An Introduction to ATM LAN Emulation

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Abstract

LAN Emulation is a software protocol allowing ATM networks to behave like local area networks, running existing applications unchanged. It also allows connectivity between ATM networks and existing LANs. LAN Emulation is necessary for two reasons:

1. High-speed LANs is a major ATM application. The extra bandwidth (155 instead of 10 Mbps) and the dedicated links appeal to many users.

2. To achieve widespread deployment, ATM must allow today’s LAN applications to run over the new ATM hardware, making migration from today’s Ethernet and Token Ring LANs to tomorrow’s ATM LANs easier.

This technical brief discusses LAN Emulation.

ATM Networks: Native and Interconnected

The simplest ATM network is comprised of an ATM switch and several ATM users (e.g., workstations). This is shown in the following figure:

![Figure 1: Typical ATM network](image)

The simple network shown Figure 1 can also be termed a native ATM network. It is native in the sense that all the network connections are pure ATM, and that no translations are required between ATM and other technologies. This kind of network can offer dedicated ATM links at

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speeds such as 155 Mbps. However, the implementation of such a network sometimes involves significant costs, as ATM network cards and switches are much higher in price than their LAN counterparts. Consequently, unless ATM access is required at all endpoints, a more economical solution will usually be desired.

A typical, more complex but cost-effective network solution is when ATM equipment is interconnected with legacy network technologies. This is shown in the following figure:

![Diagram](image)

*Figure 2: ATM equipment interconnected to a legacy network.*

In this network, only selected stations requiring the higher bandwidth associated with ATM are connected with ATM links. A typical example of such a station is the file server, where a great deal of network traffic is concentrated. The other stations remain connected via Ethernet and thus retain their original network cards.

There are several problems which must be solved for such a scheme to work:

- LAN MAC addresses must be translated back-and-forth into ATM addresses.
- Many LAN functions rely on the ability of other stations to receive broadcast and multicast messages. This is no longer true in star-shaped ATM networks. Thus, multicast and broadcast services must be provided.
- Connections to other stations are not always present and must be created.

**Why LAN Emulation?**

The introduction of a new technology such as ATM may require significant costs, unless it is performed in a stepwise fashion. There are two aspects to an economical migration: hardware
costs (new network interface cards, equipment, cabling, test equipment); and software costs
(change or rewrite of existing applications, additional management tools).

LAN Emulation is designed to help ease the migration. It is a software protocol running over
ATM equipment that offers two major points:

• The ability to run all existing LAN applications over ATM without change. The
  immediate benefit is that users do not have to reinvest in applications.
• The ability to interconnect ATM equipment and networks to existing LANs, and to link
  logically separate LANs via one ATM backbone. The advantage is that ATM equipment
  only has to be introduced where it is needed.

LAN Emulation is being defined by the ATM Forum in the LAN Emulation workgroup. The
latest version of LAN Emulation is version 1.0.2

In a nutshell, LAN Emulation translates between LAN MAC addresses and ATM addresses.
It’s design has followed several goals:

• Based on ATM Forum UNI 3.0 specifications.
• Allow high-performance, scaleable backbones.
• Allow protocol-independent switching.
• Provide low latency and high performance.
• Work in a permanent (PVC) or switched (SVC) environment.

LAN Emulation can emulate:

• The functionality of an Ethernet/802.3 segment;
• Or the functionality of a Token-ring/802.5 segment.

What LAN Emulation is Not

LAN Emulation’s greatest advantage is also its greatest disadvantage: it hides the ATM layer
from the application. This means that applications running over LAN Emulation cannot use
the additional benefits of an ATM network: support for multiple kinds of data, a specifiable
Quality of Service, priority and congestion management and more.

Additionally, LAN Emulation will not:

• Bridge between dissimilar technologies such as Ethernet and Token Ring.
• Solve the management and monitoring problem associated with moving to a star-shaped
  network, namely that stations can no longer receive all frames on the network.
• Support existing MAC-layer protocols such as token management.
• Emulate collisions, tokens, beacons and other artifacts associated with existing
  Ethernet/Token Ring networks.

2 ATM Forum - LAN Emulation over ATM specification - Version 1, Feb. 1995
The LAN Emulation Protocol Stack

LAN Emulation is implemented in all equipment required to participate in the emulated LAN; namely workstations, switches, network interface cards, bridges, etc. The following diagram describes the LAN Emulation protocol stack:

![LAN Emulation protocol stack diagram]

The end-points of the connection (the server and the workstation) run the same applications over an NDIS/ODI driver (in this example). It is the underlying layers that are different: the server runs LAN Emulation over AAL5 and the workstation runs Ethernet. The important issue is that the upper-layer application remains unchanged. It does not need to realize that ATM is running underneath. The bridge that has both technologies: a LAN port towards the legacy LAN and an ATM port towards the newer ATM network. The switch continues to run its normal stack, switches cells and creates connections.

LAN Emulation Components

There are several participants in the LAN emulation (LE) protocol operation: the LAN Emulation Client (LEC), the LAN Emulation Server (LES), the LAN Emulation Configuration Server (LECS), and the Broadcast and Unknown Server (BUS). Each of these is described below.
LAN Emulation Client (LEC)
The LEC is the user requiring LAN emulation services. Typically, it is the workstation running the application or the ATM bridge which connects the ATM network with the legacy LAN. There can be many LAN Emulation Clients in an emulated LAN.

LAN Emulation Server (LES)
The LES implements address registration (allowing stations to register their MAC and ATM addresses) and provides address resolution (answers ARP (Address Resolution Protocol) requests by converting between MAC and ATM addresses). Each emulated LAN can have only one LES. However, a physical LAN can serve several emulated LANs, each with its own LES.

LAN Emulation Configuration Server (LECS)
The LECS provides configuration information, including the address of the LE server, the type of emulated LAN and the maximum frame size. Each network can only have one LECS.

Broadcast/Unknown Server (BUS)
The BUS performs all broadcasts and multicasts. Frames are sent through the BUS in two instances:

- When the information is to be transferred (broadcast) to all stations.
- When a source LEC has sent an ARP to the LES, and does not wish to wait for a response before starting the data transfer to the destination LEC. In this case, the source LEC transmits the information to the BUS which, in turn, floods the entire network with it.

Each emulated LAN can have only one BUS. However, a physical LAN can serve several emulated LANs, each with its own BUS.

Location of LAN Emulation Service Components
While the ATM Forum specifies that there are three separate logical components to the LAN Emulation service (the LES, LECS and BUS), it deliberately does not specify whether they are physically separate or united. This decision is left to the vendors.

Many vendors merge the LES, LECS and BUS into a single physical unit. There have been two popular choices where to place this unit:

1. Adding the LE service functionality into switches.
2. Providing an external station which connects up to any switch and provides LE services.
Data Transfer Over an Emulated LAN in Reverse Order

When explaining LAN Emulation for the first time, it has proved very useful to trace the activity on an emulated LAN going **backwards** in time. If you prefer the regular, chronological order, it is described in the next section.

The Goal of LAN Emulation

The goal of LAN Emulation is to transfer LAN data. This is achieved by setting up a VCC between the source station and the destination station. Data transfer over an emulated LAN does not require the LES components to actively send data.

Let’s assume that a source LEC wants to send data to a destination LEC. The source and destination MAC address are known. The question that remains: is a data connection already set up between the source and destination stations? Two options exist:

- **Yes, a connection exists.** The source LEC formats a LAN Emulation data packet and sends it over to the destination.
- **No, a connection does not exist.** Such a connection must be created. Once a connection is created, normal data transmission can start.

To create a connection, the source LEC needs the ATM address (20-byte address) of the destination LEC, i.e., it needs to map the destination MAC address into an ATM address. The question that remains: does the source LEC have the ATM address of the destination LEC? Once again, two options exist:

- **Yes, the source LEC has the ATM address of the destination.** Create a connection using the signalling protocol and send the data over.
- **No, the source does not have the ATM address of the destination.** To get this address, ask the LES. Once this address is received, a connection can be created and normal data transfer can start.
These steps are summarized in the following decision tree:

![Decision Tree Diagram]

**How Does the LES Know the Mapping Between MAC and ATM Addresses?**

To answer ARP requests, the LES must maintain a table which matches MAC addresses to and from ATM addresses. To fill this table, every LEC registers both its ATM address and MAC address with the LES. This is done at startup, before sending any data over the emulated LAN.

Consequently, when the LES is contacted with an ARP request (e.g., with a known MAC address and a missing ATM address), it can consult its tables and return the missing ATM address. Then, the requesting station can use this address to create a data connection to the destination and send the data.
To contact the LES, the LEC creates a control connection with the LES using the signalling protocol. The question is, of course, how did the LEC find the LES in the first place?

**How Did the LEC Find the LES?**

To find the ATM address of its LES, the LEC consults the LECS. A connection (which can be torn down afterwards) is created between the LEC and the LECS. The LEC provides the requested LAN type (802.3 or 802.5), frame size and its MAC address. The LECS returns the ATM address of the LES. Once the LEC has the address of the LES, it can register with it and use the LES for any further address resolution protocol requests.

The question is, of course, how did the LEC find the LECS?

**How Did the LEC Find the LECS?**

There are a number of ways for the LEC to find the LECS:

1. Extract this address from the switch using ILMI. If successful, the LEC tries to connect to that address.
2. If unsuccessful, use a well-known ATM address (a pre-configured address, the address it used the last time, etc.) to try and establish the SVC with the LECS.
3. If unsuccessful, use a PVC at VPI=0, VCI=17 for such a connection.
4. If still unsuccessful, try to contact the LES with an ARP.

Once the LECS receives the address, the LEC can connect to it, extract the address of the LES, register and use the LES services for ARP requests leading to direct data transfers.
How are Broadcasts Performed?

Broadcasts are a necessary part of LAN operations. Theoretically, to perform broadcasts, each LEC could maintain a point-to-multipoint connection with all other LECs. However, this would create a large number of such connections (as large as the number of LECs) and require constant maintenance as stations join and leave the emulated LAN.

The solution adopted by the ATM Forum was to create the third part of the LAN Emulation services: the Broadcast Unknown Server (BUS). The BUS is the only one to maintain a point-to-multipoint connection with all other LECs. When a LEC requires a broadcast, it sends the message to the BUS which then forwards it to all stations in the LAN.

To do this, the BUS must be aware of all stations on the emulation LAN. Thus, when a LEC wishes to join the LAN, it must also register with the BUS. How does it find the address of the BUS? Easy: the MAC address of the BUS is the normal broadcast address (0xFFFFFFFFFFFF), so this is actually the first ARP request that a LEC forwards to the LES.

Once the LES returns the ATM address of the BUS, a connection may be created in order to register the LEC with the BUS.

What Unknown about the Broadcast Unknown Server (BUS)?

The BUS has another use besides intentional broadcasts. Remember that when a LEC does not have the desired ATM destination address, it consults the LES. This consultation might take some time (e.g., because the LES is busy serving other requests); sometimes too much time for the particular protocol that is executed on the LEC. In this case, the LEC may forward the data frame to the BUS which floods the network with it. In this way, the destination station will receive the desired data. This usage uses the BUS to transfer data to unknown destinations.

Of course, this is highly inefficient and as soon as the ARP request is answered by the LES, the LEC should stop sending data using the BUS. To make sure frames do not get out of sequence, the LEC sends a FLUSH message to the BUS requesting to finish all unfinished data transfers before stopping the sending of data through the BUS to unknown destinations.

Data Transfer: The Formal Approach

There are several stages pertaining to establishing connection over an emulated LAN. Showing these steps in chronological order is common in most textbooks and will be shown this way in this section. The steps are described in this section from the LEC point of view.

LAN Emulation uses the signalling protocol to establish transient connections. Each LEC has a unique ATM address (in one of the address formats supported by the ATM Forum’s UNI

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3 See “An introduction to ATM signalling” also available in the RADCOR Technical Brief series.
3.0 signalling). In the SETUP message, the Broadband Low-Layer Information element (B-LLI) is used to identify LAN Emulation connections.

Initially, the protocol ID (PID) in the B-LLI IE is ISO/IEC TR/9577. There are several types of supported PIDs:

- Control connections
- 802.3 data connections
- 802.5 data connections
- 802.3 multicast forward connections
- 802.5 multicast forward connections.

**Initialization**

In the initialization phase (after the LEC is powered on or when the LEC wishes to join the emulated LAN), the LEC must understand the type of emulated LAN that it is joining and identify the addresses of the LECS and LES.

To determine the ATM address of the LECS, the LEC tries to:
1. Extract this address from the switch using ILMI. If successful, the LEC tries to connect to that address.
2. If unsuccessful, use a well-known ATM address to try and establish the SVC.
3. If unsuccessful, use a PVC at VPI=0, VCI=17 for such a connection.
4. If still unsuccessful, try to contact the LES.

**Configuration**

Once a connection to the LECS has been established, the following information is exchanged between the LES and the LECS:

The LEC sends:

- Its ATM address
- Its MAC address
- The requested LAN types and frame sizes.

The LECS returns:

- LES address
- LAN type and frame size to use.

The LECS has a choice of which LES to point the LEC to. This can be a result of either the requested LAN type, or some division of the LECs into virtual LANs (engineering, marketing, production), as desired.
Joining

In this phase, the LEC tries to join the emulated LAN. To do this it:

- Creates a control direct bi-directional VCC with the LES.
- Transmits a join request (ATM address, LAN information, proxy indication, optional MAC address).
- Possibly accepts a control distribute VCC before join request is received.

This operation may time out or fail.

![Figure 6: Joining an emulated LAN](image)

Registration and BUS initialization

The BUS takes care of processing broadcast requests from a LEC to other LAN Emulation clients. To do this, it must be aware of all ATM stations on the line. Thus, when each LEC comes up, it registers at the BUS:

- Resolve the 0xFFFFFFFFFFFF MAC address (broadcast address) to get the ATM address of the BUS.
- Register any MAC addresses.
- Creates a unidirectional multicast send VCC to BUS. This VCC will be used when the LEC desires to perform a broadcast.
- Accepts a unidirectional multicast forward VCC from the BUS. This is the VCC that the BUS will use when performing broadcasts over to the LEC.
Data Movement

When data movement is desired, the top-level application sends over to the driver the information as well as the desired MAC address. The LAN Emulation driver can then proceed with the following steps:

- Check whether the internal cache contains the translation between the MAC address and the ATM address.
- If not, ask the LES.
- While waiting for a response, the LEC may transmit frames using the BUS.
- Once a response has been received, a direct connection is established using the signalling protocol. The translation between the ATM address and the MAC address are added to the cache.
- Connections are deleted based on inactivity.

Proxy Agents

Sometimes, it is unrealistic to ask a LEC to register all its MAC addresses. For example, an ATM-Ethernet bridge may not want to register all the MAC addresses on its Ethernet side (because it does not know them all, because there are too many, or because it would then have to continuously update this registration as stations come up or down). Instead, it may choose only to register its own MAC address with the LES but specify that it is a proxy agent acting on behalf of other stations.

When the LES receives an ARP request for the MAC address of an unregistered Ethernet station, it will broadcast this ARP. When the proxy agent receives this ARP, it will broadcast
it on its Ethernet side and respond to the LES if a response is received from the Ethernet side.
To reduce the traffic on the network, the LES may choose to send the ARP only to those
stations registered as proxy.

The possibility of stations to use proxy mechanism answers two questions that may have come
up while discussing the LES:

Question 1: Why would the LES need to send ARP requests if all the stations had already
registered with the LES?
Answer: Because some stations, like the Ethernet stations connected to the bridge, may
not have registered with it.

Question 2: Why might an ARP request take some time to respond, aside from the LES
possibly being busy?
Answer: Because the proxy agent may take some time to respond, or may be connected
to further routers and bridges down the road.

Control and Data Connections

The following table summarizes the control and data connections between the LEC and other
LAN Emulation entities. These connections will usually be created using the Signalling
protocol.

<table>
<thead>
<tr>
<th></th>
<th>LECS</th>
<th>LES</th>
<th>BUS</th>
<th>Other LECs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control connection</td>
<td>Transient connection to retrieve address of</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the LES.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data connection</td>
<td></td>
<td>VCC for multicast send. VCC for multicast receive.</td>
<td>Direct VCCs for data transfer.</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Connections between LEC and other LAN Emulation entities*
The LAN Emulation Packet Format

LAN Emulation supports two types of emulated LANs: Ethernet and Token-ring. The LAN Emulation data frames preserve all the information contained in the original 802.3 or 802.5 frames, but add a 2-byte LEC ID (the source ID), an ID which is unique to each LEC. The frame formats are shown in the following figures:

| LAN Emulation header (2 bytes) | LEC ID
|-------------------------------|--------
| Destination MAC address | Source MAC address |
| Type/Length                  | Data   |

**Figure 8: LAN Emulation Ethernet 802.3 frame format**

| LAN Emulation header (2 bytes) | LEC ID
|-------------------------------|--------
| Frame control | Destination MAC address |
| Source MAC address | Length |
| Data   |

**Figure 9: LAN Emulation Token Ring frame format**

The original 802.3 or 802.5 is maintained since it may be needed at some nodes. For example, an ATM-to-Ethernet bridge will receive LAN Emulation Ethernet frames from the ATM side, strip off the first two bytes and send the Ethernet frame on the Ethernet side.

Why do the frames contain the LEC ID at all? There are several instances that justify this. For example, an Ethernet station broadcasting over Ethernet does not know to listen to its own broadcasts (the station receives these broadcasts instantaneously). In an emulated LAN, however, the broadcasts, send through the BUS, may come after some delay. By comparing the received LEC ID with its own LEC ID, each station can ignore messages which it generated.

Summary

LAN Emulation is a key ATM protocol. Its importance to the deployment of successful and useful ATM networks cannot be underestimated. By a combination of three logical entities, the LECS, the LES and the Broadcast Unknown server, a LAN Emulation Client can receive emulated LAN services keeping its upper-layer applications unchanged.

RADCOM offers a variety of unique testing tools for developing, installing and troubleshooting ATM equipment implementing LAN Emulation. We will be happy to provide you with additional information about our testing solutions for LAN Emulation and other ATM testing areas.
# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAL</td>
<td>ATM Adaptation Layer</td>
</tr>
<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
</tr>
<tr>
<td>BUS</td>
<td>Broadcast Unknown Server</td>
</tr>
<tr>
<td>ILMI</td>
<td>Inter-switch Local Management Interface</td>
</tr>
<tr>
<td>LE</td>
<td>LAN Emulation</td>
</tr>
<tr>
<td>LEC</td>
<td>LAN Emulation Client</td>
</tr>
<tr>
<td>LECS</td>
<td>LAN Emulation Configuration Server</td>
</tr>
<tr>
<td>LES</td>
<td>LAN Emulation Server</td>
</tr>
<tr>
<td>LUNI</td>
<td>LAN Emulation UNI</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>PVC</td>
<td>Permanent Virtual Circuit</td>
</tr>
<tr>
<td>SVC</td>
<td>Switched Virtual Circuit</td>
</tr>
<tr>
<td>UNI</td>
<td>User Network Interface</td>
</tr>
<tr>
<td>VCI</td>
<td>Virtual Circuit Identifier</td>
</tr>
<tr>
<td>VPCI</td>
<td>Virtual Path Circuit Identifier</td>
</tr>
<tr>
<td>VPI</td>
<td>Virtual Path Identifier</td>
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