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ATM LAN Emulation

An Inside Look at Version 1.0 of the LANE Specification

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by Bob Klessig

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Before joining 3Com in 1992, Bob was district manager of data protocol architecture planning for Bell Communications Research. Prior to Bellcore, he was a supervisor at Bell Telephone Laboratories.

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Now that ATM products and services are becoming widely available, IS professionals are looking for ways to upgrade their building, campus, and departmental networks incrementally to ATM in order to control cost and mitigate risks. They want to reap the benefits of high-speed, high-capacity ATM while preserving the best elements of their existing network infrastructure. The ATM Forum's LAN Emulation (LANE) specification defines mechanisms that allow ATM networks to coexist with legacy systems, thereby providing a scalable migration path to ATM. It also enables ATM implementations to support standard, interoperable data networking using any data networking protocol.

This paper defines LAN Emulation and its key components. It then describes the primary focus of the first version of the LANE specification, the behavior of the LAN Emulation client. It explores in detail the communications sequences that allow LANE clients to join an emulated LAN, establish connections with servers and other clients, and resolve legacy addresses to ATM addresses for data transfers across the ATM network. It also describes how LANE enables virtual LANs and why this is an important benefit. It looks at the performance implications of LANE, and finally, considers the future of the LANE specification. The article is intended for IS professionals who want to integrate ATM into existing networks and for support engineers who want to understand more deeply the inner workings of today's ATM implementations.

Why LAN Emulation?

Many network managers today are investigating the benefits and challenges associated with migrating their networks to Asynchronous Transfer Mode (ATM). ATM's inherent capabilities—such as gigabit-level speeds, multiservice integration, virtual network support, and easy scalability—make it an attractive alternative for network growth. But network planners raise their caution flags when they consider how ATM technology will interoperate with their installed base of Ethernet and Token Ring equipment, data networking protocols, and legacy applications.

This is a valid concern, since the ATM architecture differs fundamentally from legacy LAN technologies. ATM is a connection-oriented technology. It uses an abbreviated address, called a virtual channel identifier, to exchange data between two ATM stations over a virtual channel connection, or VCC. Legacy LANs, on the other hand, employ connectionless transmission technology based on global addressing. Most of today's data networking protocols have been designed to operate over such connectionless networks. Thus, to use ATM for practical data networking, there must be some way of adapting existing network layer protocols, such as IP and IPX, to the connection-oriented paradigm of ATM.

Enter the ATM Forum

While vendors can develop proprietary solutions for these communication problems, most customers prefer greater flexibility when considering the long-term stability of their networks. The ATM Forum is a consortium of vendors, carriers, and users seeking to expedite wide-scale, cross-vendor compatible implementations of ATM. More than 800 members currently belong to this industry association. The Forum's Technical Committee, of which 3Com is an active member, develops technical interoperability specifications for ATM. One very important interface for interoperability with legacy LANs and protocols is the LAN Emulation User Network Interface (LUNI). The LUNI protocols allow ATM-attached end systems and LAN/ATM conversion devices to control the virtual connections required for transmission and to emulate the connectionless nature of a LAN—a process known as LAN Emulation, or LANE.

According to Version 1.0 of the ATM Forum LANE specification, "The main objective of the LAN Emulation service is to enable existing applications to access an ATM network via protocol stacks like APPN, NetBIOS, IPX, etc. as if they were running over traditional LANs." LANE works at the media access control (MAC) layer and enables legacy Ethernet, Token Ring, or FDDI traffic to run over ATM with no modifications to applications, network operating systems, or desktop adapters. Legacy end stations can use LANE to connect to other legacy systems, as well as to ATM-attached servers, routers, hubs, and other networking devices.

Focus of LANE Version 1.0

In order to speed the availability of standardized ATM solutions, the ATM Forum narrowed its scope when developing the first version of the LANE specification. LANE Version 1.0 defines a client-server architecture that specifies how the LAN Emulation client (LEC) interacts with the LAN Emulation service across the User-to-Network Interface (UNI). However, it does not specify the details of the different functions within the LAN Emulation service. The section "Implementing LANE—A LUNI Cast of Characters" on page 4 of this paper gives an overview of these functions.

Based on Version 1.0, all standard LEC implementations are guaranteed to interoperate, but servers from multiple vendors currently have no standard way to communicate. The second version of the LANE specification, currently under development, will define server-to-server protocols that will allow multivendor servers to work together, thereby increasing the scalability and robustness of LANE. (See "LANE Version 2.0" on page 12 for more information.) In the meantime, customers must buy their service functions from a single vendor to ensure enterprise-wide ATM interoperability.

A Conceptual View of LAN Emulation

LANE provides a translation layer between the higher-level connectionless protocols and the lower-level connection-oriented ATM protocols, as shown in Figure 1. Consider the protocol layer differences between the ATM host at the figure's far left and the Ethernet or Token Ring host at the far right. The ATM layer manages the header for the 53-byte ATM cell. It accepts the cell payload from a higher layer, appends the header, and passes the resultant fixed-length cell to the physical layer below. Conversely, it receives cells from the physical layer, strips off the header, and passes the remaining 48 bytes to the higher layer protocols. The ATM layer is unaware of the types of traffic it carries, although it can distinguish quality of service (QOS) through information learned during connection setup.

The ATM adaptation layer (AAL) sits above the ATM layer. The AAL formats data into the 48-byte ATM cell payload, a process known as segmentation. Once the ATM cells reach their destination, they are reconstructed into higher-level data and transmitted to the

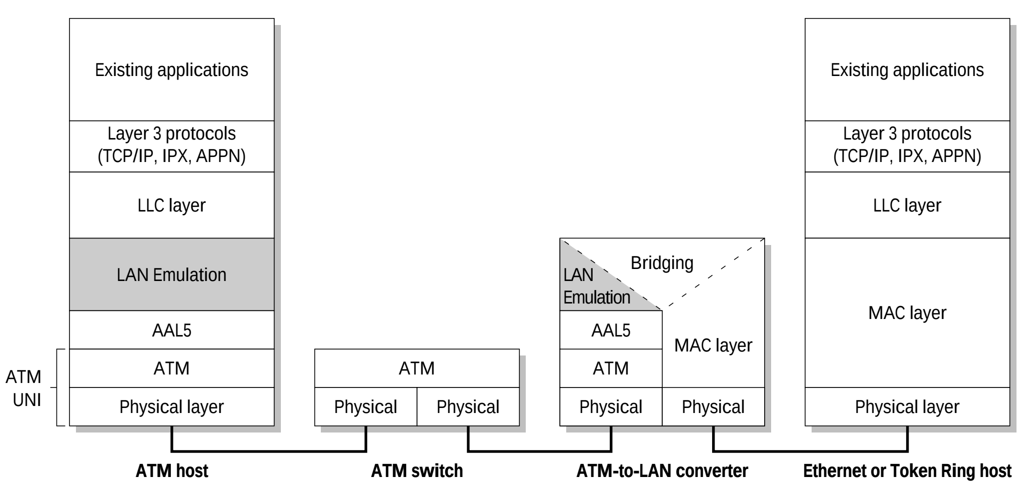

Figure 1. *Conceptual View of LAN Emulation*

Abbreviations and Acronyms

AAL
ATM adaptation layer

BUS
Broadcast and unknown server

ILMI
Interim Local Management Interface

LANE
LAN Emulation

LE ARP
LAN Emulation Address Resolution Protocol

LEC
LAN Emulation client

LECS
LAN Emulation configuration server

LES
LAN Emulation server

LUNI
LAN Emulation User Network Interface

MAC
Media access control

PVC
Permanent virtual circuit

QOS
Quality of service

SAP
Service Advertising Protocol

SNMP
Simple Network Management Protocol

SVC
Switched virtual circuit

UNI
User-to-Network Interface

VCC
Virtual channel connection

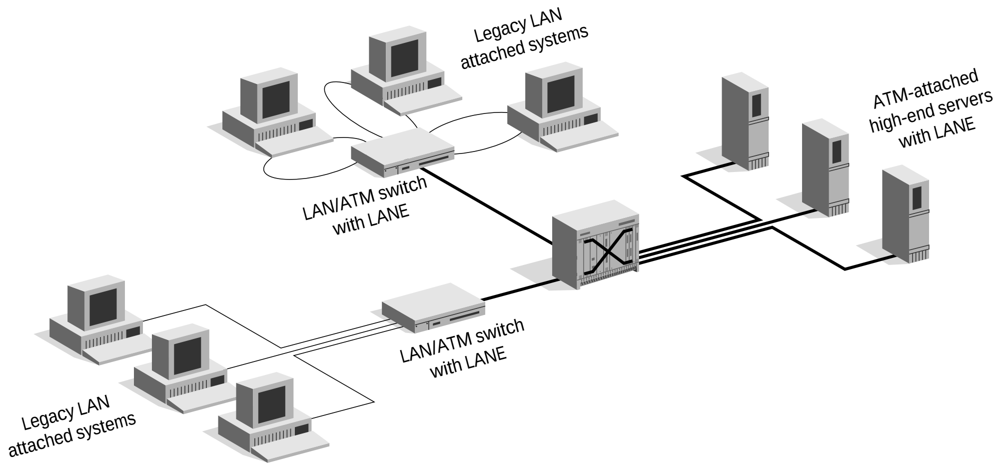

Figure 2. *LAN Emulation for Migrating Legacy LANs*

Glossary

Asynchronous Transfer Mode (ATM)
A high-speed, connection-oriented switching and multiplexing technology that can transmit voice, video, and data traffic simultaneously through fixed-length packets, called cells.

ATM Forum
A consortium of vendors, carriers, and users seeking to expedite implementation of ATM.

Broadcast and unknown server (BUS)
A LAN Emulation service function that supports LAN broadcast services and provides unicast transmission support while an ATM virtual channel connection is being established.

Connectionless communications
A form of packet switching that relies on global addresses in each packet rather than on predefined virtual circuits.

Connection-oriented communications
A form of packet switching that requires a predefined circuit from source to destination to be established before data can be transferred.

Interim Local Management Interface (ILMI)
An SNMP-like management interface for the ATM user-network interface.

Flush Message
A protocol for ensuring unicast data synchronization in LANE implementations.

respective local devices, a process called reassembly. Because ATM can carry multiple traffic types, several adaptation protocols, each operating simultaneously, can exist at the adaptation layer. AAL Type 5 is used for LAN Emulation.

LANE sits above AAL5 in the protocol hierarchy. It masks the connection setup and handshaking functions required by the ATM network from the higher protocol layers and thus is completely independent of upper-layer protocols, services, and applications. Conversely, it maps the MAC address-based data networking protocols into ATM virtual connections so that the higher-layer protocols think they are operating on a connectionless LAN.

LAN Emulation in Practice

Figure 2 shows an example of how LANE works with legacy LANs. Low-end PCs in Ethernet and Token Ring environments access high-end servers that have native ATM interfaces through a LAN/ATM switch, such as a SuperStack™ II Switch 2700 stackable workgroup switch. Because LANE makes ATM look like a classical LAN, standard bridging techniques allow the LAN/ATM switch to provide protocol-independent connectivity.

No change is required in the legacy PCs, yet they experience improved performance because of the high input/output capacity of the server, made possible through the high-speed ATM interface. In addition, they benefit from the dedicated bandwidth provided by the switched LAN implementation.

Implementing LANE—The LUNI Cast of Characters

The LANE specification is based on a client-server implementation model. An emulated LAN consists of one LAN Emulation service and multiple LECs communicating through the LUNI (Figure 3).

A LEC is a combination software and hardware agent, embedded within networking devices, for handling data forwarding, address resolution, and other control functions. Each network component can support multiple instances of a LEC, allowing multiple emulated LANs to exist simultaneously on the same physical network. For example, an ATM-capable router that manages the traffic between two separate emulated, or virtual, LANs would support two instances of the LEC, one for each emulated LAN.

The LAN Emulation service consists of a LAN Emulation server (LES), a broadcast and unknown server (BUS), and a LAN Emulation configuration server (LECS). The LANE specification does not describe the details of implementing the service components. For example, they might be implemented in standalone devices, software in end systems, or ATM switch modules in the backbone network. Figure 3 uses a cloud to represent the LAN Emulation service, signifying the possible implementation options for the different server functions.

While legacy LANs make heavy use of multipoint-to-multipoint broadcast, ATM supports only point-to-point (unicast) and point-to-multipoint (broadcast or multicast) connections. The LES and BUS work together to transfer unicast and broadcast traffic:

- The LES handles address resolution and control information. Its primary job is to register and resolve MAC addresses to ATM addresses.
- The BUS is designed for carrying broadcast data, such as TCP/IP address resolution broadcasts or Novell Service Advertising Protocol (SAP) messages. It also handles all multicast traffic. Finally, it broadcasts the initial unicast frames sent by the LEC while the LES works in tandem to provide the appropriate ATM address for establishing a data-direct VCC.

Typically, the LES and BUS are co-located in a single device, although this configuration is beyond the scope of LANE Version 1.0. Version 2.0 is expected to formalize this requirement.

The LECS is responsible for dynamically assigning different LECs to different emulated LANs. It provides the clients with the address of the most appropriate LES and maintains a database of the resultant associations. It can assign a LEC to an emulated LAN based on either physical location, as specified by the LEC's ATM address, or by logical association. A single LECS can manage the configuration information for a very large ATM network, since its responsibilities are limited to initial configuration, as described below in "Finding the LECS."

LECs communicate with the LAN Emulation service functions through two different types of VCCs:

- Control connections carry administrative messages, such as requests for initial configuration and for addresses of other LECs.
- Data connections handle all other communications. In particular, they link clients to each other for data-direct unicast communications, and they link clients to the BUS for broadcast and multicast messages.

These VCCs can operate over dynamically allocated switched virtual circuits (SVCs), preallocated and provisioned permanent virtual circuits (PVCs), or a mix of the two. Since SVCs deliver the real power behind LANE Version 1.0, VCCs described in this article imply SVCs.

A LEC's First Day on the Network

To illustrate how the different LUNI components work together to implement LANE, the rest of this article describes what happens from the time a LEC first joins an ATM network until it exchanges data with its peers. The typical first day begins when the LEC initiates communications with the LECS and registers its interest in joining an emulated LAN.

Finding the LECS

When a LEC first powers up, it must obtain configuration information from the LECS in order to join an emulated LAN. The LANE

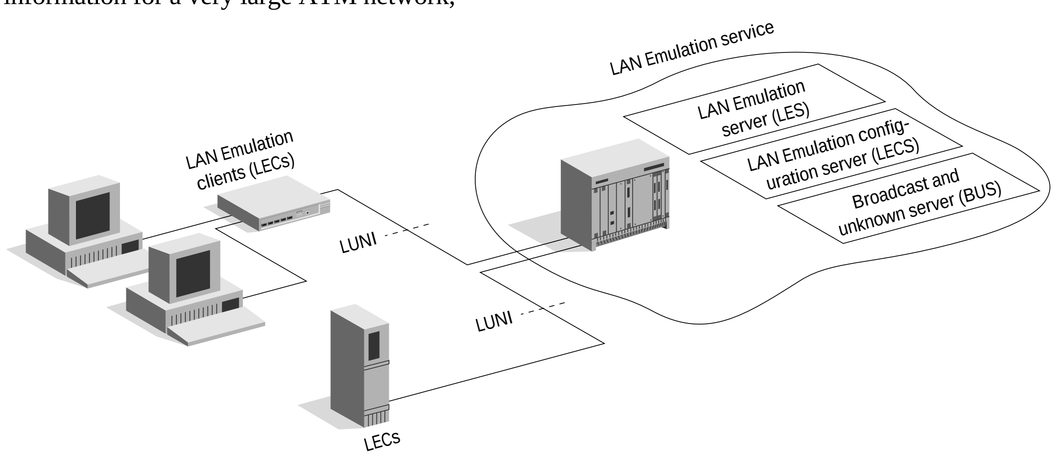

Figure 3. *LANE Components and Their Relationships*

Glossary (Continued)

LAN Emulation (LANE)
A standard paradigm for integrating legacy LANs and applications transparently with ATM networks.

LAN Emulation client (LEC)
Functions implemented in networking devices that handle data forwarding, address resolution, and other control functions for data equipment implementing LANE.

LAN Emulation configuration server (LECS)
A LAN Emulation service function that assigns individual LECs to different emulated LANs and maintains a database recording these assignments.

LAN Emulation server (LES)
A LAN Emulation service function that registers and resolves MAC addresses to ATM addresses for LECs.

LAN Emulation service
A combination of a LES, BUS, and LECs that implements the server functionality for LANE.

LEC ID
A unique identifier for a LAN Emulation client.

Nonproxy LEC
A LEC whose MAC address identifies the actual device, such as a host.

Permanent virtual circuit (PVC)
A virtual circuit (X.25), virtual connection (Frame Relay), or virtual channel connection (ATM) that is established by administrative means, much like a leased or dedicated real circuit.

Glossary (Continued)

Proxy LEC
A LEC, such as a bridge, that represents the MAC addresses of other attached devices.

Switched virtual circuit (SVC)
A virtual circuit (X.25), virtual connection (Frame Relay), or virtual channel connection (ATM) that is established dynamically in response to a signaling request message.

Virtual channel connections (VCCs)
Logical communications paths in two or more physical circuits that create an end-to-end ATM connection.

Virtual LAN
A logical association that allows users to communicate as if they were physically connected to a single LAN, independent of the actual physical configuration of the network.

LAN Emulation Service in the CELLplex 7000

3Com's CELLplex™ 7000 ATM switch provides all of the LAN Emulation service functions—the LES, BUS, and the LECS—within its switching engine. In a typical large network, only one CELLplex ATM switch would be designated and maintained as the LECS; the other switches would disable the LECS capability. The LES/BUS functions can be active simultaneously across all CELLplex switches because a LES/BUS can serve any LEC attached anywhere to the ATM network. Thus, LANE service capacity scales naturally as more CELLplex switches are deployed.

specification offers several options for locating the LECS:

- The LEC can use a "well-known address," conceptually an address like 1-800-FIND-LECS. Theoretically, this method provides an elegant, easy-to-implement solution for configuring multiple LECs. However, the "well-known address" capability and the address format were defined in anticipation of future ATM signaling specifications, and therefore this is not an interoperable approach today; this issue will be addressed in a future version of the LANE specification.
- The LEC can send Interim Local Management Interface (ILMI) messages to its ATM switch. This alternative requires the network manager to configure the address of the LECS in each ATM switch in the network. When the LEC powers up, it would send ILMI messages across the UNI requesting a LECS address; the attached switch would then respond. Currently this is the most convenient method for discovering the LECS, since it requires the configuration of only ATM switches, not the hosts, bridges, routers, and other LEC devices on the network.
- The LEC could use a predefined VCC. This alternative requires a preconfigured VCC to the LECS from every ATM interface on the network—every port with a UNI. This approach requires a large number of VCCs, the majority of which will be idle most of the time.
- Finally, the LECS can be bypassed completely by configuring the ATM address of a LES in the LEC.

Once the LEC locates the LECS, it sets up a connection and forwards some useful information, such as its ATM address, its MAC address, its LAN type, and its maximum frame size. The LECS responds with the actual LAN type, the actual maximum frame size, and the ATM address of a LES. Figure 4 shows this interaction. By providing a LES address, the LECS implicitly assigns the LEC to an emulated LAN.

The LANE specification currently does not define how devices with multiple ATM addresses, such as a LAN switch, organize their addresses. Similarly, it does not specify

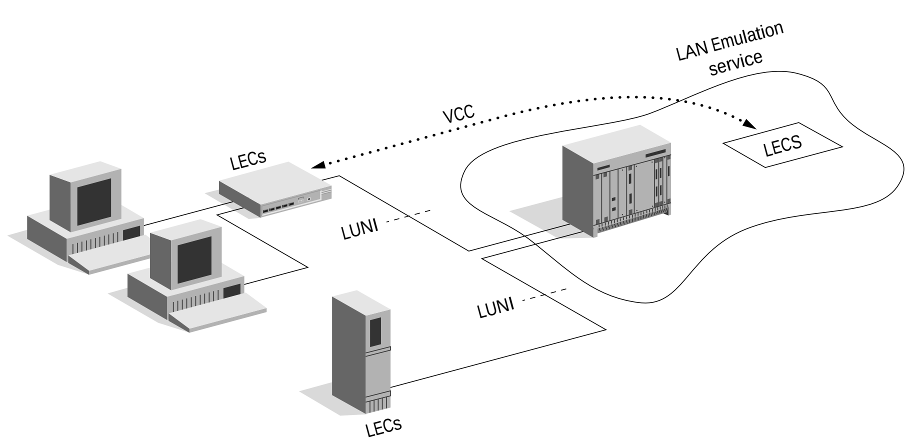

Figure 4. *Initial LEC Configuration Through the LECS*

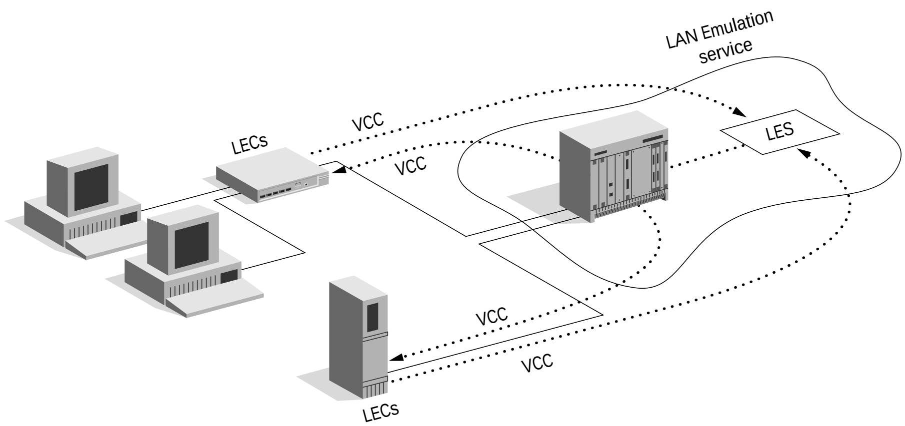

Figure 5. *Joining an Emulated LAN*

how the LECS maintains its database. These decisions are left to the individual LANE implementations and the network manager.

Joining an Emulated LAN

Once a LEC knows the ATM address of the LES, it sets up a connection to the LES. When the LES receives the connection setup message from the client, it learns the LEC's ATM address from the calling party field in the message. Typically* it responds by adding the LEC as a leaf node on a point-to-multipoint connection, as Figure 5 shows.

The LEC then registers its MAC address and associated ATM address with the LES, and the LES assigns the client an LEC ID. The specification allows the LES to either discard the address or store it for future reference. (The box "Proxy vs. Nonproxy LECs" describes one way intelligent LESs could use this address information.) At this point, the LEC now can resolve MAC addresses to ATM addresses. The first address it needs is that of the BUS.

The LEC sends a message to the LES requesting the ATM address associated with the All-1s MAC address—the broadcast address. The format of this request looks like any LAN Emulation Address Resolution Protocol (LE ARP) message. The LES responds with the ATM address of the BUS. How the LES learns the address of the BUS initially is beyond the scope of the specification, but when the LES and BUS are co-located, the address is obvious to the LES.

Proxy vs. Nonproxy LECs

There are two types of LECs:

- A proxy LEC is one that represents the MAC addresses of devices other than itself. In other words, it acts as a bridge.
- A nonproxy LEC is a device like a host that has a unique MAC address of its own.

Version 1.0 of the LANE specification allows servers to distinguish between types of LECs for added efficiency in address resolution. In this case, the server maintains two point-to-multipoint trees, one for proxy LECs and one for nonproxy LECs (Figure 6). The LECs identify themselves as proxy or nonproxy when they join the emulated LAN.

When a LE ARP message comes in, the LES checks its address table and responds with the appropriate ATM address if it finds a match. If no match is found, the LES can assume the MAC address is associated with a proxy. It then forwards the LE ARP request to those stations on the proxy point-to-multipoint tree for resolution.

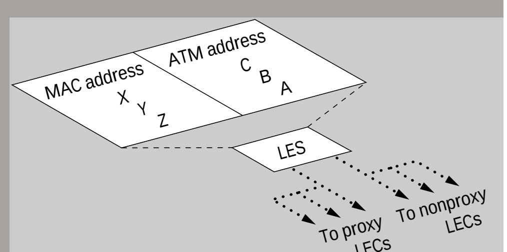

Figure 6. *Intelligent LES with Dual Point-to-Multipoint Trees*

* The LES is allowed to set up point-to-point VCCs to the LECs, but the use of point-to-multipoint VCCs relieves the LES from duplicating and transmitting many copies of each message.

Once the client knows the BUS address, it sets up a VCC to the BUS; the BUS in turn observes the ATM address of the client. Like the LES, the BUS typically† adds the LEC as a leaf node in a point-to-multipoint connection.

As its name suggests, the BUS participates in the forwarding of both unicast and broadcast/multicast messages. A LEC can use its BUS connection to broadcast unicast frames to all stations on the emulated LAN while the LES locates the unknown ATM address of the intended receiver and performs the necessary handshaking operations to establish the data-direct connection. The section “Data-Direct VCCs and Unicast Frames” on page 9 provides more information.

Managing ATM Broadcasts

Whenever a LEC receives a MAC data frame for transmission, the leading bit of the destination MAC address indicates whether the packet is unicast or broadcast/multicast:

- A leading 1 indicates a broadcast or multicast message.
- A zero indicates a unicast message.

Figure 7 illustrates an ATM broadcast interaction. The LEC immediately passes broadcast/multicast frames to the BUS via the VCC established initially (1). The BUS forwards that message to all nodes on its point-to-multipoint tree—that is, all LECs on the emulated LAN receive the broadcast (2). If the BUS receives two broadcast or multicast frames simultaneously, it buffers one briefly while it sends the other one out. This serialization prevents intermixing of cells from different data frames on the VCC to the LECs. AAL5 allows a LEC to reassemble only one data frame at a time on a single VCC.

Protocol information in the head of every frame uniquely identifies the LEC that originated the broadcast to the BUS. This information is the LEC ID, which the LES assigns. To speed broadcast frame processing, a LEC checks the ID for every incoming frame; if there is a match, the LEC disposes of the frame immediately. Otherwise it looks at the destination address. A nonproxy LEC saves only those frames whose destination MAC address matches its own multicast address. Proxy LECs save all multicast frames.

The BUS mechanism is designed to handle low-level broadcast traffic, such as IP address-resolution requests and SAP messages. However, it suffers from inefficiency when faced with vast quantities of broadcast frames. For example, suppose a LEC wanted to multicast live video to five LECs out of a population of 100 on an emulated LAN. Using the current distribution scheme, 95 LECs would end up discarding the transmitted frames immediately upon reception. Even high-capacity ATM networks can become congested when bandwidth is wasted. LANE Version 2.0 will provide ways to handle heavy-duty broadcast traffic, such as video-on-demand, more efficiently.

Data-Direct VCCs and Unicast Frames

When a LEC receives a unicast data frame for transmission, it first checks its local tables to

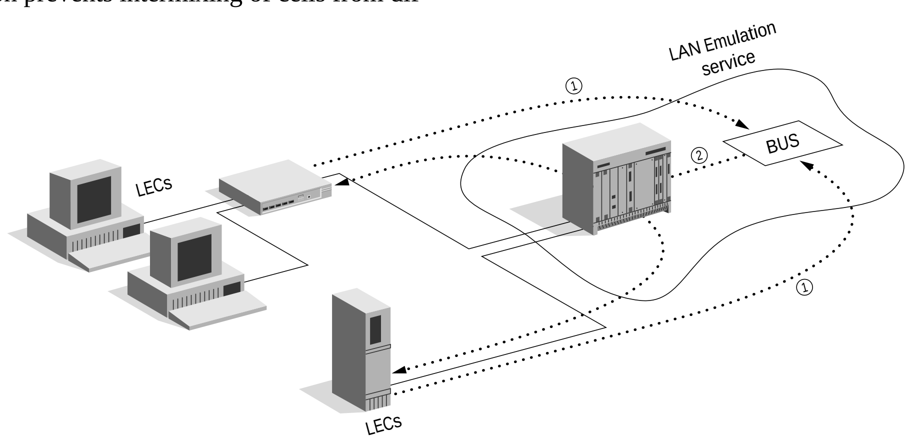

Figure 7. *Broadcast and Multicast Messages Managed by the BUS*

† The BUS is allowed to set up point-to-point VCCs to the LECs, but the use of point-to-multipoint VCCs relieves the BUS from duplicating and transmitting many copies of each message.

see whether it knows the ATM address associated with the MAC address. If it does not, it cannot immediately set up a data-direct connection to the target. The LEC then has three options:

- It can throw the frame away but initiate resolution of the MAC address to an ATM address.
- It can hold onto the frame until it learns the ATM address of the target and sets up a VCC.
- It can forward the frame to the BUS to keep the data moving. In this case, the BUS responds in its usual manner—it forwards it to every client (Figure 8a on page 10). The clients decide to save the frame based on the destination unicast MAC address.

Simultaneously, the LEC sends a LE ARP request to the LES, trying to resolve the unknown MAC address (Figure 8b). The LE ARP message includes the source ATM address of the LEC making the request. In most implementations today, the LES simply forwards the LE ARP to all clients, much like the BUS has done (Figure 8c).

The target client recognizes the MAC address and sends an LE ARP response to the LES, which includes both its own ATM address and the source ATM address for the LEC originating the LE ARP request (Figure 8d on page 11). The server forwards the response message with the target ATM address to all the LECs, in broadcast fashion (Figure 8e). The cycle ends when the originating LEC recognizes its own ATM address contained in the response. At that point, it has learned the ATM address associated with the unknown MAC address and can set up a data-direct connection to the target LEC (Figure 8f). When the source LEC receives subsequent frames with the newly learned MAC address, it immediately forwards them down the data-direct VCC.

Each LEC builds up its own table of MAC addresses, ATM addresses, and VCC bindings. If a particular MAC address has not been active for some time, a LEC eventually will drop it from its cache. When there are no more MAC addresses associated with a data-direct VCC, the LEC can drop the connection.

Multiple Emulated LANs

The client/server architecture defined by the LANE standard makes for a logical separation between multiple emulated LANs. LECs associated with one LES cannot learn the addresses of LECs associated with another LES, since all LE ARP requests remain local to the point-to-multipoint tree maintained by each LES. A virtual LAN results when several different LANE domains exist through one or more switches on a network.

Virtual LANs create secure workgroups and erect firewalls against broadcast storms to make better use of existing network bandwidth. A MAC-layer broadcast from one LEC reaches other LECs in the same VLAN, but no others. End stations no longer waste resources processing packets from unrelated interest groups. Virtual LANs also simplify network management by letting network administrators group users based on common interests rather than common location. Network administrators can implement adds, moves, and changes simply by redefining groups in the network management system and remotely configuring software in the end device or ATM switch. They do not need to change cabling or add equipment.

A critical component of managing virtual LANs is a network management application that goes beyond physical connectivity to show how systems logically interconnect across the network. 3Com's Transcend® suite of network management applications provides this type of "bigger picture" by allowing administrators to manage their corporate networks as logical groups of related devices.

Constraints of Multiple Emulated LANs

As the figures in this paper illustrate, a number of VCCs are required to establish and maintain an emulated LAN. Each LEC has VCCs to and from the LES and the BUS, which can be bidirectional or unidirectional. In the worst case, these VCCs are unidirectional, requiring a total of four per LEC.

Because servers are not capable of supporting an infinite number of VCCs, there is a limit to the number of LECs an emulated LAN can contain. For example, the limit for

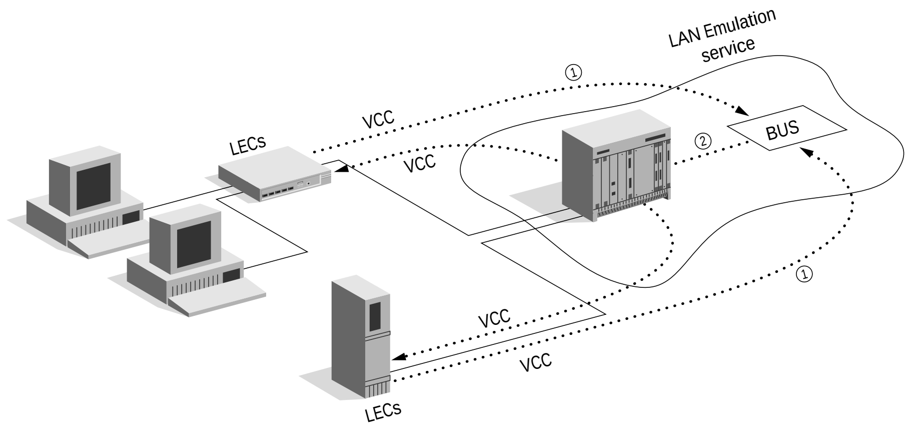

Figure 8a. *BUS Broadcast of Unicast MAC Frames*

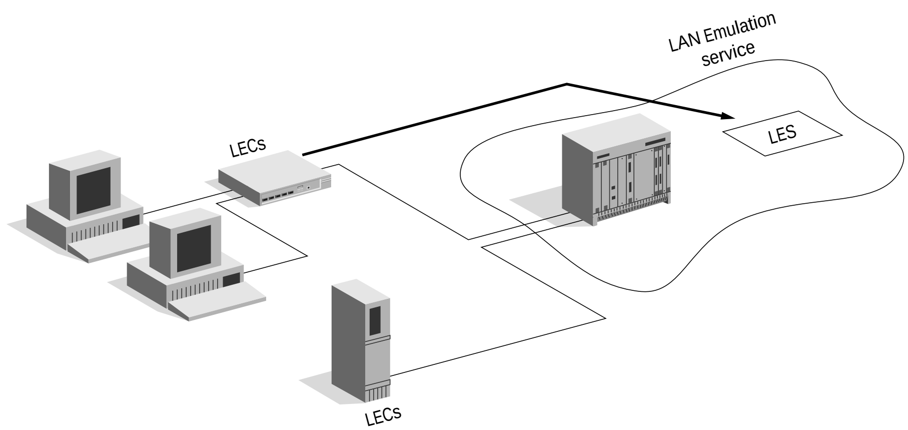

Figure 8b. *Simultaneous LE ARP Request to LES*

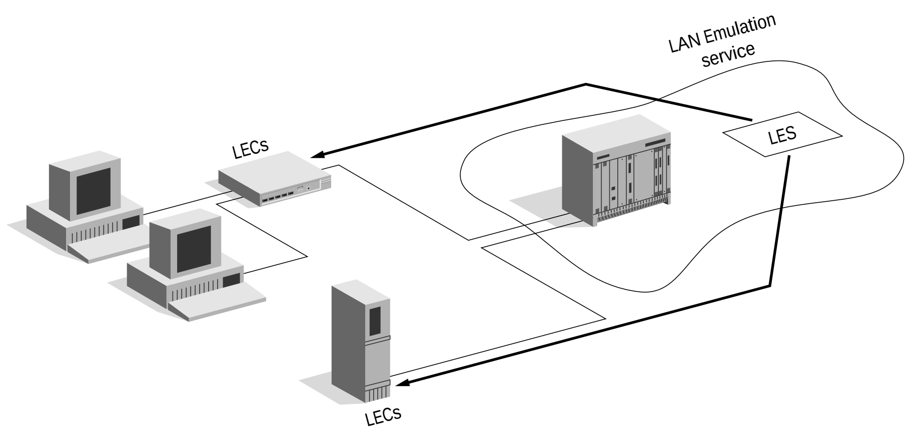

Figure 8c. *Broadcast LE ARP from LES to All LECs*

the CELLplex 7000 ATM switch is 1000 VCCs to the LES/BUS. That means each CELLplex switch currently can support 256 clients (4 x 256 = 1000). The CELLplex implementation invokes that limit by allowing up to 16 emulated LANs per switch, each with up to 16 clients (16 x 16 = 256).

Supporting 32 emulated LANs would require a second CELLplex switch; virtual LAN capability enables the second switch to be located anywhere on the ATM network. Adding more switches naturally scales the number of emulated LANs an ATM network can support.

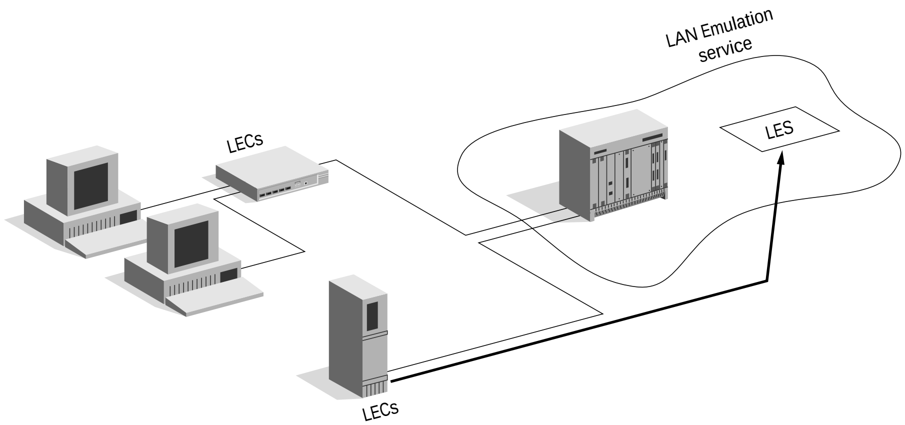

Figure 8d. *LE ARP Response with Target ATM and Source ATM Addresses*

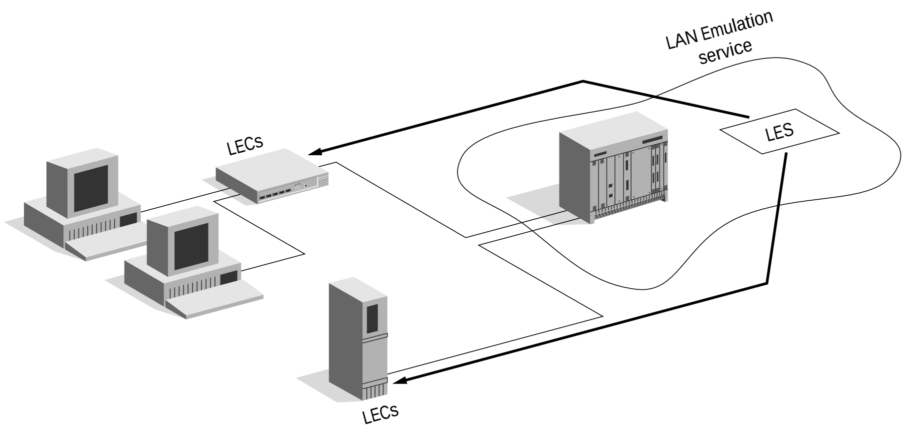

Figure 8e. *LES Broadcast of LE ARP Response*

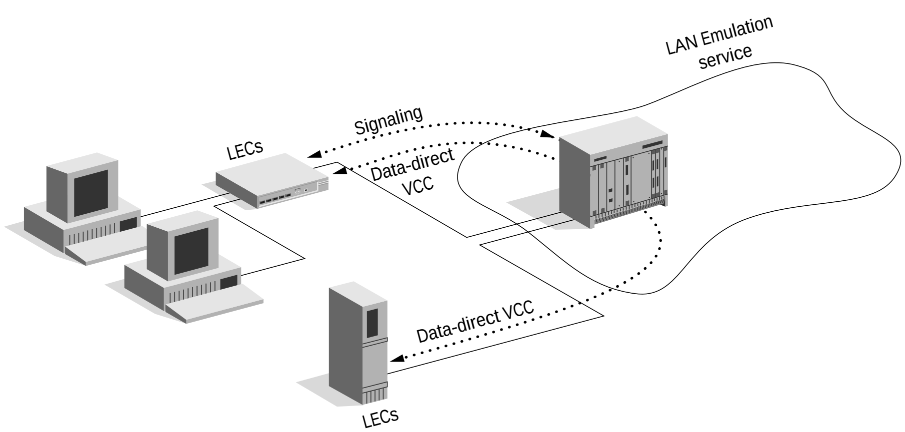

Figure 8f. *Data-Direct VCC from Source LEC to Target LEC*

Keep in mind that a LEC is not equivalent to an end station. A LEC could be a high-speed LAN switch, such as a SuperStack II Switch 2700 stackable workgroup switch supporting hundreds of end-users. However, the number of clients each emulated LAN supports affects how well networks can leverage their point-to-multipoint connections. This issue will gain importance as ATM migrates outward to the desktop.

Overhead of LANE

While the client-server communications of LANE seem complicated when described in

Unicast Frame Synchronization

As shown in Figures 8a to 8f, the LEC may send unicast frames to the BUS while resolving a MAC address to an ATM address. Once the data-direct VCC is established, the LEC can send unicast frames directly to the destination LEC. However, this opens up the possibility for frames to become out of order, since the first frames sent on the data-direct VCC could arrive before earlier frames sent via the BUS. The LANE specification defines a mechanism that ensures that unicast frames remain in order during this transition.

When the source LEC establishes the data-direct VCC to the target LEC, it sends one last broadcast message, called the Flush Message, down the VCC to the BUS. The Flush Message succeeds any data previously sent. Eventually the Flush Message reaches the target LEC through normal broadcast distribution. The target LEC then forwards the Flush Message back to the source LEC down the data-direct VCC, completing the triangle (Figure 9). This signals to the source LEC that all frames previously sent to the BUS have been flushed. The source LEC then can send data across the data-direct VCC without the risk of frames becoming out of order.

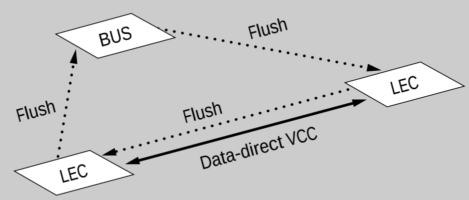

Figure 9. *Flush Message Synchronization*

print, in practice their performance implications are minor for several reasons:

- All traffic between LANE clients and servers travels over broadband connections, usually 155 Mbps, and ATM switching engines incur minimal latency. For example, the CELLplex 7000 has a 16x16 switching engine with a typical latency of no more than 10 microseconds.
- Because of the large capacity of ATM switches, sizable ATM networks can be built without many hops.
- Even in a backbone network large enough to have three hops between a PC and server, LANE call setup overhead is insignificant compared with the file transfer itself. For example, with CELLplex 7000 switches, LES and BUS transactions take about 1 millisecond, and call setup takes about 10 milliseconds per switch. Thus, after completing three hops, the aggregate time to establish a VCC takes fewer than 40 milliseconds. This connection setup delay occurs only at the beginning of a session between LECs. The vast majority of the data is forwarded immediately on the data-direct VCC. Hence, the effect of the connection setup delay is minimal.
- Finally, regardless of LANE overhead, the combination of LAN switches and an ATM backbone—providing dedicated bandwidth to every end station—outperforms any conventional shared-media alternative.

LANE Version 2.0

The Technical Committee of the ATM Forum is currently exploring which enhancements will appear in Version 2.0 of the LANE specification. Two important extensions under development are interserver protocols and quality of service (QOS).

- LANE Version 2.0 begins to distinguish the elements within the LAN Emulation service cloud. It will accommodate multiple LES/BUS pairs by defining protocols between them. These protocols will provide a high level of scalability for LANE and will support server function redundancy for improved robustness.
- QOS is designed to manage integrated voice, video, and data traffic in an ATM environment. Through the use of different virtual connections, QOS supports applications that require constant, variable, available, and unspecified bandwidth. ATM switches can build a virtual circuit for each application and use QOS information to set traffic priorities,

choose network routes, and manage trunk availability. QOS is particularly important in handling real-time applications such as videoconferencing or video-on-demand, because it guarantees that bandwidth will be available when it's needed.

A critical characteristic of LANE Version 2.0 is backward compatibility with the existing LANE specification. 3Com ATM products were among the first to incorporate standard LANE and thus are well positioned to migrate to Version 2.0 as the details of its specification become formally defined and finally ratified by the ATM Forum.

Summary

The first version of the ATM Forum LANE specification, approved in February 1995, has paved the way for integrating ATM with legacy systems, protocols, and applications across the enterprise. It defines standard ways for LANE clients to resolve addresses, communicate with other clients, and forward data across the ATM network.

Using LANE, network managers can enjoy the bandwidth benefits of ATM without modifying existing protocols, software, or hardware. By defining multiple emulated LANs across an ATM network, network managers can create switched virtual LANs for improved security and greater configuration flexibility. Intelligent network management applications, such as 3Com's Transcend network management suite, provide logical views and control of switched virtual LANs.

As the LANE specification matures, it will provide greater flexibility, interoperability, and robustness to ATM networks. Network managers that choose standard LANE implementations today have a smooth migration path for taking advantage of these improvements. ❑

For More Information

Printed Documents

Integrating ATM Across the Enterprise Data Network (3Com stock no. 500600-00X).

ATM User-Network Interface Specification, Version 3.1, September 1994, available from Prentice Hall at http://www.prenhall.com.

LAN Emulation over ATM v1.0 Specification, January 1995, available from the ATM Forum.

Internet and World Wide Web Information

For the latest 3Com ATM product information, visit our Networking Solutions Center at http://www.3Com.com/.

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