LAN Emulation, Virtual LANs, and ATM Internetworks
January 1996
**LAN EMULATION TUTORIAL**

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LAN Emulation Tutorial

Definition

LAN Emulation (LANE) is an ATM-based internetwork technology that enables ATM-connected end stations to establish MAC-layer connections. It allows existing LAN protocols, such as Novell NetWare, Microsoft Windows, DECnet, TCP/IP, MacTCP or AppleTalk, to operate over ATM networks without requiring modifications to the application itself.

LANE provides:
• data encapsulation and transmission
• address resolution
• multicast group management

The main components of LANE are:
• the LANE driver within each end station (e.g., host, server, or LAN access device)
• one or more LANE Services residing in the ATM network

The LANE driver within each end station provides an IEEE 802 MAC-layer interface that is transparent to higher layer protocols, such as IP or IPX. Within the end station, the LANE driver also translates 802 MAC-layer addresses into ATM addresses, using an Address Resolution Service (ARS) provided by a LANE Server. It establishes point-to-point ATM switched virtual circuit (SVC) connections to other LANE drivers and delivers data to other LANE end stations.

LANE drivers are also supported on access devices (e.g., routers, hubs, and LAN switches) attached to the ATM internetwork. The access devices differ from end stations on the ATM internetwork in that access devices act as a "proxy" for end stations. As such, they must receive all multicast and broadcast packets destined for end stations located on attached LAN segments.

This combination of LANE drivers and services transparently supports the operation of existing 802.x LAN applications over the ATM internetwork. LANE is a logical service of the ATM internetwork. By using multiple LANE Services, multiple 802 LANs can be emulated on a single physical ATM internetwork. This allows LAN administrators to create virtual LANs (VLANs)—a logical association of users sharing a common broadcast domain.

Benefits

The advantages provided by LANE compare favorably to those of LAN bridging. LAN bridging technology was developed to support the expansion of local area networks. Ethernet bridges are transparent and require minimal configuration.
Attached PCs do not require any modifications to operate in a bridged environment, saving much of the administrative cost associated with other internetworking technologies.

LANE and classical bridging both support MAC-layer connectivity between LAN applications. LANE, however, removes the limitations of classical bridging, making it a key component of ATM internetworking.

**Reduce Broadcast Traffic**
Traditional LAN bridges have limitations that an ATM internetwork removes. LAN bridges do not scale to support very large networks. The flooding of unknown packets and broadcast traffic consumes valuable wide area bandwidth, leading to congestion on bridged LAN segments. In addition, bridges do not support active mesh topologies, limiting network performance.

**Support Multiple VLANs**
A single ATM network with LANE supports multiple VLANs. Because each VLAN is distinct from the others, broadcast traffic in one VLAN is never seen in any other VLAN. It does not require any filtering or other mechanisms on stations not in that particular VLAN.

**Support Dynamic Configuration**
A LAN Emulation Configuration Service (LECS) allows dynamic configuration capabilities within the ATM internetwork—eliminating the need to define the physical connection between a host computer and the VLAN(s) to which it belongs. This allows a host computer to be moved from one building to another while remaining a member of the same VLAN.

**Improve Network Security**
The LECS also provides security and efficient bandwidth management. The system administrator controls VLAN membership, allowing the administrator to limit access to a particular VLAN.

**Provide Bandwidth Management**
In addition, users who commonly communicate with one another can be grouped into the same VLAN. Another possibility is grouping users by the specific types of traffic, such as IP or IPX. Therefore, managing membership to a VLAN based on the frequency of communication or traffic type uses bandwidth more efficiently.

**Support Existing LANs**
By using existing 802.x frame types, and emulating the behavior of 802.x LANs, ATM network adapters appear to end stations and upper layer protocols to be Ethernet or Token Ring cards—or both. Any existing protocol that has been defined to operate over Ethernet or Token Ring LANs can also operate over ATM LANE without modification.
ATM Forum Standard LAN Emulation v1.0

In the spring of 1995, the LAN Emulation Sub Working Group of the ATM Technical Forum passed the LAN Emulation-Over-ATM v1.0 Specification. It defines the LAN Emulation User-to-Network Interface (LUNI) over which existing LAN protocols operate. The LUNI describes how an end station communicates with the ATM internetwork. Further work by the ATM Forum will focus on the LAN Emulation Network-to-Network Interface (LENNI).

The ATM Forum LAN Emulation v1.0 specification for LAN Emulation, co-authored by FORE Systems, consists of two components:

- LAN Emulation Clients (LEC)
- LAN Emulation Services including the LAN Emulation Server (LES), the Broadcast and Unknown Server (BUS) and the LAN Emulation Configuration Server (LECS)

![Figure 1: Components of the ATM Forum LAN Emulation specification.](image)

LAN Emulation Services can be implemented in an ATM intermediate system, an end station such as a bridge, router, or dedicated workstation, or a PC. They may also be implemented on ATM switches or other ATM specific devices.

LAN Emulation Services exist as a single centralized service where the LECS, LES and BUS are implemented on an end station or ATM switch. But, they can also be implemented in a distributed manner, where several servers operate in parallel and provide redundancy and error recovery.
LAN Emulation Services can operate on one or more LEC. For example, the LECS may reside on one end station, which is also a LEC, while the LES and BUS reside on another end station running LEC code.

**LAN Emulation User-to-Network Interface**

The definition of the LUNI model allows independent vendors to implement LANE end stations, while providing interoperability between their products. The LUNI defines initialization, registration, address resolution, and data transfer procedures for the interaction of the LEC and the LAN Emulation Services.

As ATM Forum continues to develop LANE standards, the current specification allows for a wide range of implementations in the host computer. Pre-LENNI solutions are possible today and are available from a single vendor, such as the ones deployed by FORE, or multiple vendors who use the same signaling technique for network-to-network interfaces.

The LUNI defines initialization and registration. The LECS (server) controls the assignment of individual LECs (clients) to VLANs, using information contained in the LECS’s database as well as information provided by each LEC.

**Example of LANE Operation**

When an ATM host running LEC software (e.g., UNIX host, PC, Macintosh, switch processor, or LAN access device) becomes active on the network, it automatically locates the LECS by either the Interim Local Management Interface (ILMI), the well-known address, or on a Configuration Direct PVC (i.e., permanent virtual circuit).

**A Client Joins a VLAN**

The LECS provides a list of VLANs to which that end station may belong. In the simplest case, if the end station is a member of one VLAN, there is one inquiry and one response. The end station disconnects from the LECS and joins the VLAN.

In a more complex case, the end station is a member of multiple VLANs and there are several iterations of inquiries and responses to discover the VLANs to which the end station belongs. The LECS also returns the address of the LES for each of the VLANs for which that the ATM host is a member. The ATM host starts a LEC instance for each VLAN and joins those VLANs by contacting the LES for each VLAN.

The LEC sends an ARP to the LES with a MAC address of hexadecimal “FF.” The LES provides the LEC with the address for the BUS. The LEC now has all the necessary LAN Emulation Services information to actively participate in the VLAN.
Data Transfers Over a VLAN

As with 802.x LANs, each end station in the ATM LAN has a unique MAC-layer address. When ATM end station “A” needs to send data to ATM end station “B,” “A” first looks for the MAC address for end station “B.”

If the MAC address to ATM address translation is not already in its cache, “A” determines the ATM address of “B” by sending an Address Resolution Message to the LES. Since any ATM-connected host must register with the LES, the LES can directly answer “A,” providing the ATM address of “B,” contained in the LES cache. This is illustrated in Figure 2, Steps 1 and 2.

Multicast and Unknown Traffic

Multicast traffic is any message that uses a multicast MAC address (i.e., broadcast, group, or functional MAC addresses, where destination address of the 802.3 frame is all hexadecimal “FF”). Multicast traffic and unknown traffic are handled by the Broadcast and Unknown Server (BUS).

The most common multicast address is the broadcast address. Any message sent to the broadcast address, by definition, must be sent to every station in the VLAN. When the BUS receives a broadcast request, it transmits that message to every member of the VLAN. Multicast traffic capabilities support true multicast applications, such as distance learning and multipoint video conferencing, and protocols (e.g., NetBIOS, IP, and IPX).
Unknown traffic is any data for which the sender has not yet obtained an ATM address. For example, end stations on different LAN segments (e.g., via a transparent bridge) will not receive the ATM address resolution messages. The transparent bridge answers such inquiries. Once the bridge learns of the remote host, it will answer the address resolution messages and a direct connection will be used.

**BUS Example: ATM-to-Ethernet**

Figures 3a and 3b describe the sequence of events that occur when end station “A” on the ATM LAN wants to discover end station “X” on the Ethernet LAN and then transfer data to “X.” First, “A” sends an address request message to the LES. See Figure 3a, Step 1. The request is forwarded to the LAN access device and two outcomes are possible:

- the LAN access device, acting as a proxy LEC for “X,” knows the address and provides its own ATM address in response to the request (See Figure 3a, Step 2a) or
- the LAN access device does not know the address of “X” and sends no response.

As “A” sends an address request message to the LES, it simultaneously sends the data to the BUS (See Figure 3b, Step 2b). The BUS sends (i.e., floods) the data to all end stations on the VLAN. When the data reaches the LAN access device (previously registered as a proxy LEC with the LES), it is broadcast to all end stations on the Ethernet LAN. “X” receives the data and then responds to the LAN access device. The LAN access device stores the MAC address of host “X” in its table.

When “A” receives no response to its initial request, it resends the address request message. (See Figure 3b, Step 2c.) This time, when the LAN access device receives the request, it has the MAC address of “X” in its table. So, the LAN access device can reply, sending its ATM address to “A”. “A” can now send its data to the LAN access device which forwards the data to “X.”

Once “A” knows the ATM address of the proxy LEC, a connection to the LAN access device is established, if one does not already exist. Data transmission begins with the LAN access device sending data directly to end station “X”. See Figure 3a, Step 3 or Figure 3b, Step 3.
Figure 3a ATM end station "A" discovers Ethernet end station "X," and transfers data to "X." The LAN Access Device knows the MAC address of "X."

Figure 3b. The LAN Access Device must discover the MAC address of "X."
How Existing LAN Protocols Operate Over ATM

Most existing LANs are connectionless systems using bridges or routers to expand the size of the network. They reduce internetwork traffic by dividing the network into smaller, more manageable pieces called segments. These bridges and routers use broadcast techniques that send every message on a network segment to every end station on that segment.

In contrast, ATM networking uses a connection-oriented scheme. Data sent from one device to another on an ATM network is seen only by the destination device. ATM networks use two types of connections—permanent virtual circuits (PVCs) and switched virtual circuits (SVCs). PVCs are manually configured by the network manager. SVCs are created dynamically by ATM switches using signaling software.

ATM network and existing LANs differ in another way—address structures. ATM networks use a 20-byte OSI Network Service Access Point (NSAP) address and existing LANs, a 48-bit Media Access Control (MAC) address.

Address Resolution

ATM LANE handles the connections (i.e., PVCs and SVCs) transparently and implements an address resolution procedure to accommodate the different addressing schemes. LANE provides a mechanism for end stations to obtain a mapping between conventional 48-bit MAC addresses and 20-byte NSAP ATM addresses.

Data transmitted across the LUNI is converted from packets to cells, and vice-versa, using the ATM Adaptation Layer 5 (AAL5) to perform the SAR function—segmentation (i.e., packets to cells) and reassembly (i.e., cells to packets).

Figure 4 shows this flow of data from an ATM host to an Ethernet host. (In this example, both hosts are using IP or IPX as the network layer protocol.) LANE software on the ATM host receives an Ethernet Packet Data Unit (PDU) and passes it to the ATM adapter in the host.

The LAN access device recognizes that the data must be sent to an Ethernet client and reassembles the cells into packets in the AAL SAR on the LAN access switch. Next, LANE software transforms the data into an Ethernet PDU and sends it to the Ethernet host.
Transparent Operation

So that existing LANs and ATM networks can interoperate, Ethernet or Token Ring frames are transferred using ATM Forum LANE software. This allows two things:

- carrier-type LAN access devices, linking LANs to ATM networks and
- support for existing operating systems and protocols designed for 802.x LANs.

While routers routinely span different LAN media, the ability to use bridges to do the same is important in many LANE environments. By connecting existing LANs with bridges, new stations connected to the ATM internetwork appear as if they are still part of the same pre-existing LAN.

This means applications that previously worked with all stations on the same LAN will continue to work correctly—even though some stations are now directly connected to the ATM internetwork. From a network construction perspective, ATM LANE allows the ATM segment to be treated as just another LAN segment.

Application Example

Electronic mail is a familiar application and clearly illustrates the benefits of LANE. Figure 5 shows a typical corporate network consisting of both ATM hosts and Ethernet hosts. The e-mail server is attached to an ATM switch in the network, as are various hosts. Servers are placed on the ATM network to take advantage of
ATM’s performance and quality of service. Ethernet hosts are also connected to the ATM network via a LAN access device.

Figure 5 An ATM network application example: electronic mail.

Users who communicate most frequently with one another are grouped within their own VLAN. LANE allows the creation of multiple VLANs on the ATM internetwork. These users would typically be grouped based on department or functional group (e.g., accounting, engineering, or marketing).

Although users in the accounting department communicate with one another on a daily basis, they also need to communicate with others in the company. If the e-mail server on the ATM network is a member of several/all VLANs, it could distribute e-mail within one VLAN, as well as between VLANs.

Further, the ability to group users into separate VLANs is an issue for network administrators using legacy LAN technology. With LANE and the LECS, network administrators can easily define VLANs—regardless of physical location. Host computers can be dynamically added or removed from a VLAN.

Using LANE, hosts on the Ethernet segment can also be grouped into a VLAN, or with hosts on the ATM network. The seamless migration between the Ethernet LAN and the ATM internetwork provides access to the e-mail server and to other hosts on network, regardless of the LAN technology being used by those hosts.
LAN EMULATION FROM FORE

FORE's LANE is part of a unique distributed internetworking software called ForeThought. With ForeThought-based products, interoperability issues are eliminated. FORE has complete line of component services including LES, BUS, LECS, and a VLAN Configuration Application.

FORE is a leader in specifying LANE in the ATM Forum. FORE was the first company to ship LANE software with PC ATM adapter products (i.e., ForeThought LANE v 0.4). This pre-standard version of LANE v0.4 began shipping with FORE’s PC adapters in 1994. It provided a LANE solution to customers in a timely manner, and the complete functionality required when fully deployed in large LANs.

FORE continues its leadership in ATM LAN solutions by providing a complete ATM Forum-compliant LANE solution with the release of ForeThought v4.0. With ForeThought v4.0, ATM Forum LANE v1.0 is available across FORE's entire line of switches and adapters.

**ForeThought LANE v0.4**

*ForeRunner* ATM adapters with ForeThought LANE v0.4 used the connectionless service available in ForeRunner ATM switches. This allowed customers to immediately implement VLANs without upgrading ForeRunner ATM switch software.

This approach provided a single connectionless service available within the network that supported one VLAN. This initial version of LANE achieved the primary goal of providing a LANE mechanism and supporting conventional LAN traffic.

ForeThought LANE v0.4 was the industry's first ATM Forum-compliant version of LANE. It is supported by the ForeRunner ATM switches, ForeRunner ESA-200EPC, PCA-200PC, and NBA-200 adapters for desktop connections, and the ForeRunner LAX-20 LAN access switch.

ForeThought LANE v0.4 also supported RFC 1483—the ATM Forum specification for data encapsulation. This defines how ATM information is added to the higher-layer SDU for point-to-point virtual circuits (VCs) and uses an RFC 1483 address header (i.e., a 2-byte address header followed by the data).

Connectionless traffic was handled similarly to the Logical Link Control SubNetwork Access Protocol (LLC SNAP) encapsulation format. An IEEE 802.6 (8-byte) bridged connectionless header was used instead of 802.2 (6-byte) headers for compatibility with FORE’s Simple Protocol for ATM Network Signaling (SPANS) signaling software.

**NOTE:**

The LAN access switch provides seamless internetworking between the ATM network and Ethernet, Token Ring, and FDDI LANs. For seamless interconnection between ATM and non-IP legacy LANs, LANE must be present on the LAN access switch as well as the ATM adapters.
ATM Forum LAN Emulation Standard 1.0

The ForeThought v4.0 release provides ATM Forum LANE v1.0. The initial version of ForeThought LANE will provide seamless connectivity between ATM and Ethernet LANs. In addition to the components specified in the ATM Forum LANE v1.0 (i.e., LEC, LECS, LES, and BUS), ForeThought v4.0 also provides value-added functionality.

ForeThought v4.0 supports multiple, distinct VLANs. Each VLAN acts like a separate network with respect to any other VLAN, and each has its own LES and BUS. Broadcast and unknown traffic is seen only by the hosts connected to a particular VLAN. One host can belong to more than one VLAN. FORE ATM adapters support a maximum of 16 VLANs or LEC instances per adapter.

Each LEC is assigned a unique MAC address. Therefore, each host can be a member of a maximum of 16 VLANs. The exception is the Macintosh ATM drivers running over Open Transport. Open Transport supports only one active LEC at a time.

Figure 6 shows two VLANs labeled “A” and “B”. For host “X” (IP address = 192.100.x.x) on VLAN A to communicate with host “Y” (IP address = 192.101.y.y) on VLAN B, there must be a default router to route IP packets between VLANs. This router can be a SunOS, NT, or NetWare workstation.

In this example, host “X” has one LEC and belongs only to VLAN A. To communicate with host “Y,” belonging only to VLAN B, the NT station designates the default router as the SunOS, NT, or NetWare workstation's address.
The default router would then have one LEC for each VLAN. Using one ATM adapter, there would be two LEC instances:

- LEC1 on interface EL0 and
- LEC2 on the EL1 interface.

Each LEC would have a distinct IP address. The default router automatically sends traffic from one interface to the other, depending on the destination's subnet address.

In another example, host “X” may be part of VLAN A and VLAN B—simultaneously—by having two occurrences of a LEC: LEC1 and LEC2. In this case, host “X” routes traffic from one interface to another depending on the subnet address of the message’s destination.

![Diagram showing default router equipped with two ATM adapters and configured with one LEC instance per adapter.](image)

**Figure 7.** This figure shows the default router equipped with two ATM adapters and configured with one LEC instance per adapter.

### Advantages of *ForeThought v4.0*

FORE is committed to providing a system solution for ATM internetworking. FORE is deploying LANE across the entire line of *ForeRunner* ATM switches and adapters. *ForeThought v4.0* provides value-added advantages beyond the ATM Forum LANE standard including:

- **VLAN Manager**
  FORE provides a VLAN Configuration Application—a graphical interface using *ForeView* network management software. The *ForeView* VLAN Manager allows the dynamic set-up and creation of VLANs. This graphical user interface allows the system administrator to add and delete individual hosts and end stations from VLANs. Further, it provides a simple way to manage the LES/BUS processes. The *ForeView* VLAN Manager is available on all platforms supporting *ForeView*. 
• Intelligent BUS
  ForeThought v4.0 also provides an intelligent BUS to reduce broadcast traffic. For example, the LAN Emulation Services are tightly coupled to handle unknown frames by allowing the BUS to probe the LES cache for a specific MAC address.

• VLAN Roaming
  ForeThought v4.0 also supports VLAN roaming. LANE allows the network administrator to define VLANs without regard to physical location. VLAN roaming goes one step further by allowing actual physical moves to occur without disrupting the logical framework of the network. For example, a user could move to another floor, or another building, and the network administrator would not have to reconfigure the VLAN. This is done through the Interim Local Management Interface (ILMI) and automatic address registration.

• Redundant LANE Services
  A single LAN Emulation Configuration Server (LECS) in a network is a single point of failure. Enhancements to the LAN Emulation services (distributed and replicated) will be implemented by FORE to provide redundant LECS, operating simultaneously at different points in the network—eliminating the single point of failure.

  Currently, FORE has implemented redundant LES and BUS, with a LEC failover function. Rather than associating a single LES with a single VLAN, FORE’s LEC maintains an ordered list of the redundant LES/BUS pairs per VLAN. Up to nine redundant LES/BUS pairs can be defined simultaneously.

  While the LEC is only interacting with one LES at a time, it is ready to move to the next LES/BUS pair in the list should the current server fail. When any LES supporting a single VLAN fails and is restarted, the LECs in that VLAN will re-establish connectivity with the functioning LES/BUS that appears earliest in the ordered list.

  The LEC continually attempts to reconnect to servers defined earlier in the list. When the primary LES/BUS is again functioning, the LEC reconnects to that server and normal operation continues.

**ForeThought v4.0 and ForeRunner Compatibility**

ForeThought internetworking software is the cornerstone of the FORE’s product line. ForeThought runs on every ATM switch, adapter, and access product provided by FORE. The main feature of ForeThought v4.0 is ATM Forum LANE v1.0. Figure 8 shows how LANE functions are deployed across FORE’s product line.
<table>
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<tr>
<th>Host Operating System</th>
<th>ForeRunner ATM Adapter Hardware</th>
<th>LAN Emulation Client (LEC)</th>
<th>LAN Emulation Services (LECS, LES, and BUS)</th>
<th>VLAN Configuration Application</th>
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<td>SunOS 4.1.x</td>
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<td>Yes, Yes, Yes</td>
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Figure 8 This table shows ForeRunner ATM adapters, their compatible operating systems, and whether they support LEC, LANE Services (LECS, LES, & BUS), and ForeView’s VLAN configuration Application.
ATM Forum LANE specifies a LEC for each of end station, an instance of a LES and BUS per VLAN, and an LECS. Any ForeRunner ATM switch or adapter can be a LEC.

LECS, LES and BUS operate on all ForeRunner ATM switches except the ASX-100. One instance of the LECS, LES and BUS services operate per switch processor. If a customer does not have a ForeRunner ATM switch for every VLAN they need, a dedicated Sun SPARCstation with SunOS can provide LANE v1.0 services.

**ForeThought Partners Program**

*ForeThought* v4.0 is also available as a software source product through the ForeThought Partners Program. Partners can incorporate *ForeThought* with their own hardware to: ensure interoperability with FORE equipment and further the use of standards-based ATM software in the industry.

Partners licensing *ForeThought* v4.0 software have access to FORE's LANE v1.0 LEC and LANE v1.0 services code and the advanced SPANS UNI and NNI functions currently shipping with *ForeThought* source code v3.x.

## CONCLUSION

LAN Emulation provides a simple and efficient way to introduce ATM into networks by ensuring that the raw bandwidth of ATM can be used to alleviate congestion and traffic problems on existing LANs.

ATM is the only technology capable of supporting newer applications being developed—desktop video services, collaborative workgroups, medical imaging and other real-time, bandwidth intensive applications. Further, with the emergence of wide-area ATM solutions, ATM will further simplify network administration.
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