MODELING LANE DYNAMICS  
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Abstract: - In campuses and other medium organizations, ATM networks co-exist with newer networks such as Fast Ethernet, Gigabit and legacy Ethernet & Token-Rings. Such networks use ATM LAN emulation (asynchronous transfer mode LANE) to access the ATM network. The need to have intelligent answers to questions of cost, performance, and the direction of growth (trend analysis and capacity planning) that frequently arise throughout the life cycle of the network drives network design experts to model and simulate the network. The purpose of this paper is to study the details of the ATM LANE protocol in order to include, in a simulation model, the required dynamics of the LANE traffic. Many simulation tools have no built-in modeling elements to simulate networks with multiple ATM Emulated LANS (ELANs). The research work has resulted in a state-wise description of the network operations in emulated LAN environment that helps create objects that could be used to model and simulate LANE so as to improve the performance and interaction of ATM with newer generation of networks. 

Key-Words: - Modeling, LAN Emulation, ATM Networks, LANE, LEC, LAD, ELAN. 

1 INTRODUCTION 

The tool used in this research work to model and simulate the network is COMNET. The model's topology consists of a number of nodes and links. The nodes directly attached to the ATM switches represent LECs, which are directly part of the ELAN. They are assumed to have a LANE module in their respective protocol stack modeled as session source LANE-D, application source LANE-I, which is described on the next page LES and BUS are independent servers. A LAD is connected to both the ELAN (ATM side) as well as a traditional Ethernet LAN. All these nodes are modeled using a COMNET [5] Computer & Communications node. They are connected to the ELAN through point-to-point OC-3 or DS-1 links. Apart from the LAD, workgroups are also connected to the Ethernet LAN, using a COMNET Computer Group. [5, 7] 

2 LAN Emulation (LANE) 

2.1 LAN Emulation Components 

In LANE, a typical ELAN consists of the following components: 

- LAN Emulation Clients (LECs). LANE workstation is an Ethernet client, which has generic network applications such as Web, Email etc. running over LANE. It uses ATM as the data link layer for transmitting data over an ATM network. 
- LAN Emulation and Configuration Server (LECS). 
- ATM Switch: An ATM Switch is capable of switching VCs and VPs. 
- LAN Emulation Server (LES). LAN Emulated Server serves generic network applications such as Web, Email etc. running over LANE. A client running applications over LANE can connect to the LANE server. LANE uses ATM as the data link layer for transmitting data over an ATM network 
- Broadcast and Unknown Server (BUS). 
- LAN Access Devices (LADs) or proxy-LECs. These devices are the LAN access routers to the legacy networks. 

Together, these components allow the formation of an ELAN. The interactions between these ELAN components are as follows: upon receipt of a traditional LAN frame from the higher layer protocols, the LEC performs its address resolution function. Each LEC maintains a mapping (ARP cache) of known MAC addresses to ATM addresses. However, this mapping might not be exhaustive and furthermore is purged periodically. When a frame is received with an unknown MAC/ATM address, the LEC sends an address resolution request to the LES. Each member of the ELAN has to register its MAC/ATM address with the LES upon joining the ELAN. If the LES has an entry for the required ATM address, it replies to the LEC, which is then able to set up a direct connection to the destination using the connectionless AAL5 service. The LAN Emulation and Configuration Server (LECS) maintain information about all the ELANs. [7]
In some cases, however, even the LES may not have an entry for the MAC/ATM address pair; in particular, if the destination MAC is hidden behind a LAD or if it is part of another ELAN. For this reason, the LEC also sends the first few frames of the transmission to the BUS, which floods these frames to all the members in the ELAN. At the same time, the LES initiates an address resolution protocol, possibly prompting other LESs for the requested address. Should one of these flooded frames reach the destination, possibly through an LAD, the destination informs the LES about its address. Again, once the address resolution is completed, the source LEC establishes a data direct VCC ATM connection to the destination using AAL5 [1, 2].

This paper is organized as follows. A brief introduction into the elements and operations of LAN Emulation is provided followed by list of assumptions made in the research. Following this are the sections that detail the network under study and enumerate the parameters for analyzing emulated LANs. The details of the dynamics of LAN emulation that result in a discrete, state-wise description of the steps involved, follow in the next section followed by a conclusion summarizing the salient points.

2.2 Assumptions

The assumptions underlying the model are as follows:

- All the devices in the ATM part of the model are included as members of the ELAN. Total of four ELANs are defined.
- The explicit address resolution protocol of the server is not modeled. Instead, the process is modeled by a time delay of 0.05 seconds. This simplification ignores some of the network traffic, which is generated by the ARP process. However, this traffic is considered insignificant with respect to the other traffic load in the network.
- A LEC is assumed to have the destination ATM addresses cached in 50% of all transmissions. The other 50% of the transmissions have to go through the LANE process, as outlined above, simulating the cases where the cache entry has either been purged or when the destination is hidden behind a LAD. Equal number of LEC’s and Legacy LAN clients are defined.
- In the case where the LEC has to request the address from the LES, only a single packet is sent to the BUS for flooding.
- The congestion is perceived to be in the internal traffic of the network under study as opposed to the traffic that is external to the network.
- Within the transit network ELAN; the ATM switches are interconnected by OC-3/DS-1 links.
- Each legacy LAN (Ethernet) is terminated by a computer object, which form’s a workgroup of 5 clients (approximated).
- The network ELAN consists of 20-30 LAN Emulation Clients (LECs). Four subnets are identified as having LECs in the network area. Each subnet consists of 5 LECs with traffic sources and sinks.

3 The Network Model

The ELAN itself is modeled by a COMNET transit net. A single ATM switch or a group of interconnected ATM switches represent the physical aspects of the ELAN in the model. All the nodes of the ELAN are connected to this switch through the OC-3 or DS-1 links. The transit net retains its default network service class and its default connection type [1]. However, the protocol of this connection is set to ATM AAL5 with the following parameter values:

Basic protocol: Data bytes 48, overhead bytes 16 & other parameters default.

A number of COMNET default traffic sources define the ELAN traffic. The LECs generate direct and indirect traffic, the former representing those frames where the LEC has the destination address cached; the latter representing the case where the LEC has to go through the LES. The direct traffic with suffix LANE-D is generated using an COMNET node session source. The destination of this direct message source is either the remaining LEC, or the LAD. A COMNET node application source is also associated with each LEC. This source models the indirect traffic, which has to go through the LES. [5, 7]

Traffic components of LEC are as follows:
LANE-D:
Traffic source to model direct ATM connections (the LEC has the MAC address of the destination in its cache). Modeled as a message source. Destination: Random list of all LECs and LADs of that ELAN.
LANE-I:
Traffic source to model indirect ATM connections (wherein the LEC does not have the MAC address of the destination in its cache). Modeled as an application source.
Sequence of commands:
SendARP – sends ARP request of 28 bytes
Broadcast
Await Response – Responds to any default received message text
Setup LANE

The first command sends a 30-byte message to the LES to simulate the address resolution request. This command is defined as a global transport command, and hence it is available to all the application sources in the model. At the same time, the application sends a message to the BUS by executing the command ‘Broadcast’. After these two transmissions, the application then waits for a response from the LES. This is implemented in the model in the form of a global filter command. The message to wait for is set to ‘ARP’, which corresponds to the message text by which the LES responds to the request. Upon arrival of such a message, indicating that the address resolution request has been terminated, the LEC then establishes a connection with either the other LEC or the LAD. This is modeled using a local session command, the parameters of which are identical to those outlined under the direct transmission above [1, 2, 5, and 7].

Connected to the LES is a single COMNET process response source. This source is triggered upon arrival of the 28-byte message, which is generated by the execution of the command ‘send ARP’ on the LECs. After the delay of 0.05 sec for address resolution, the response source returns a 28-byte message to the requesting LEC. This message is associated with the text ‘ARP’, which, upon arrival at the LEC, triggers the continuation of the LEC’s command sequence.

The list contains all the nodes, which are part of the ELAN.

BUS
A message source “Flood” is used to model the broadcast operation in LANE. A broadcast is sent to a multicast list comprising all LECs, LADs & Ethernet workgroups.
Scheduling: By received broadcast request from the LECs.

The interactions of the ELAN with the traditional Ethernet LAN are modeled at the LAD. The process node model is associated with three process traffic sources labeled ‘LANE’, ‘LANE-FwI’, and ‘LANE-FwD’. The principal function of these sources is to convert the protocol stack between the Ethernet LAN and the ELAN. The two sources, ‘LANE-FwI’ and ‘LANE-FwD’, handle the traffic from Ethernet to the ELAN. The source, ‘LANE’, handles the traffic in the other direction.

The message source, ‘LANE’, is triggered by indirect and direct messages from the LECs, respectively. Notice that the LECs’ operations, as described above, do not establish a connection with the workstations on the traditional LAN directly. Instead, the direct and indirect traffic is transmitted to the LAD, since the connection-oriented ATM protocol cannot be part of the traditional Ethernet LAN. The source, ‘LANE’, is triggered by any message originating from either LECs, then assembles the message and transmits it in a connectionless mode to any one or more of the workstations on the traditional LAN. The parameter settings for this traffic source are as follows:

LAD (LAN Access Device)
A message source, a session source, and an application source are used to model the traffic to and from the LAD.

LANE:
A message source, LANE, models the traffic from the LECs to the Ethernet workgroups. Scheduled by received message “LANE” from the LECs.
Routing class: Standard; Transport protocol: Ethernet.
Destination: Random list of Ethernet workgroup computers across the corresponding LAD.

LANE-FwD:
A process session source model, LANE-FwD, is used to model the direct traffic from the Ethernet workgroup computers to the LECs.

LANE-FwI:
An application process source, LANE-FwI, is used to model the indirect traffic from the Ethernet workgroup computers to the LECs. The command sequence for this application is as follows: SendARP – sends ARP request of 28 bytes to the corresponding LES
Similarly, the workstations on the traditional LAN do not directly establish a connection with the LECs. Instead, they transmit their messages to the LAD. This is indicated in the model through the two COMNET process message sources with the suffixes ‘LANE/D’ and ‘LANE/I’, respectively, which are connected to the computer group icon. These sources generate a connectionless traffic to the LAD using the Ethernet protocol. The only difference between both sources is the name of the source, which is subsequently used as a trigger at the LAD. The process source with the suffix ‘LANE/D’ triggers the COMNET session source named ‘LANE-FwD’, whereas the process source with the suffix ‘LANE/I’ triggers the application process source named ‘LANE-FwI’. The two forwarding sources are very similar to the sources connected to the LECs. ‘LANE-FwD’ generates messages with one of the LECs as destination following the Ethernet protocol. Like above, the Ethernet frames are segmented into ATM AAL5 cells on the ELAN. Similarly, the message source, ‘E-LANE/I’, triggers the application source, ‘LANE-FwI’, which again executes the command sequence of commands:

- Send ARP
- Broadcast
- Await Response
- LANE

LEGACY WORKGROUP COMPUTERS
Two process messages sources – one each for direct and indirect, are used to model the traffic from legacy LANs to the LECs. With the suffix LANE /D:
Traffic source to model direct ATM connections (wherein the MAC address of the destination is with the LAD). Modeled as a process message source.
Destination: Corresponding LAD
With the suffix LANE /I:
Traffic source to model indirect ATM connections (wherein the MAC address of the destination is not with the LAD). Modeled as a message source.
Destination: Corresponding LAD

The parameters for these commands are identical to those described above. Here, the modules defining the ELAN are no longer associated with dedicated physical nodes. Instead, they are represented by the traffic sources only. The ELAN is thus modeled through the relationships between the sources that are established through triggers and the destination lists of the sources.

Figures 14 and 15 show the snapshots of model developed. These models represent the traffic engineering and LANE dynamics.

4 Dynamics of ELAN traffic

Traffic flow dynamics were modeled using the node model, process model and interface attributes for message response and session source objects. Application configuration and User configuration objects are used to model different combinations of traffic parameters and types with user profiles. A typical example of the most common activities on the network includes email, web browsing, video audio streaming and videoconferencing. Dynamics of LANE are shown in figure 1.

The email transactions at the client side were split into two traffic types – one corresponding to a user sending email and the other corresponding to the user receiving email. On COMNET, these were respectively represented by a message source that sends the email to the mail server and another message source that triggers the mail server to send the mail. The email transactions on the mail server side were split into two traffic types – one corresponding to the mail server receiving and storing the mail and the other corresponding to the mail server reading and sending the mail. In COMNET, these were respectively represented by an application source that responds to the client mail send requests and receives the email, and another application source that responds to the client mail receive requests and transfers the mail.[5,7]

The web service at the client side is modeled using a traffic message source that requests web pages through a proxy server and sets up a web session. At the proxy server, the response to this request is modeled using an application source.

The proxy LECs serve the edge devices, local LAN, and remote LAN. Each of these routers supports Token-Ring and Ethernet segments. All the segments are terminated with a set of workgroup computers, each having 10 users. Each user generates email, web, and audio video streaming traffic requests from the services that are attached to the network ELAN.

All the traffic generated from the Token-Ring and Ethernet segments are directed to the proxy LEC. The routers use ATM adaptation layer protocol AAL5 to forward the traffic from the legacy Token-Ring/Ethernet side to the ATM side.
Traffic profiles were decided on the basis of access patterns of typical users in the network. Two workload components are considered in the model: e-mail, and web. The traffic parameter values of each traffic scenario are summarized in Table 1. The workload intensity parameters are described below:

<table>
<thead>
<tr>
<th></th>
<th>Low Load</th>
<th>Medium Load</th>
<th>Heavy Load</th>
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<tbody>
<tr>
<td><strong>E-mail:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-mailRequestSize</td>
<td>100 bytes</td>
<td>100 bytes</td>
<td>100 bytes</td>
</tr>
<tr>
<td>E-mailInterarrival</td>
<td>Exp 720 sec</td>
<td>Exp 360 sec</td>
<td>Exp 180 sec</td>
</tr>
<tr>
<td>E-mailSize</td>
<td>Exp (1 KB)</td>
<td>Exp (3 KB)</td>
<td>Exp (5 KB)</td>
</tr>
<tr>
<td>Web:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WebRequestSize</td>
<td>100 bytes</td>
<td>100 bytes</td>
<td>100 bytes</td>
</tr>
<tr>
<td>WebInterarrival</td>
<td>Exp 360 sec</td>
<td>Exp 120 sec</td>
<td>Exp 120 sec</td>
</tr>
<tr>
<td>WebPageSize</td>
<td>Exp (30 KB)</td>
<td>Exp (100 KB)</td>
<td>Exp (200 KB)</td>
</tr>
</tbody>
</table>

Table 1 Workload components and traffic parameters under different loads

- **E-mailRequestSize:** It is the size of the initial packet generated by a mail client. This packet represents the request initiated by the client to read or receive the email from the mail server.
- **E-mailInterarrival:** It is the rate at which emails are sent or received by a mail client.
- **E-mailSize:** For a mail client, this variable represents the size of the email sent to the mail server. For the operation of a mail receive, this means the size of the email received from the mail server.
- **WebRequestSize:** It is the size of the packet generated by a web client. This packet represents the request to retrieve a web page from the web server.
- **WebInterarrival:** It is the rate at which a client generates web requests (http, ftp etc).
- **WebSize:** The size of the web page requested by a web client and provided by the web server.

4.1 Dynamics of Email transactions:

Typically, mail transactions consist of mail send and receive activities. The process of sending and receiving email is modeled separately. A message source is used to model the process of a client sending email. The client generates an email send request called ‘EmailSendRequest’ of size ‘E-mailRequestSize’. The frequency of this is governed by the parameter ‘E-mailInterarrival’. On any LEC, the message text of this message is ‘Email-Send’ and the destination is the mail server. On a node attached to a legacy LAN, this request is destined to the corresponding LAD or the proxy-LEC. At the LAD, the ‘EmailSendRequest’ triggers an application source that is used to model the process of the LAD forwarding the mail request from the client to the server. This application source, called ‘Email Send LANE-FwD’, generates the message called ‘Email-Send’ destined for the mail server and of size ‘EmailRequestSize’. At the mail server, an application source is used to model the process of receiving the user mail and storing it. This application source ‘Exchange Store’ is triggered by the message with message text ‘Email-Send’.

A message source is used to model the process of a client generating an email receive request. This request, called ‘E-mailReceiveRequest’, is generated every ‘E-mailInterarrival’ seconds and its size is ‘E-mailRequestSize’. On any LEC, the message text of this message is set to ‘E-mail-Receive’ and the destination is the mail server. On a node attached to a legacy LAN, this request is destined to the corresponding LAD or proxy-LEC. At the LAD, the ‘E-mailReceiveRequest’ triggers an application source ‘E-mail Receive LANE-FwD’ that is used to model the process of the LAD requesting the user mail from the mail server. This application source generates a message with text ‘E-mail-Receive’ and size ‘E-mailRequestSize’ destined for the mail server. At the mail server, a response source is used to model the process of processing the mail request and then delivering the mail. This response source ‘Exchange Transfer’ is triggered by the message with message text ‘E-mailReceive’, which in turn sets the text of its reply to ‘UserMail’. The response source responds by replying to the node at which the message originated. LECs receive the requested emails directly. For the clients on the legacy LANs, the email receive request is forced to go through the LAD to reach the mail server. Hence, the response source always sends the mail to the LAD from which the request originated. At the LAD, a message source, ‘Email-LANE’, is used to transfer the messages received from the mail server to the client. This message source triggers on the arrival of the message with text ‘UserMail’, which is generated by the mail server and which represents the message with the user mail in it. For the purpose of collecting and monitoring statistics, the application type of all email transactions is set to ‘Email’. [6, 7]
A processing node models the behavior of the Exchange mail server with a storage capacity of 20 Gigabytes. This source models the Exchange Store, which saves the mails of all users on its local hard disk & Exchange Transfer, which reads and transfers the mails of individual clients.

The time sequence diagram of the mail exchange operation of legacy LAN clients is shown in Figure 2, and a similar diagram for the mail exchange operation of the LAN emulation clients is shown in Figure 3.

4.2 Dynamics of Web Transactions

Typically, a web transaction consists of a client requesting a web page from a web server. The server is directly attached to the ELAN. Two web servers are used in this model and any one of them can service a particular client request. A message source is used to model the process of a client sending a web request. The client generates a page retrieve request called ‘Web E-LANE/D’ of size ‘WebRequestSize’. The frequency of this is governed by the parameter, ‘WebInterarrival’. On any LEC, the message text of this message is ‘WebClient’ and the destination is the web servers. On a node attached to a legacy LAN, this request is destined to the corresponding LAD or the proxy-LEC. At the LAD, the ‘Web E-LANE/D’ triggers a session source that is used to model the process of the LAD forwarding the web request from the client to the servers. This session source, called ‘Web LANE-FwD’, generates the message called ‘WebClient’ destined for the web servers and of size ‘WebRequestSize’. At the web server that receives the request, a response source is used to model the process of receiving the user web page request and sending the web page to the requester. This response source, ‘ProxyResponse’, is triggered by the message with the message text, ‘WebClient’. Itself sets the text of its reply to ‘UserWebPage’. The response source responds by replying to the node at which the message originated. LECs receive the requested web page directly. For the clients on the legacy LANs, the web page request is forced to go through the LAD to reach the web server. Hence, the response source always sends the web page to the LAD from which the request originated. At the LAD, a message source ‘Web LANE’ is used to transfer the web pages received from the web server(s) to the clients. This message source triggers on the arrival of the message with text ‘UserWebPage’ which is generated by the web server(s) and which represents the message with the user requested web page in it. For the purpose of collecting and monitoring statistics, the application type of all web transactions is set to ‘Web’.

A processing node with default parameters achieves the modeling of web servers. To fully understand the interactions between a web client and a proxy server, please refer to the time sequence diagram of the web application shown in Figures 4 and 5.

5 Simulation Scenarios

The simulation was executed with the following three “what-if” scenarios as shown in the above Table 1:

5.1 Scenario-1: Low Email and Web Load

Typically, an email client generates 5 emails per hour exponentially distributed and of the size 1KB. A web client requests web pages of size 30KB at the rate of 10 pages per hour exponentially distributed.

5.2 Scenario-2: Medium Email & Web Load

Typically, an email client generates 10 emails per hour exponentially distributed and of the size 3KB. A web client requests web pages of size 100KB at the rate of 30 pages per hour exponentially distributed.

5.3 Scenario-3: Heavy Email and Web Load

Typically, an email client generates 20 emails per hour exponentially distributed and of the size 5KB. A web client requests web pages of size 200KB at the rate of 30 pages per hour exponentially distributed.

6 Conclusion

This paper has presented ways to model and simulate emulated LANs in ATM networks using COMNET. A detailed state-wise description of the LAN emulation process has been achieved. Test simulation runs have been done on different traffic scenarios and results obtained.

The results of the above scenarios are shown in the following figures (figure-6 to 13). In all the above scenarios the link utilization for different links were studied. Expectedly the results inferred from our study show the link utilization for slower links (T1, E1, etc) is much higher when compared to the high-speed links. The link utilization and performance was also compared as the load was increased from medium to heavy. The results we got were what we expected. The results also show successful modeling of LANE dynamics, the results shown in figures-6 to 13 show clients from ATM networks (LANE client) and legacy Ethernet and Token-Ring networks. The LAN clients successfully communicated with the Application server serving those
applications. Similarly the LEC’s which are connected and assigned different ELAN’s also communicated across ELAN’s and the server.

This paper has described the LAN emulation over ATM client/server model. LAN emulation is an ATM service that provides the migration from existing LANs to an ATM environment. LAN emulation does what its name implies; it emulates the operation of traditional LANs, and in doing so, makes the connection-oriented nature of ATM transparent to existing applications on all end-user workstations. This paper also describes the functions, frame formats and protocols used by LAN emulation as specified by the ATM Forum. It shows how to model and implement LAN emulation over ATM.

Ways to improve this work would be to extend the methodology to include quality-of-service parameters in the model. A significant result could be achieved by having a real-time network topology and traffic integrated into the network model to validate and increase the accuracy of the modeled network.

7 References

[5] COMNET III is a performance analysis tool for communications networks from CACI

8 Figures

Figure 1 Time Sequence diagram representing modeling of LANE

Figure 2 Time sequence diagram of mail exchange operation of legacy LAN clients
Figure 3 Time sequence diagrams of the mail exchange operation of the LECs

Figure 4 The time sequence diagram of the web page request operation by legacy LAN clients

Figure 5 The time sequence diagram of the web page request operation by LECs

Figure 6 VCC count for the three scenarios. Note that the VCC count is same for all scenarios

Figure 7 LANE throughputs in bits/sec for the three scenarios. Note that the throughput varies for all the scenarios
Figure 8 Ethernet delay for the three scenarios. Note that the Ethernet delay increases as the traffic load increases.

Figure 9 ATM AAL5 delay for the three scenarios. Note that the ATM AAL5 delay increases as the traffic load increases.

Figure 10 ATM AAL5 delay Variation for the three scenarios. Note that the ATM AAL5 delay variations increases as the traffic load increases.

Figure 11 HTTP Web page response time for Low, Medium and High load. Note that the time response increases as the load increases.

Figure 12 Graph of top link Utilization. Link T1 and link E1 which has the highest utilization (average 10%). The graph is for Low Load of Web

Figure 13 Graph of top link Utilization. Which has the highest utilization (reaches saturation on an Average of 99%). The graph is for High Load Web.
Figure 14 Snapshot of the Network model with LANE dynamics and traffic engineering.

Figure 15 Snapshot of the network model with LANE dynamics, traffic engineering and interfacing