5-04-15.1 Multimedia Networking Technologies

T.M. Rajkumar
Amitava Haldar

Payoff
A host of technologies are emerging to help organizations support the enterprisewide delivery of new multimedia applications. Some of these technologies work well at the workgroup or local area network level, and others work at the backbone or wide area network level. This article reviews many of the technologies in these two groups and evaluates their suitability for distributing multimedia information.

Introduction
Multimedia applications involving data bases, the World Wide Web and desktop videoconferencing challenge Information Systems organizations to implement networking technologies that support a wide variety of information forms. Multimedia applications place different demands on the network than do traditionally supported discrete media (such as text and data). They require support for continuous, delay-sensitive media such as audio and video that need connection-oriented links. Because most networks today support connectionless links, they are poorly suited to support multimedia data.

A host of technologies are emerging to support enterprise multimedia applications. Some of them work well at the local area network (Local Area Network) or workgroup level, and others work at the wide area network (Wide Area Network) or backbone level. This article discusses the multimedia networking technologies within these two groups and their suitability for distributing multimedia information.

LAN Technologies
Because traditional LAN technologies such as Ethernet and Token Ring are designed to process data packets and operate in contentious mode, they cannot meet the demands placed on the LAN by multimedia applications. Several technologies have been proposed to support multimedia on the LAN, including isochronous Ethernet, fiber distributed data interface (Fiber Distributed Data Interface), Fast Ethernet, and asynchronous transfer mode (Asynchronous Transfer Mode).

Isochronous Ethernet
In contrast to packet-switched technologies, isochronous transmission guarantees timely delivery of information, avoiding delay and jitter. The premise behind isochronous Ethernet is that voice (not audio or video) is the critical component in multimedia communications.\textsuperscript{116} Hence, this technology is most important at locations where videoconferencing is the primary multimedia application.

To ensure that voice receives priority, a special isochronous integrated services digital network (Integrated Services Digital Network) 6.144M-bps line is added to the standard Ethernet technology. This additional bandwidth is sufficient for a multipoint videoconference with six participants, each using 384K bps and additional bandwidth for

\textsuperscript{116} N. J. Muller, "Multimedia over the Network," Byte(March 1996), pp. 73-80.
such ancillary functions as white boarding. In addition, isochronous Ethernet is easy to add to existing Ethernet networks, because all that is required is an isochronous Ethernet hub and cards for the computers involved in videoconferencing. On segments where such isochronous capability is not required, it need not be added. ¹¹⁷

**Suitability for Multimedia Traffic.**

Isochronous Ethernet is a shared-media approach with limited multicasting support for audio only. It is not suited for full-motion video (i.e., the Moving Picture Experts Group or Motion Picture Experts Group standard), but it supports H.261 video (the teleconferencing standard). It provides truly isochronous support for voice. ¹¹⁸ From a business perspective, isochronous Ethernet is only suitable as a small workgroup solution and where multimedia needs are not great. The technology should be viewed as a transitionary step to ATM technology.

**Fast Ethernet**

The IEEE 802.3 or 10Base-T is rapidly becoming the technology of choice for providing bandwidth to users because it uses the same Carrier Sense Multiple Access/Collision Detection (carrier sense multiple access with collision detection) technique as the widely used 10Base-T Ethernet. The high-speed 100Base-T offers 100M-bps performance for a small increase in cost for network adapters and hubs. In addition, it allows existing 10M-bps cards to share the same network, providing for easy transition.

This Fast Ethernet technology has limitations however. It needs a repeater every 250 meters as opposed to the every 2,500 meters required by 10Base-T systems. Because the regular Industry Standard Architecture bus architecture is not fast enough to handle the 100M bps of bandwidth 100Base-T provides, the technology needs PCs with Peripheral Component Interconnect buses.

100Base-T supports three different signaling schemes that require specific types of repeaters. It may require four wires as opposed to the standard unshielded twisted pair (Unshielded Twisted Pair) wiring existing in some organizations. The availability of mitigating technologies minimizes these problems.

100Base-Tx also has a new duplexing feature, allowing it to boost network speed to 200M bps. In general, the network adapter must always be listening on the receiving pair of wires to check for a collision. When Ethernet switching is used, a dedicated 100 Mbps is available to the adapter, avoiding the need to check for collisions. In this way, the UTP wiring can be used and 200M-bps bandwidth is available. This option is typically used for the server and not for each desktop.

**Suitability for Multimedia Traffic.**

Ideally, 100Base-T is a workgroup solution, because the 100M-bps bandwidth is shared among the different users. It relies on appropriate use by every user station, and it cannot make any delay guarantees or provide quality-of-service (Quality Of Service) considerations. This high-speed Ethernet technology is useful because it provides backward compatibility with existing 10Base-T networks, making it easy to configure,

¹¹⁷ N.J. Muller, pp. 73-80.
install, and manage. In addition, a new set of gigabit Ethernet standards expected by mid-1997 should allow groups employing the technology to use increased bandwidth in the near future.

**100VG-AnyLAN**

A second alternative high-speed Ethernet solution is the 100VG-AnyLAN option. This technique does not use the standard CSMA/CD access technique, but rather a new demand priority access (DPA) technique. DPA enables the system to assign priorities and ensures on-time delivery of multimedia information.

100VG-AnyLAN also depends on more intelligence in the hub. Under DPA, a node wishing to transmit sends a request-to-send to the hub. If the message is a priority message, a special bit stream sent over two pairs of wiring indicates this to the hub. The hub continuously scans and grants the requests based on their priority. The hub also sends a notice to the receiving node that it is about to receive a message. It then routes the packet from the sending node to the receiving node or nodes. Implementing the priority 100VG-AnyLAN thus requires use of all four wires, which can be costly to implement. The primary advantage of 100VG-AnyLAN over 100Base-T4 is that it also supports Token Ring technology.

**Suitability for Multimedia Traffic.**

100VG-AnyLAN supports multimedia better than Ethernet, because it assigns priority to multimedia traffic and supports multicasting. It is particularly more suited than 100Base-T, because with a small number of workstations (i.e., less than 30) it can support delays of less than 10 microseconds.\(^{119}\)

Despite these advantages, 100VG-AnyLAN does not provide QOS guarantees or support for existing (i.e., Ethernet) infrastructure. From a business perspective, 100VG-AnyLAN is useful for organizations that have invested heavily in Token Ring systems. For these groups of organizations, 100VG-AnyLAN provides an efficient way of supporting multimedia at the workgroup level.

**FDDI**

Because of its speed, fiber distributed data interface (FDDI) is used extensively as the backbone to interconnect LANs. FDDI uses a token-passing method to provide 100M-bps of bandwidth. It can also be spread over larger distances (i.e., 200K meters) than bus-type networks and supports up to 500 stations on a ring.

FDDI uses two counter rotating rings for data transfer. The use of two rings ensures against failure of the ring when a single node fails. FDDI has extensive network management support, and its cost has fallen to $1,500 to $3,000 per hub.

**FDDI II**

FDDI II provides a circuit-switched service while maintaining the token-controlled packet-switched service of the original FDDI. This is done by imposing a fixed-frame structure on the original FDDI and regularly repeating time slots in the frame (i.e.,

\(^{119}\) Stuttgen, pp. 42-59.
Suitability for Multimedia Traffic.

FDDI II adds constant bit rate traffic to FDDI to support multimedia. Its bandwidth is sufficient for LANs and supports multicasting. To bring FDDI II to the desktop is a costly proposition, however. Like FDDI, FDDI II is used mostly at the backbone to interconnect LAN systems. It is also incompatible with FDDI in the sense that a station with FDDI cannot read a FDDI II frame; the reverse, however, is possible.

Asynchronous Transfer Mode

Asynchronous transfer mode (ATM) is a technology that serves equally well at the LAN and WAN levels. The following sections provide a general description of this still-emerging technology and specifics on its LAN emulation technology.

ATM uses fixed-size 53-byte cells (i.e., a 48-byte information field and a 5-byte header field) and breaks all traffic into these cells to ensure quicker switching and multiplexing. It provides point-to-point and point-to-multipoint connections through virtual circuits. ATM currently supports speeds as high as 155M bps and 622M bps and will reach 10G bps in the future. It operates as a DS3 or T3 line (i.e., 45M bps) or possibly a DS1 line (i.e., 1.544 Mbps).

ATM Architecture

ATM functionality corresponds to the physical layer and data link layer of the Open Systems Interconnection (Open Systems Interconnection) model; the architecture is depicted in Exhibit 1. In the physical layer, information is transferred from one user to another by cell-based asynchronous transmission or, more frequently, by an externally framed synchronous transmission structure, typically a Synchronous Optical NETwork structure (synchronous optical network). Thus in the latter option, the ATM cells are carried inside a SONET structure (i.e., 90 columns and 9 rows of 8-bit bytes) with a bit rate of 51.84M bps (i.e., one frame is transmitted every 125 microseconds—the sampling interval used in digitizing voice for telephone systems).

ATM Layer Architecture

The ATM layer multiplexes cells over the physical link. The major function of this layer is to complete the ATM cell structure and set up the cell streams for transmissions of outgoing process, receive the incoming cells, and send them to the corresponding stream. The cells are distinguished by the virtual channel identifier (Virtual Channel Identifier) and virtual path identifier (Virtual Path Identifier) in the cell header. A table in the switch helps the ATM layer place the cell in the appropriate output link. A generic flow control is used for media access by the user network interface to control the amount of traffic entering the network.

The ATM adaptation layer (ATM Adaptation Layer) has the job of adapting higher-level data into the format needed by the ATM layer. When the necessary adaptation is completed, many different kinds of traffic can be carried over the same system, enabling...
ATM networks to aggregate network traffic to cut costs while simultaneously providing flexible service provisioning. AAL identifies four service classes based on the following three parameters:

- The timing relation between source and destination (i.e., yes/no).
- Constant, variable, or available (C, V, A) bit rate.
- Connection mode (connection-oriented or connectionless).

**Suitability for Multimedia Traffic.**

ATM's greatest advantage is its ability to specify QOS by applications. This allows ATM switches to efficiently allocate network resources among applications with very different needs. For example, LAN data traffic may be able to tolerate delay but no loss, and desktop video can drop frames but tolerates no delay. Choices of quality and the class of applications that can exploit them are shown in Exhibit 2.

### Quality and Application Classes in ATM

<table>
<thead>
<tr>
<th>Name</th>
<th>Priority</th>
<th>Negotiation</th>
<th>Advantage</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Bit Rate</td>
<td>High priority</td>
<td>“Contract basis” for maximum data rate</td>
<td>No cell loss</td>
<td>Real-time audio and video</td>
</tr>
<tr>
<td>Variable Bit Rate</td>
<td>Rate Medium to high</td>
<td>Peak cell rate and sustained cell rate</td>
<td>QOS guaranteed for cell loss and bandwidth availability</td>
<td>Not for LAN traffic but for most others</td>
</tr>
<tr>
<td>Available Bit Rate</td>
<td>Medium</td>
<td>Negotiates bandwidth availability and cell loss</td>
<td>Reliable delivery of bursty data</td>
<td>LAN traffic</td>
</tr>
<tr>
<td>Unspecified Bit Rate</td>
<td>Low to medium</td>
<td>No QOS</td>
<td>Efficient use of bandwidth</td>
<td>Noncritical applications</td>
</tr>
</tbody>
</table>

---

ATM also has several other advantages, including:

- Network resources given on demand (i.e., statistical multiplexing).
- Easy transition from the existing network.
- AAL-specific adaptability.
- Easy network management.
- Reduced error checking means that it works only on low rate links.

The problems associated with ATM technology include:

- The need for traffic parameters to be stated on start-up.
- The need to resolve interoperability issues. The private network-to-network interface (PNNI) standard has just been defined and approved by the ATM Forum (a standards group for ATM).
- The need for switching architectures capable of supporting the high data rates of broadband applications.

**LAN Emulation**

As seen in Exhibit 3, ATMs and LANs differ in their basic nature; ATMs are inherently connection-oriented while LANs are connectionless. The aim of LAN Emulation (LANE) is to make the ATM switch invisible to legacy LANs. It also provides a way to protect existing investments in bus and Token Ring networks.

---

As shown in Exhibit 4, LANE provides a mechanism for tying legacy networks to ATM networks and using them without modification to software. It allows ATM's connection-oriented fabric to mimic a connectionless system and makes two separate LANs appear as one big LAN. LANE does this by emulating the media access control (Media Access Control) layer protocol so that the ATM network looks like just another media access control sublayer similar to either Ethernet or Token Ring. Because of this, it is not possible to mix Token Ring and Ethernet medias on the same LANE. However, they can be emulated separately and bridged. LANE provides mechanisms to map the media access address to the ATM address and vice versa and to multicast the same information to different systems on the network.\(^{123}\)

**LAN Emulation**

The ATM switch itself does not emulate. It basically sets up a virtual connection and switches 53-byte cells as usual. By separating the physical and logical infrastructure into multiple segments, this virtual connection provides significant benefits in terms of increased security and scalability.\(^{124}\)

---


Suitability for Multimedia Traffic.

Although LANE is attractive, it lacks robustness as defined currently, because a single broadcast server is used to do all multicasts and broadcast. Hence, the system is exposed to a single point of failure. The current LAN emulation service does not specify the interaction between LAN emulation service components (LNNI), a specification necessary to ensure interoperability. The ATM Forum is working on this aspect and a standard is expected shortly.

Because different types of networks (i.e., Ethernet or Token Ring) must still be bridged or routed, LANE is only useful at the workgroup level and cannot be used at the WAN level. In addition, LANE does not allow applications to take advantage of the QOS characteristics that are the greatest benefit of ATM. LANE’s greatest benefit lies in the protection of investments in the existing infrastructure; as such, it serves as an important step in the ATM migration strategy for many organizations.

WAN Technologies

As is the case for LANs, several technology options are available for supporting multimedia communication on the WAN. Chief among these transport technologies are the Internet Protocol (IP), frame relay, switched multimegabit data service (Switched Multimegabit Data Service), fiber channel, and ATM.

Frame Relay

Frame relay typically connects at speeds of T-1 lines and is an evolution of standard X.25 networks. Like X.25, it combines packets into frames and allocates bandwidth to multiple data streams. Frame relay uses the link access procedure direct (LAP-D) frame structure with a data link connection identifier to route the data. Its payload is as high as 4K bytes and it handles Ethernet data without segmentation. It does not provide for error checking or flow-control mechanisms.

Frame relay connections are either permanent virtual circuits (Permanent Virtual Circuit) or switched virtual circuits (Switched Virtual Circuit). PVC establishes a fixed path through the network for each source/destination node and remains defined for long periods of time. SVCs are defined and used only for the specific sessions. Multicasting services can be added over PVC lines, and the bandwidth assigned to each PVC is the committed information rate.

Frame relay over ATM lets a frame relay site communicate directly with an ATM site so that frames can be sent through the ATM backbone. Edge devices convert frame relays to ATM cells and vice versa. This allows LANs to be interconnected through ATM switches or IP to be transmitted over frame relay.

Suitability for Multimedia Traffic.

Frame relay is not suitable for voice or video traffic because it does not provide for latency or constant bit rate transmission. The protocol does not add substantially to the delay itself, but it cannot guarantee a set delay. Frame relay provides for committed information rate on PVC lines and has been tested for videoconferencing with limited success. It is a popular mechanism for providing wide area data interconnections. Frame relay and ATM together enable a company to handle both low-speed and high-speed
multimedia networking over the WAN. Frame relay is currently more affordable than ATM because it has been available longer.

**Internet Protocol**

The Transmission Control Protocol/Internet Protocol (TCP/IP) has become the backbone of the WAN for carrying data services. The problem for carrying multimedia data with IP is the delay associated with the routing of the packets from one node to another. IP does not allocate a specific path nor guarantee a specific bandwidth to the multimedia application. Several technology options are being developed to resolve these problems, including Classic IP over ATM, resource reservation protocol (RSVP), multiprotocol over ATM (MPOA), and next hop resolution protocol (NHRP).

**Classic IP over ATM.**

Classic IP over ATM uses the bandwidth of ATM to provide IP services without changing the fundamental nature of the protocol. The technology uses 9,000-byte frames at the higher layers and reduces packet overhead, which is advantageous for bulk data transfers. Classic IP over ATM also uses a modified version of IP's address resolution protocol (Address Resolution Protocol) to find ATM's Virtual Channel Identifier/Virtual Path Identifier connectionless correspondence to the IP network address.

**Suitability for Multimedia Traffic.**

Classic IP over ATM aims to expand and use the huge bandwidth of ATM switches, but it fails to provide for QOS considerations. Because the approach shifts a lot of work to the router feeding the ATM switch, the TCP/IP network may be congested and slow regardless of the speed of the switch. In addition, the fact that two separate routing/switching structures are trying to find the best path adds to a lot of confusion.

**RSVP.**

A better option for carrying multimedia using IP is to use the Internet Engineering Task Force's (Internet Engineering Task Force) resource reservation protocol (RSVP), which should be available in mid-1997. To support a mix of voice, data, and video, RSVP confirms QOS parameters with the networking devices using vendor-specific APIs.

RSVP operates through allocation of the following types of resources:

- Active resources (such as a Central Processing Unit that is a service provider).
- Passive resources, which are the system capabilities used by the active resources. They include main memory or bandwidth (i.e., link throughput).

In addition to reserving and allocating resources so that traffic flows follow QOS specifications, RSVP uses proper service disciplines and allocation strategies for multimedia delivery and adapts to resource changes.

---


Suitability for Multimedia Traffic.

RSVP essentially allows a router-based network to mimic a circuit-switched network on a best-effort basis. Best effort suffices if there is adequate bandwidth; otherwise quality suffers. RSVP tries to ensure that the bandwidth is reserved and available. It has the advantages of working over both physical network architectures (Ethernet and Token Ring) and matching well with the new IPV6, which allows applications to label packets with traffic patterns. Packets belonging to a particular traffic flow from an application are easily switched.

RSVP thus allows the user to provide QOS to the network workstation without extending ATM to the workstation. Multicast extensions such as the MBone are separate extensions from RSVP. Because the Internet is so widely available, however, and despite the presence of delay and jitter, RSVP is being used as an experimental multimedia communications platform.

Multiprotocol over ATM.

MPOA allows ATM switches to route LAN-based traffic between subnetworks, eliminating the router bottlenecks. In addition, IP switching is becoming available. It removes all ATM overhead and uses just the switching feature of ATM, enabling routing to be bypassed. IP switching is still an experimental technology and should be viewed with caution.

NHRP.

Another technology designed to allow multimedia to be carried over IP is the next hop resolution protocol (NHRP) being developed by the IETF. NHRP aims to eliminate or bypass some or all of the routers used by Classic IP over ATM by directly connecting to the ATM fabric. Disjoint IP subnets are viewed as one logical nonbroadcast multiaccess network (NBMA). Each NBMA has a server that resolves IP addresses to NBMA addresses using dynamic address-learning mechanisms. Once addresses are resolved, a node then connects to the destination node with the required QOS parameters.

Although NBMA servers reduce the number of hops, they may increase the response time by a round-trip time (a critical factor for some applications). NBMA servers add network management complexity and introduce additional points of failure in the system.

Switched Multimegabit Data Service (SMDS)

SMDS is a connectionless service to interconnect LANs that enables access at T1 and T3 speeds. It can slice up to 9K bytes of data into fixed 53-byte cells (same as ATM) that are then switched through the network. Because it supports up to 9K bytes, it allows entire LAN frames to be encapsulated and provides reliable interconnections between LANs. The advantages of SMDS include scalability, bandwidth on demand, connectionless service, and multicasting support for some protocols.

Suitability for Multimedia Traffic.

Because SMDS is packet-based, the delivered data stream can experience delays. This delay is not large and is less than 30 microseconds. In addition, SMDS does not provide for any synchronization of the data. The application is responsible for multiplexing
audio and video and synchronizing the data at either end. The choice of 53-byte cells was made to provide a migratory path to ATM technology, rendering SMDS an interim technology.

**Fiber Channel**

Fiber channel is a new technology that integrates the channel technology of mainframes and networking fiber technology. Fiber channel provides a single standard for network storage and data transfer and moves device interconnection and switching to a fabric. Each network node is responsible only for the single point-point connection between itself and the fabric. The fabric is responsible for routing between nodes, error detection and correction, and flow control. It supports distances of up to 10K meters at speeds of 266M bps to 4G bps.

**Suitability for Multimedia Traffic.**

Applications that are compatible with ATM run on fiber channel, which offers an even shorter delay than ATM. Because fiber channel integrates both storage devices and networking, it is ideal for use on servers such as video servers. To bring the technology to the desktop is costly, however, running roughly $2,000.

Because of its limit of 10K meters, fiber channel is really more suited to LANs or metropolitan area networks. Unlike ATM technology, the entire standard for fiber channel has been formalized and interoperability is not an issue. Exhibit 5 compares the ATM and fiber channel technologies.

### Comparison of ATM and Fiber Channel

<table>
<thead>
<tr>
<th></th>
<th>ATM</th>
<th>Fiber Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion Handling</td>
<td>Discards</td>
<td>Not an option</td>
</tr>
<tr>
<td>Multivendor and</td>
<td>Struggles</td>
<td>Handles easily</td>
</tr>
<tr>
<td>Multiprotocol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Suitability of WAN-based ATM**

As previously discussed, ATM has been designed from the ground up to carry multimedia traffic on the WAN.

Although ATM provides the capability necessary for delivering multimedia traffic, much of the backbone or desktop connections have not been implemented. Making a desktop unit ATM-capable costs around $1,000. ATM on the WAN costs an average of $100,000/month when traffic exceeds 1.54M bps. Another issue that must be resolved is the interoperability of the switches from different vendors. Standards (in addition to PNNI) are still evolving to provide this and other capabilities. PNNI automatically disseminates
network topology and resource information to all switches in the network and enables QOS-sensitive cell switching.

Despite these issues, ATM's support for real-time and data applications, quality of service, and multicasting, and its low delay and jitter make it the perfect match for multimedia communications. ATM's ability to be the transmission system for multiservice networks—those designed to carry voice, data, and video—provides profound advantages to a business by reducing the costs for equipment and support.\footnote{R. Madge, “Technology's Real-World Edge,” Information Week (September 16, 1996), p. 178.} Because ATM also allows great flexibility and every other multimedia technology provides an access path to it, ATM is the logical long-term choice networking solution.

**Conclusion**

Each available multimedia technology should be considered one of the many tools in the manager's kit. Each technology can be mixed and matched to suit the enterprise's networking needs (e.g., bandwidth, priority, and availability) and budget. Cooperation between network architectures and application architectures is important for predetermining traffic patterns and proactively managing bottlenecks.\footnote{E. Horwitt, “IP over ATM,” Network World (April 15, 1996), pp. 40-42, 45.}

Almost all multimedia networking technologies provide for interconnection and incremental deployment. Because early implementations of any technology may mean interoperability issues have yet to be resolved, cautious integration is prudent.

Developing a strategic plan for multimedia networking that meets the goals and objectives of all users should encompass both computers and communications needs. Because voice and video communications will in all likelihood be a part of the network plan, users of these applications should be included in the planning and implementation team. To reduce the disruption that accompanies a technology transition, careful attention should be paid to migration planning.

Resource planning and project planning software help estimate the network resources needed to deliver a multimedia solution. Implementation should also take place in stages. For example, a workgroup solution may first be installed and pilot-tested before introducing the backbone technology. Network management is another area that mandates careful planning. It should encompass planning for configuration management (i.e., network element administration to provide services), fault management (i.e., detecting and isolating faults in network elements), and performance management (i.e., monitoring performance and managing traffic). These and other business issues involved in the design of multimedia networks and implementation of multimedia applications are discussed in article 3-01-60.1, “Business Aspects of Multimedia Networking.”

**Author Biographies**

T.M. Rajkumar
T.M. Rajkumar is associate professor of MIS at Miami University in Oxford OH.

Amitava Haldar
Amitava Haldar is a senior systems analyst for AIC Consulting in Chapel Hill NC currently working for the software network division of IBM.

---
