical media and essentially the same media line rate as does IEEE 802.3 10BASE-T. As a superset of IEEE 802.3 10Base-T, IsoEthernet readily provides an upgrade for IEEE 802.3 10Base-T with the capability to transport isochronous data streams along with the normal packet data. For backward compatibility, it interoperates with existing IEEE 802.3 10Base-T end stations.

Figure 1 illustrates a multimedia service using IsoEthernet as the integrated services LAN. A typical IsoEthernet configuration includes a set of multimedia end stations connected to an access unit (AU) in a star configuration. The network side of the AU offers connections to both an integrated services digital network (ISDN) and a 10Base-T LAN, providing global connectivity. Each end station can simultaneously access ISDN (up to 6.144 Mb/s for isochronous traffic using four primary rate connections) as well as 10Base-T LAN (10 Mb/s packet traffic) services.

By providing a network that accommodates both packet traffic and an isochronous data stream, IsoEthernet allows existing packet-based applications to be run side-by-side with the new multimedia applications, a very important consideration to users.

In this article, architecture, operation, and applications for IsoEthernet are presented, along with comparisons to other evolving and related technologies. This article concludes by describing the ongoing standards activities of the IEEE 802.9 Standards Committee to further enhance IsoEthernet.

For ease of reading, the following naming conventions will be followed throughout this article. Interfaces conforming to the IEEE 802.9a standard on ISLAN-16 will be referred to as *IsoEthernet*; hubs or access units conforming to the IEEE 803.9b standard for AU-to-AU interworking will be referred to as IsoEthernet *access units*, or simply *AUs*; and multimedia-capable IsoEthernet workstations will be referred to as *end stations* (*ESs*).

ISOETHERNET ARCHITECTURE

Figure 2 shows an example of an IsoEthernet network configuration. End stations are connected point-to-point to AUs using category 3 unshielded twisted pair (UTP). A typical configuration (Fig. 1) may include a server and a set of multimedia ESs individually connected to the AU. Conventional analog telephones or PCs which do not conform to IsoEthernet may be configured using an IsoEthernet terminal adapter.

The network side of the AU is connected to the ISDN wide area network (WAN) as well as to a 10Base-T LAN. Current implementations of IsoEthernet support both a basic rate interface (BRI) and a primary rate interface (PRI) connection to ISDN. The AU acts in a hub capacity to connect to the 10Base-T LAN.

Thus, both 10Base-T packet traffic and 6.144 Mb/s isochronous traffic — corresponding to 96 B channels at 64 kb/s — are accommodated by IsoEthernet and may be connected across the WAN.

PHYSICAL CHANNEL

IsoEthernet uses category 3 UTP between each multimedia workstation and the AU, which is the same medium as that of 10Base-T LANs. The key to the additional bandwidth provided is the use of 4B/5B coding, achieving 80 percent transmission efficiency as opposed to the 50 percent transmission efficiency of 10Base-T Manchester encoding. The use of 4B/5B coding results in a gain of 60 percent in the capacity of the existing infrastructure without increasing the stress on the physical link. This increase facilitates the transport of 6.144 Mb/s over and above the 10 Mb/s currently used for 10Base-T LANs. Thus, IsoEthernet brings multimedia applications to the desktop without the requirement to rewire the existing 10Base-T LAN infrastructure.

IsoEthernet uses a 20.48 MHz clock rate (as compared to a 20 MHz clock rate for 10Base-T). Using 4B/5B nonreturn to zero inverted (NRZI) encoded data provides a line data rate of 16.384 Mb/s and an effective line data rate of 16.304 Mb/s (multiservice mode) or 16.032 Mb/s (all-isochronous mode).

Figure 3 conceptually shows the data services accommodated by IsoEthernet over UTP category 3 cable. In addition to the 10 Mb/s packet traffic and 6.144 Mb/s isochronous traffic, IsoEthernet also provides a D-channel and an M-channel for signaling (64 kb/s) and maintenance (96 kb/s), respectively.

An IsoEthernet link may operate in an IEEE 802.3 10Base-T mode to provide connectivity to existing Ethernet-only stations. In this mode of operation, data formatting, encoding, and clocking on the physical medium are identical to those of 10Base-T. The data rate is 10 Mb/s using Manchester encoding with a 20 MHz clock rate.

For IsoEthernet operation a time division multiplexing (TDM) frame is used. A TDM frame is exchanged between each end station and the AU every 125 μs. The period of 125 μs represents 2560 ticks of the bit clock for the 20.48 Mb/s

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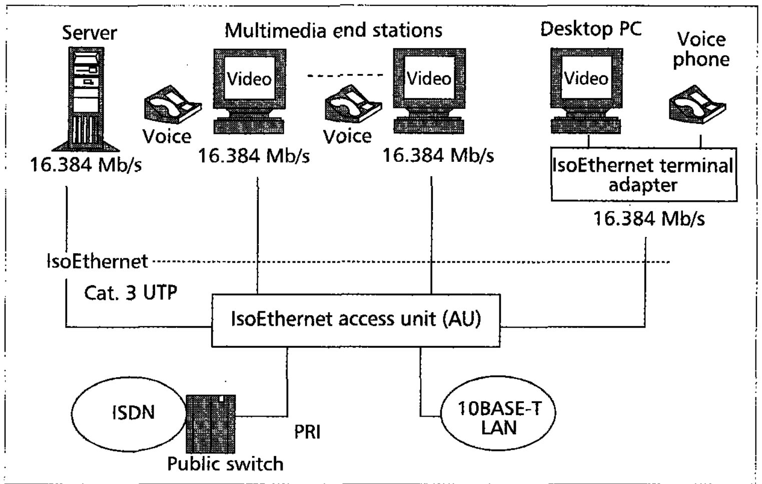
4B/5B encoded data. The 2560 bits of 4B/5B encoded data correspond to 256 bytes of decoded data since 4B/5B coding requires 10 encoded bits for each byte (two symbols) of decoded data.

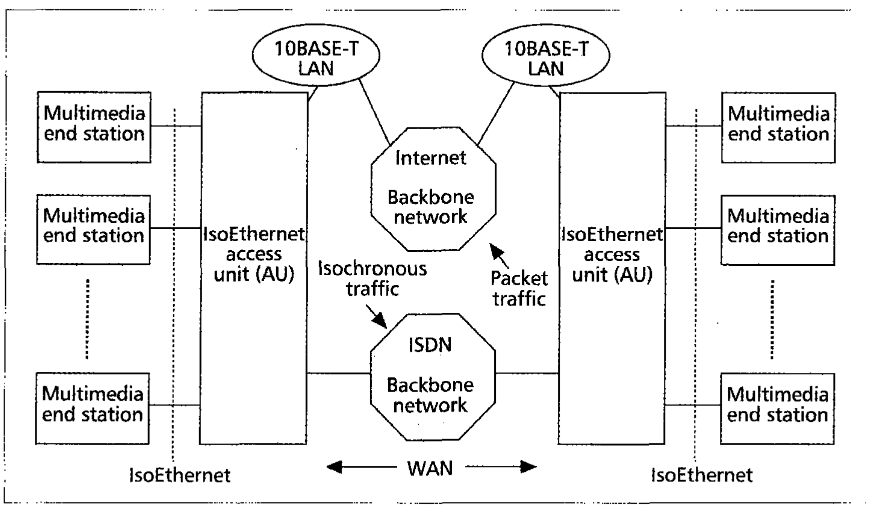
The 4B/5B coding potentially results in a total of 32 5-bit codes for transmission. Of these 32 5-bit codes, 16 are used to encode 4 bits (one symbol) of hexadecimal data, 5 are used for control symbols, 4 are reserved, and 7 are invalid and not used. The 5 control symbols are: J and K, which are unique in the code set and are used together as the TDM start delimiter; I, which is all 1s and is used as the idle symbol; S, which is used to indicate no data; and U, which is used to indicate unaligned data.

TDM frames start with a JK symbol pair, which delineates the TDM frame and conveys the 125-μs clock across each IsoEthernet link. A negotiation using M-channel data has established which component — it may be either an IsoEthernet hub (AU) or an end station — is the master chosen to generate the 125-μs clock that is, in turn, to be used by all components in a specific IsoEthernet AU configuration. This clock is passed throughout the configuration, since the start of a TDM frame can be used by each receiving port to establish the 125-μs clock that it, in turn, uses to generate TDM frames for transmission. By this means one, and only one, master 125-μs clock is recognized for TDM frame generation.

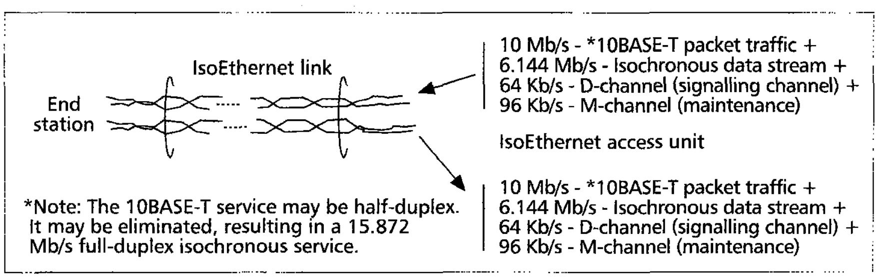
Table 1 shows how the 256 bytes of data in each TDM frame are allocated to the four data services that IsoEthernet provides. Interleaving of these four data services in the flow of data of an IsoEthernet link is on a symbol (1/2 byte) basis since this provides a smooth flow of data, reducing buffering and decreasing delay through IsoEthernet components. These services are full-duplex, except for the P-channel for which considerations of compatibility with 10Base-T LAN dictate half-duplex operation. Although the link capacity would allow full-duplex operation in IsoEthernet for 10Base-T LAN configuration, existing 10Base-T installations are almost exclusively half-duplex.



■ **Figure 1.** *IsoEthernet multimedia configuration example.*



■ **Figure 2.** *IsoEthernet network configuration example.*



■ **Figure 3.** *IsoEthernet link services.*

LOGICAL CHANNELS

The physical channel TDM frame transports four logical channels as follows:
- P-channel
- C-channel
- D-channel
- M-channel

The P-channel is a half-duplex 10 Mb/s packet channel. Whenever 10Base-T LAN services are required, the IEEE 802.3 medium access control (MAC) frames are transported over the P-channel.

The C-channel is the isochronous channel. It consists of 96 full duplex B-channels (64 kb/s per B-channel) or 248 B-channels, depending on the IsoEthernet mode of operation. When IsoEthernet supports 6.144 Mb/s full-duplex isochronous services, 96 B-channels are provided by the C-channel. When IsoEthernet supports 15.872 Mb/s full-duplex isochronous services, 248 B-channels are provided by the C-channel. The C-channel bandwidth is used for ISDN services.

The individual B-channels within the C-channel may be aggregated in any combination to create multiple channels of N x 64 kb/s. A common aggregation is 6 B-channels (H0) corresponding to the 384 kb/s commonly used

Service	IsoEthernet - Multiservice mode		IsoEthernet - All-isochronous mode	
	Bytes per TDM frame	Data rate	Bytes per TDM frame	Data rate
P-channel - packet data	156.5	10 Mb/s*	0	0
C-channel - isochronous bearer	96	6.144 Mb/s	248	15.872 Mb/s
D-channel - signaling channel	1	64 kb/s	1	64 kb/s
M-channel - maintenance	1.5	96 kb/s	1.5	96 Mb/s
Overhead and miscellaneous	1	80 kb/s	5.5	352 kb/s
Total	256	16.384 Mb/s	256	16.384 Mb/s

*Note: P-channel data rate is adjusted to be exactly 10 Mb/s average by not using 0.5 bytes (one symbol) of the P-channel data every other TDM frame.

■ **Table 1.** *IsoEthernet data services.*

for video conferencing. Since these channels support isochronous transmission, a guaranteed quality of service may be provided [1].

The D-channel is a full-duplex 64 kb/s channel used to exchange signaling information between an ES and the IsoEthernet AU. One byte of D-channel information is transported in each TDM frame. IsoEthernet uses ISDN signaling protocols with extensions to support multicasting and supplementary services (i.e., call transfer, call forward, and conference call) [2, 3].

Signaling procedures based on ITU Q.931 are used over the D-channel to set up these N x 64 kb/s connections between one end station and another. The second end station may be remote, using an ISDN connection and signaling procedures.

The M-channel is a full-duplex 96 kb/s channel. It is used to exchange maintenance information between an IsoEthernet AU and an end station. One-and-a-half bytes of M-channel information is transported in each TDM frame. The M-channel data is connected with the control function; however, it is not forwarded to the backbone networks. The information it carries includes link synchronization status, maintenance requests/grants, master/slave status, D-channel capability, loopback, backup power status, and error status.

Multimedia End Station Architecture

In order to fully utilize the capabilities of IsoEthernet, it is important to note that the desktop end station should be capable of supporting multimedia applications. In this context, a typical ES consists of a screen, a keyboard, a mouse, video and audio encoders/decoders (codecs), and speakers for broadcast audio with stereo capability. The screen should be capable of displaying full-motion video, still images, and a whiteboard. Also, the ES should be able to use all existing Windows and other software applications for supporting different multimedia applications. In IEEE 802.9 standards, this ES is referred to as integrated services terminal equipment (ISTE).

Figure 4 depicts the block diagram of a multimedia ES. The video component consists of an input/output (I/O) for an external screen and an H.320 conferencing component. It may also have an external video output for a conventional television display. The primary video codec is based on H.261. The audio component consists of an audio codec and an I/O for external speakers and an H.320 conferencing component. The whiteboard data is for interactive data applications. The H.320 component is the basic narrowband video conferencing facility that facilitates video conferencing between different sites. It supports video data rates from 64 to 1920 kb/s. A typical ES for IsoEthernet may have a conferencing session that involves transport of 384–576 kb/s for video, 64 kb/s for high-quality voice, and 128 kb/s for collaborative data. The most commonly used video rate is 384 kb/s. The T.120 component facilitates multipoint video conferencing. There is also an internal management function to facilitate interworking between different components within the ES. The ES has application tools such as Windows to provide a user-friendly environment for the multimedia conferencing application.

The IsoEthernet interface provides basic protocol support for transport of isochronous and packet-mode communications. Software support for IsoEthernet includes support for signaling services for ISDN connection [2, 3].

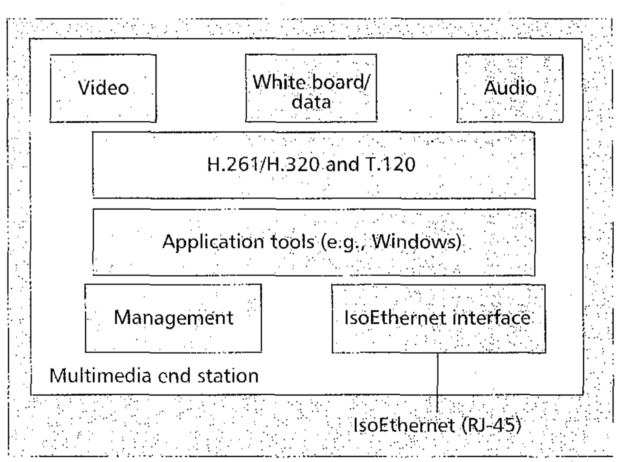
The use of the H.261 codec and H.320 video conferencing system facilitates the portability of applications in multiple workstation platforms. In addition, the use of H.320 permits synchronization of voice and video decoding; there is no buffering or delayed adaptation required for multimedia conferencing. Also, with the isochronous service, there is no loss such as the frame loss encountered in packet mode services.

Access Unit Architecture

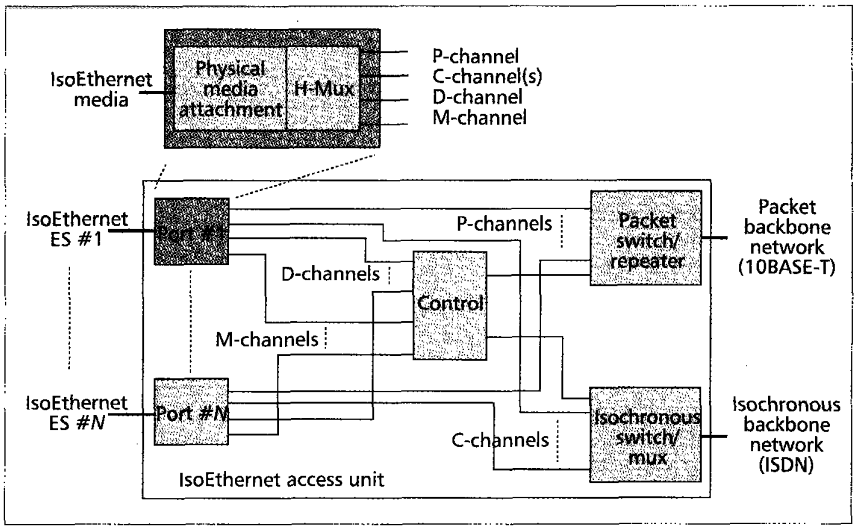
Figure 5 depicts the architecture of a typical AU. It offers multiple IsoEthernet interfaces for connecting ESs, and backbone interfaces for both ISDNs and 10Base-T LANs.

The control function provides for the overall operation within the AU. It has access to both D-channel and M-channel information. Control includes signaling, bandwidth allocation, and buffer management functions. Signaling is responsible for providing the signaling to establish isochronous connection between ESs, and providing a global isochronous connection to remotely located ESs. Bandwidth allocation provides the bandwidth allocation for the C-channel operation.

The switch/multiplexer function provides switching/multiplexing for the 96 B-channels (multiservice mode) or 248 B-channels (all-isochronous mode), and the connection for the isochronous traffic to the backbone network. The packet switch/repeater function provides the connection for the 10Base-T traffic to the backbone network.



■ **Figure 4.** *Multimedia end station.*



■ **Figure 5.** *Access unit architecture.*

MODES OF OPERATION

IsoEthernet supports three modes of operation between the AU and its connected ESs. These are selected based on ES capabilities and service requirements. These modes are:

- 10Base-T mode
- Multiservice mode
- All-isochronous mode

These alternate modes of operation use the auto-negotiation signaling developed for IEEE 802.3 networks. The increasing number of types of links becoming available — 10 Mb/s, 100 Mb/s, full-duplex, and so on — necessitate the development of a means of signaling basic information about the link and the attached equipment over the medium of a quiescent IEEE 802.3 link. Auto-negotiation is backward-compatible with the current IEEE 802.3 link integrity test for 10Base-T signaling, yet broad enough to encompass IsoEthernet and its two variations: multiservice and all-isochronous. Auto-negotiation uses a series of pulses that are transmitted every 2 ms over quiescent links. These pulses delineate 16 intervals which provide for the transmission of 16 bits of binary data.

10Base-T Mode: 10Base-T Packet Data Only — In 10Base-T mode, IsoEthernet allows the port of an IsoEthernet AU to be connected to an ES requiring a conventional IEEE 802.3 10Base-T connection. In this mode, carrier sense multiple access with collision detection (CSMA/CD) packet data is handled, but there is no isochronous data associated with it. The D- and M-channels are also not available. The AU port switches to a 10Base-T mode of operation. Thus, each end station operates as a 10Base-T device, and the AU operates as a 10Base-T repeater [4] for that ES.

Multiservice Mode: Normal IsoEthernet Mode — In multiservice mode, the C-channel provides 6.144 Mb/s or 96 B-channels of full-duplex isochronous data, and the 10 Mb/s P-channel is used as a half-duplex CSMA/CD channel for 10Base-T LAN services. The D-channel (signaling data) and M-channel (maintenance data) are also available.

Table 1 details the allocation of the 256 bytes of data contained in each TDM frame and the services offered for the multiservice and all-isochronous modes.

All-Isochronous Mode: All-Isochronous Data — In all-isochronous mode, an IsoEthernet AU port may be connected to an ES or another device, such as a video server, that requires increased bandwidth for isochronous data. The all-isochronous mode eliminates the P-channel bandwidth with the freed-up bandwidth being used for isochronous traffic. In this case the C-channel(s) is 15.872 Mb/s, which is the equivalent of 248 B-channels, each at a rate of 64 kb/s. The D-channel (signaling data) and the M-channel (maintenance data) are also available.

ISOETHERNET OPERATION

The mode of operation for an IsoEthernet link between an ES and an AU is chosen at power-up time. If 10Base-T mode is selected, the link is configured to provide half-duplex 10Base-T packet channel operation. In multiservice or all-isochronous mode, the link reverts to the IsoEthernet TDM frame mode of operation.

The 10Base-T packet traffic is forwarded via the switch/repeater function in the AU. It may be directed to an ES located locally or remotely via the IEEE 802.3 network and its WAN connections.

For isochronous traffic, an isochronous connection is established by signaling over the D-channel. These are negotiated in terms of N x 64 kb/s of bandwidth. Connection establishment procedures are similar to those of ISDN. Connections may be between locally located ESs, or alternately, one of the stations may be remotely located. In the latter case, connections are established over the ISDN backbone.

COMPARISON WITH OTHER RELATED MULTIMEDIA NETWORK TECHNOLOGIES

To best understand the importance of IsoEthernet and the unique advantages it offers, it is useful to look at some multimedia concepts and requirements. The term "multimedia" is often abused. As used herein, multimedia includes conventional packet data traffic, but also encompasses video data, audio data, and any other data traffic that has requirements on the maximal delay and delay variation. Traffic subject to such delay requirements is widely referred to as *real-time traffic*.

While this article often takes the perspective of the basic multimedia services offered, such as video and audio, it is important to understand that the driving applications, which are complex and varied (e.g., video conferencing, distance learning, and collaborative computing), often depend on a combination of these basic service components. Let us look at some of the more important requirements common to a number of these applications.

MULTIMEDIA NETWORK REQUIREMENTS

Participants in a multiparty multimedia video teleconference have stringent requirements on real time traffic. They may be viewing images of one another or a selected subset of the participants. They may be sharing and editing documents, the whiteboard, or still images. They may all be receiving the identical audio or video content from some remote server, with one or more of the participants possibly controlling or otherwise participating in the playback. Alternatively, video or still images may be generated by one of the participants, with pointer and/or by voiceover, and transmitted to the other participants.

These modes of operation put stringent requirements on networks that connect multimedia ESs. Consider the following:

- End-to-end delays must not be too large, or an unacceptable delay is observed by the participants whenever an interactive interchange takes place between remote participants.
- Video must be in synchronization with audio, or the sound of, for example, a tennis ball being hit will not match the video event.
- The pointer must be in synchronization with video, or one participant cannot point to a video and differentiate one object or action from another for the other participants.
- The pointer must be in synchronization with audio, or one participant cannot point to a series of items in a document and vocally differentiate one from another for the other participants.
- Data must not be lost. Data loss becomes particularly serious when compression techniques are used, since even the loss of a small amount of data may have a serious effect.

For certain applications these examples require that the end-to-end delay does not exceed 150 ms [5] and that different components, such as the video and audio of the same multimedia connection, do not have a path differential exceeding 50 ms [5]. To satisfy the first requirement, network delays between ESs must be minimized. In some cases, due simply to the large physical extent of a network, the delay between ESs will necessarily exceed 150 ms, compromising the quality of service realized. The second requirement prohibits different components of a multimedia connection from using different paths through the network, or, if they do, requires that path delay equalization be applied.

IsoEthernet provides an 10BASE-T packet channel which has identical characteristics to the 10BASE-T packet channel provided by IEEE 802.3.

ISOETHERNET PROPERTIES

IsoEthernet provides a 10Base-T packet channel which has identical characteristics to the 10Base-T packet channel provided by IEEE 802.3. This means that IsoEthernet can provide an equivalent packet service, and is able to switch to actual 10Base-T operation to accommodate non-IsoEthernet-capable ESs. An AU may form part of an IEEE 802.3 network with the IsoEthernet 10Base-T packet traffic switched, bridged, routed, and so on in the IEEE 802.3 networks exactly as IEEE 802.3 native packet traffic is.

Of real interest in meeting multimedia requirements is the isochronous traffic that can be carried in real time by IsoEthernet.

In contrast to a packet-based network, in an isochronous network the data flows smoothly throughout the network using preallocated bandwidth and incurring no contention delays. There is no need to collect a packet's worth of data at any point in the network before the next action can be taken. The delay much more closely matches the fundamental physical delays of network elements and will consequently be considerably less than the delay of a corresponding packet network. Delay variation (jitter) will be introduced at the interface between clocking domains to achieve alignment between the 125-μs clocks, but this delay variation can be managed to be considerably less than the delay variation introduced by a corresponding packet network.

Consequently, the important elements of overall delay can be much reduced in a fully isochronous network.

IsoEthernet is the only fully isochronous network available at a viable cost-performance point that enables an isochronous network to be extended all the way to the desktop. As a result, it is the only LAN that offers the hope of realizing the goal of 150 ms delay from desktop to desktop [5] in complex networks which span an enterprise network or countries. This fact, coupled with IEEE 802.3 interoperability and an easy IEEE 802.3 10Base-T migration path, makes IsoEthernet an attractive choice to bring multimedia to the desktop.

PACKET NETWORKS

Packet networks are not well suited to multimedia applications. Simply making a higher-speed packet network does not address the requirements of multimedia applications.

Network Delay Considerations — The overall delay requirements of multimedia are extremely difficult (one might argue impossible) to satisfy using a packet network. In the real-time world of multimedia devices, data is a continuous flow — an isochronous data stream. In contrast, packets contain a finite number of bytes (often a large number to increase efficiency) of data that are handled as one entity at various points in the network. The isochronous data for multimedia devices has been generated over a given time period at the source and is to be used over a similar time period at the destination.

To convert this isochronous data stream at the source to a fixed-length packet format and then convert it back at the destination adds both delay and delay variation at both ends, to say nothing of the hardware cost. Furthermore, there may be a number of the components in the path between the ESs that will have to receive, store, and forward the packets. Because of the fixed-length nature of packets, these components will necessarily add both delay and delay variation. At any interface between the LAN and the WAN, it will be necessary to adapt the packets to the WAN, which is an isochronous network. This also adds both delay and delay variation.

To make matters worse, in a real packet network there will be other packet traffic, and thus points of contention for bandwidth that will cause additional packet delay and further increase the delay variation. Furthermore, packets can become lost in transmission, a nonevent that must be detected with a time-out function.

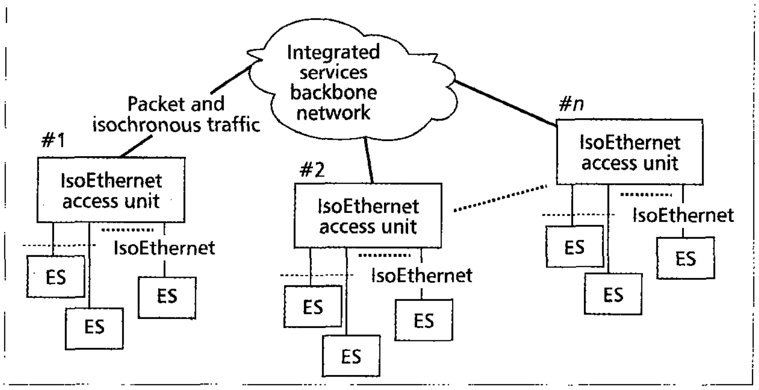
Delay variation presents a challenge throughout the network. Since the original data source presents an isochronous data stream and the destination requires an isochronous data stream, all the delay variations must be resolved in the network. There is only one way to do this, which is to insert a variable delay equal to the maximum possible delay variation so that the earliest arriving packets can be delayed to match the latest packets, which would have no delay inserted. Packets between the two extremes would have corresponding delay compensation added. Thus, the resultant delay of each network component becomes the maximum delay plus the maximum delay variation.

Path Differential Considerations — As noted above, the path differential delay for different data components of multimedia communications between ESs must be minimized, with a differential of 50 ms suggested as acceptable. At the source ES the various data components are generated as isochronous data streams. These must travel the same path or between ESs or much greater path differential delay times will be experienced.

In a packet network these data components might typically be combined into a series of packets such that each packet contains all of the data from an ES for a given time period, regardless of its nature. This can add considerable complexity at both source and destination.

In an isochronous network, however, the different data components of an ES's traffic can easily be multiplexed into the same isochronous service. This then ensures that the proper time relationships are preserved among the different data components of the connection. In some cases, where a single channel with sufficient bandwidth is not available in the isochronous backbone network, an inverse multiplexing function may be employed to enable the use of multiple channels. This inverse multiplexing function may be supplied external to the IsoEthernet at the WAN connection or as part of the IsoEthernet AU.

The advantages of IsoEthernet, allowing the isochronous network to be extended all the way to the desktop, are again evident.



■ **Figure 6.** *Integrated services backbone configuration example.*

ATM Networks — ATM networks are based on the universal use of 53-byte cells. This small size alleviates many of the delay problems inherent in packet networks which use larger packets in that much smaller units of data can be handled at each step of the process. The rather small cell size does, however, introduce a number of complexities. Specifications are being developed for ATM networks that resolve these complexities while taking advantage of the reduced delays possible using 53-byte cells. These specifications have added many other technical innovations. Signaling procedures similar to those used for isochronous data streams are being specified.

The result is a compromise — a network with performance characteristics somewhere between a packet network and an isochronous circuit-switched connection. Large packets of LAN data are divided into 53-byte cells for a smoother flow of traffic than would occur in a true packet network. Isochronous traffic, on the other hand, is collected into 53-byte cells for a somewhat more uneven transmission than would occur in a true isochronous connection.

Much has been heard about the promise of ATM technology to satisfy all classes of traffic demands, including those of both packet and isochronous traffic, in an integrated scalable network. The fulfillment of this promise and attainment of the great expectations for ATM networks remains to be realized. At this time, IEEE 802.3 CSMA/CD technology remains firmly entrenched in the LAN, but fails to satisfy the quality-of-service needs of isochronous traffic.

Other Isochronous Network Technologies

Several other isochronous network technologies are of interest. These include fiber distributed data interface II (FDDI-II) and IEEE 1394, both real time networks based on a TDM frame structure with jitter and overall delay characteristics similar to those of IsoEthernet.

FDDI-II — FDDI-II [6] has an ideal set of qualifications as an isochronous backbone for a network of IsoEthernet AUs. It can carry up to 100 Mb/s of mixed packet and isochronous traffic and can span a distance of up to 100 km. The wideband channels of FDDI-II each accommodate 6.144 Mb/s of isochronous traffic, exactly matching the bandwidth of IsoEthernet isochronous traffic. In a configuration such as the one shown in Fig. 6, FDDI-II would provide an ideal solution for the integrated services backbone network.

FDDI-II has been standardized, and is currently available in products. However, the range of deployment of FDDI products at this time is somewhat more limited than one might have hoped.

IEEE 1394 — IEEE 1394 [7] has gained acceptance as the LAN for use with PCs, carrying both packet and real-time isochronous information. IEEE 1394, like IsoEthernet, uses a TDM frame structure. In this case, 4-byte quadlets of batch and real-time data are multiplexed on a serial bus to accommodate both packet and isochronous traffic. The serial bus structure may link both backplane components and local units via a cabled interface. Data rates of 100, 200, and 400 Mb/s are offered.

IEEE 1394 provides for distribution of ISDN services in the small-system environment and the home. In this capacity it provides a perfect counterpart to IsoEthernet, which provides equivalent services but at a higher-end performance point more suited to the corporate user. One can envision applications based on the use of IsoEthernet at the corporate provider level and IEEE 1394 at the private user level.

Application Areas

A major application area for IsoEthernet is multimedia conferencing. Typical user applications that require multimedia conferencing include:

- Distance learning
- Banks — kiosk-based interactive information exchange
- Healthcare — remote diagnostics
- Global industry — better customer service support and telecommuting

IsoEthernet provides this capability with both packet-mode services over 10Base-T LAN and isochronous services using ISDN. Internet access for packet services is accomplished via a 10Base-T LAN backbone connection.

Current implementations of IsoEthernet support multipoint multimedia conferencing for configurations such as those depicted in Figs. 1 and 2.

Multimedia ESs are connected to the AU at each site. Cascading AUs provides for the connection of additional ESs at a site. Multiple sites are connected using the AU ISDN PRI access connection. Each ES participates in the conference using H.320 384 kb/s video, 64 kb/s voice, and 128 kb/s collaborative data. The aggregate data of each ES are multiplexed and transported on ISDN PRI. Also, the multimedia conferencing application is capable of supporting many different PBX feature services, including multimedia call forwarding and multimedia mailbox.

Some IsoEthernet implementations have used an additional audio channel as a companion to the H.320 video conference call.

Another feature of video conferencing which has been implemented using IsoEthernet is the facility of "managed multiparty call." The AU directs multiple H.320 calls to a dedicated desktop. The desktop will manage to deliver multiple videos to all ESs on an as-need basis. This is a useful fea-

Standard	Services	Status	Application	Comments
IEEE 802.9	LAN and ISDN services	Standard 1994, published	384 kb/s video services	Provides for both 4.096 Mb/s and 20.48 Mb/s physical layers
IEEE 802.9a	10BASE-T and ISDN services	Standard 1995, published	Data services and 384 kb/s video services	Provides for 16.384 Mb/s physical layers. Several known implementations
IEEE 802.9b	AU-to-AU Interworking	In progress	Interconnects IEEE 802.9 LANs via a backbone network	Specifies interworking over various backbone networks including IEEE 802.9 and ISDN
IEEE 802.9c	MOCS	Standard 1995, In print	Enables interoperability of multivendor management solutions	Specifies management information elements. Applicable only to IEEE 802.9
IEEE 802.9d	PICS	Standard 1995, published	Enables interoperability of multivendor protocol operations	Protocol implementation conformance. Applicable only to IEEE 802.9
IEEE 802.9e	ATM cell bearer service	In progress	Provides ATM network services	Applicable only to IEEE 802.9a
IEEE 802.9f	Remote terminal powering	In progress	Provides remote power to maintain telephony services at all times	Applicable only to IEEE 802.9a

■ **Table 2.** *Family of IEEE 802.9 ISLAN standards.*

ture for distance learning. Access to Internet services using 10Base-T LAN enables additional features such as delivering documents from a Fast Transfer Protocol (FTP) site without disrupting a multimedia conferencing setup via ISDN.

FUTURE DEVELOPMENT FOR ISOETHERNET

The IEEE 802.9 ISLAN standards committee which developed the standard for IsoEthernet is currently working on future enhancements to IsoEthernet and other ISLAN standards. Table 2 lists the family of IEEE 802.9 ISLAN standards. Of particular interest to IsoEthernet is the ongoing work on the following standards: IEEE 802.9b, AU-to-AU interworking; IEEE 802.9e, ATM cell bearer mode; and IEEE 802.9f, remote line powering.

IEEE 802.9b specifies the interworking of IsoEthernet AUs. This standard specifies the interconnection and operation of AUs located either locally or remotely via a WAN connection. Thus, it permits different IsoEthernet sites to be connected by a backbone network as an enterprise network, thus facilitating true scalability. Features transport may also be achieved by other backbone networks.

IEEE 802.9e provides an enhancement to IsoEthernet by adding an ATM mode of transport in addition to isochronous and packet modes. This will enable IsoEthernet networks to communicate with ATM-based backbones and WANs.

IEEE 802.9f provides an enhancement to IsoEthernet by adding the capability to power ESs, or portions thereof, in case of local power loss by providing 8 W of power on the same cable as the IsoEthernet signal. This enables normal operation of voice services to the desktop even if the associated ES is without power.

As markets become more sophisticated and competitive, the need for multimedia services becomes an important consideration for improving productivity in the increasingly global competitive environment. IsoEthernet and its future enhancements will interoperate and compete favorably with other technologies in this marketplace. The IEEE 802.9 standards committee, with the help of industrial participants, will provide an effective standardization process to move technology enhancements to the market, enabling the development of multivendor products to coexist in an interoperable manner.

ACKNOWLEDGMENT

The authors wish to acknowledge the IEEE 802.9 Standards Committee members who have made contributions to the development of the ISLAN family of standards, and industry organizations who have put their faith and resources into development of the ISLAN16-T solution as a competitive integrated services technology for the near future.

REFERENCES

[1] D. R. Vaman and W. Zakowski, "Quality of Service: Point of View of Multimedia Communications Forum (MMCF) on Multimedia Interoperability," *Proc. Broadband Multimedia and the Internet Conf., Int'l. Eng. Consortium*, Session E-2: Traffic Management and QoS, Bal Harbor, FL, Dec. 4–6, 1995.

[2] ANSI T1.607, "Telecommunications — ISDN — Layer 3 Signaling Specification for Circuit Switched Bearer Service for Digital Subscriber System No. 1," 1990.

[3] ITU-T Recs. Q.931:1988, 1992, "ISDN User-Network-Interface Layer 3 Specification for Basic Call Control."

[4] IEEE Std 802.9a-1995, "Supplement to IEEE 802.9 ISLAN — Specification of ISLAN16-T", IEEE, Dec. 1995.

[5] MMCF QOS-1995, "Multimedia Quality of Service Requirements: Part I: Framework, Part II Multimedia Desktop Collaboration Requirements," available at www.mmcf.org

[6] ANSI X3.186-1992, "Fiber Distributed Data Interface (FDDI) — Hybrid Ring Control (HRC)," aka FDDI-II.

[7] IEEE Std 1394-1995, "IEEE Standard for a High Performance Serial Bus," *to be published Summer 1996.*

BIOGRAPHIES

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