A General Local Area Network Analysis System

GLAS

User Manual

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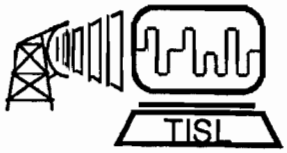

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ABSTRACT

Simulation software has been developed to accurately predict Local Area Network (LAN) performance in a user friendly environment. The LAN model integrates a link access protocol and a media access protocol. Token ring, token bus, and the CSMA-CD can be selected for the media access protocol. This tool allows specification for the processing times for each protocol function. By integrating the link access and media access protocols and allowing specification of all protocol parameters and processing times, this tool allows for detailed studies of multilayer LAN models. The simulation allows interactive modeling of protocols, LAN topologies, and traffic characteristics. LAN performance is reported with a concise table of performance measures and confidence intervals. The accuracy of the LAN model and the simulation's ease of operation combine to make a valuable engineering tool.

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1.0 INTRODUCTION

The University of Kansas Telecommunication and Information Sciences Laboratory (TISL) now has a General LAN Analysis System (GLAS) that predicts LAN performance more accurately than previous models and provides an easy to use interface for modeling LAN's and interpreting simulation results.

Past studies have concentrated on the Logical Link Control (LLC) or Media Access Control (MAC) protocol alone. Integrated LLC and MAC studies have not accurately modeled processing times which are an important factor in network performance. The TISL LAN model allows specification of LAN topology, traffic characteristics, and LLC and\or MAC protocol parameters. The LLC, CSMA-CD, TOKEN RING, and TOKEN BUS protocols are modeled with explicitly specified processing times for each protocol function. For more information on the protocol models and verification of the simulation's performance, see [1].

GLAS offers a menu-driven interface for interactive LAN modeling. Simulations are run in background and produce output files containing tabulated performance measures. This document explains the modeling capabilities of the simulation system, operation of the user interface, and how to interpret the simulation output.

In the following section the General LAN modeling capability of (GLAS) is discussed. Seven different models can be studied; LLC, CSMA-CD, token ring, and token bus models can be individually studied. Integrated LLC-CSMA/CS, LLC-token ring, LLC-token bus can also be evaluated. Common to each model is the description of the network topology and application layer, i.e., traffic model; these are also discussed. Section 3 provides an overview of the GLAS user interface. It is strongly recommended that the example presented in section 6 be exercised to gain a full understanding of the user interaction. The performance measures collected by GLAS are explained in section 4. Specific modeling considerations for effective use of GLAS are given in section 5.

2.0 LAN MODELING

2.1 APPLICATION LAYER AND TOPOLOGY MODELING

2.1.1 Application Layer Traffic Model

In GLAS, the application layer is considered to be at the user level of a node. When discussing the node as a whole, the application layer will be referred to for topics such as traffic distribution. The traffic distribution is specified for each network node under the individual node specifications menu. The interarrival distribution options can be viewed under the individual node specifications menu. These options are for all of the simulation models.

2.1.2 Application Layer Queuing Model

For each of the network nodes of the simulation model, a buffer size is specified for the application layer. Any packets received while the buffer is full are discarded by the LLC layer of that particular node. An option available to the user is to abort the simulation (Section 5.1) if the queue fills for any network node. One can find this option in the general simulation controls menu. An option such as this is good for aborting an unstable simulation or a misdefined simulation. This will prevent wasteing CPU hours for such a simulation.

2.1.3 Topology

The topology of the simulation model is specified by the distances parameters of the network. For each network node, the link to media distance and the distance to the next node are specified. These distances are shown in Figure 1. The link to media distance is the distance from the node to the physical interface unit of the media. These parameters are under the individual node specifications menu.

2.1.3.1 Bus Topologies

The CSMA-CD, TOKEN BUS, and the integrated versions of these two have bus topologies which is shown in Figure 1a. The bus distance specified for node number i is the distance on the bus between node number i and i+1. This would be dimension A in the bus topology figure. The bus distance for the last node on the

bus is not used although it will have a value in its specifications. The link distance is the same as described above and is shown in dimension B in the figure.

2.1.3.2 Ring Topologies

The TOKEN RING and the INTEGRATED TOKEN RING have ring topologies as can be seen in Figure 1b. The ring distance is the distance from the physical interface unit of the last node to the physical interface unit of the first node which is just the distance between adjacent nodes. This distance described is shown as dimension D in the figure. Dimension C is the link distance as discussed previously.

2.1.3.3 LLC Topology

In the LLC model, two nodes are paired together separately as if a full-duplex line ran from only one terminal to another. If a simulation were to have ten nodes, it would be equivalent to having five separate pairs. All node pairs are statistically independent because there is no contention for the bus. Five data points would be obtained in this ten node simulation since node pairs are independent. Therefore, an entire performance curve may be generated with one simulation job.

2.2 LLC Model Protocol

The LLC protocol is used for the link layer. For this model, only the link level is evaluated. Once the link level passes a packet down to the media, the packet is immediately received by its paired node. This is because of the fact that there is no MAC layer involved. The user specifies the link access parameters and processing times listed in Table 1. The parameters for this protocol are explained below. For a more detailed description of this model, refer to [3].

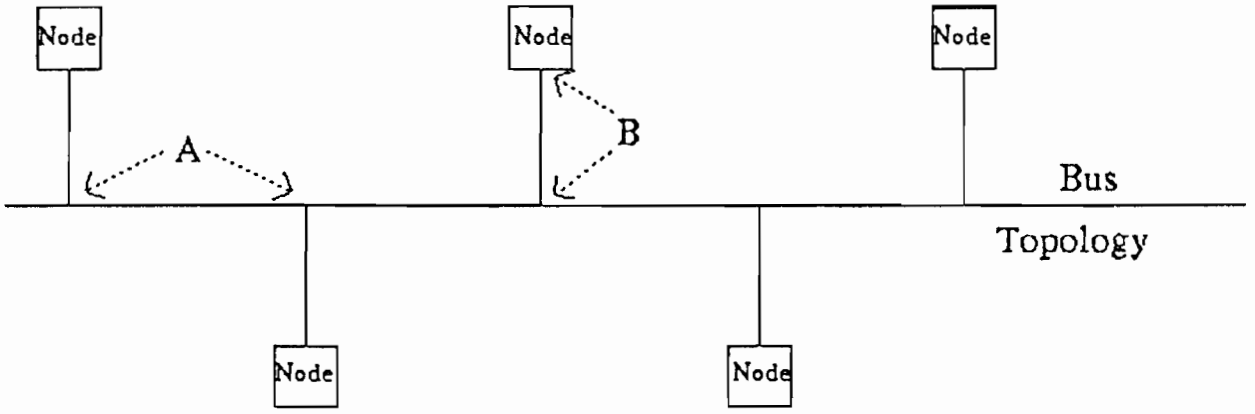

Figure 1a : Bus Topology Definitions

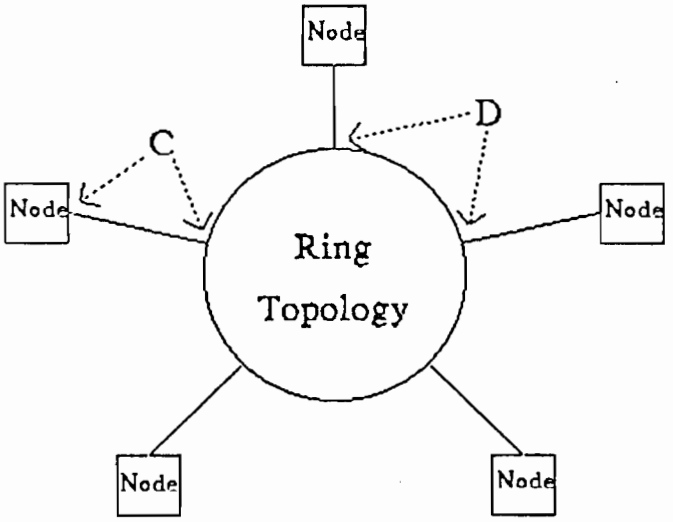

Figure 1b : Ring Topology Definitions

The LLC protocol parameters are used by the simulation to describe the model. In Table 1a, parameter #1 refers to the maximum sequence number. This is usually set to eight for eight bit sequence numbers ranging from 0 to 7. This provides a window size of eight. The repeat buffer size would then be the window size minus one. Parameter #2 is the timeout period which is the duration of timer that is started when the transmitting station transmits a frame or delivers it to the MAC layer for transmission. If this timer runs out before an acknowledgment is received then recovery procedures will be taken. Parameter #3 is the probability of a bit being an error. Parameter #4 is the number of nodes in the simulation. Parameter #5 is the line rate in megabits per second. Parameters #6 and #7 refer to the maximum and minimum packet size after overhead has been added. Packets that are not within these limits are either truncated or padded. Parameter #8 is the header of the LLC packet which is also equivalent to the supervisory frame. Parameter #9 is the time that the receiving node waits to piggyback an acknowledgment with an information packet to be sent to the original transmitting node. If this timer runs out, an explicit RR acknowledgment will be sent. This timer should obviously be much less than the timeout period of the original transmitting node. The recovery procedure is very inefficient compared to sending an explicit RR acknowledgment.

Figure 2 illustrates the functions associated with these processing times. The following parameters are the processing times which can be viewed in Table 1b. Parameters #1 and #2 of the processing times refer to the function of exchanging commands between the application layer and the link layer. An example of this might be to set up a data link to node number four or to dissolve a particular link. These type of operations are not modeled in the simulation but can be accounted for through these processing times. Parameters #3 and #4 are the processing times for transmission and reception. Parameters #5 and #6 represent the time required to receive a packet from the MAC layer and to send a packet to the MAC layer. Parameter #7 is the time required to update the LLC header for a packet to be retransmitted. Parameter #8 is the process time a received acknowledgment requires.

Parameter #9 represents the block movement of data in memory from the application layer to the LLC layer. Some studies have shown that this processing time is important. Parameter #10 is the time required to copy the packet into the repeat buffer in case retransmission is needed. Parameter #11 is the time to obtain a

packet from the repeat buffer for retransmission. Parameter #12 accounts for the time to update the supervisory frame.

Link Access Parameters

1	Window size (maximum sequence number).	(integer)
2	Timeout period.	(μS)
3	Probability of a bit being in error.	(real)
4	Number of network nodes.	(even integer)
5	Line rate.	(Mbps)
6	Maximum packet size.	(bits)
7	Minimum packet size.	(bits)
8	Overhead bits per pkt, also S-frame size.	(μS)
9	Acknowledgement timeout period at receiver.	(μS)

Table 1a: Link Access Parameters

Link Access Protocol Processing Times

1	Appl. layer receiving commands from LLC.	(μS)
2	Appl. layer sending commands to LLC.	(μS)
3	Transmission of any frame.	(μS)
4	Reception of any frame.	(μS)
5	Receive packet from media access layer.	(μS)
6	Send packet to media access layer.	(μS)
7	Information frame processing or decoding.	(μS)
8	Process received acknowledgements.	(μS)
9	Block movement of data within memory	(μS)
10	Enqueue packet to the repeat buffer.	(μS)
11	Dequeue packet from the repeat buffer.	(μS)
12	Prepare/send supervisory frame.	(μS)

Table lb: Link Access Processing Times for LLC Simulation

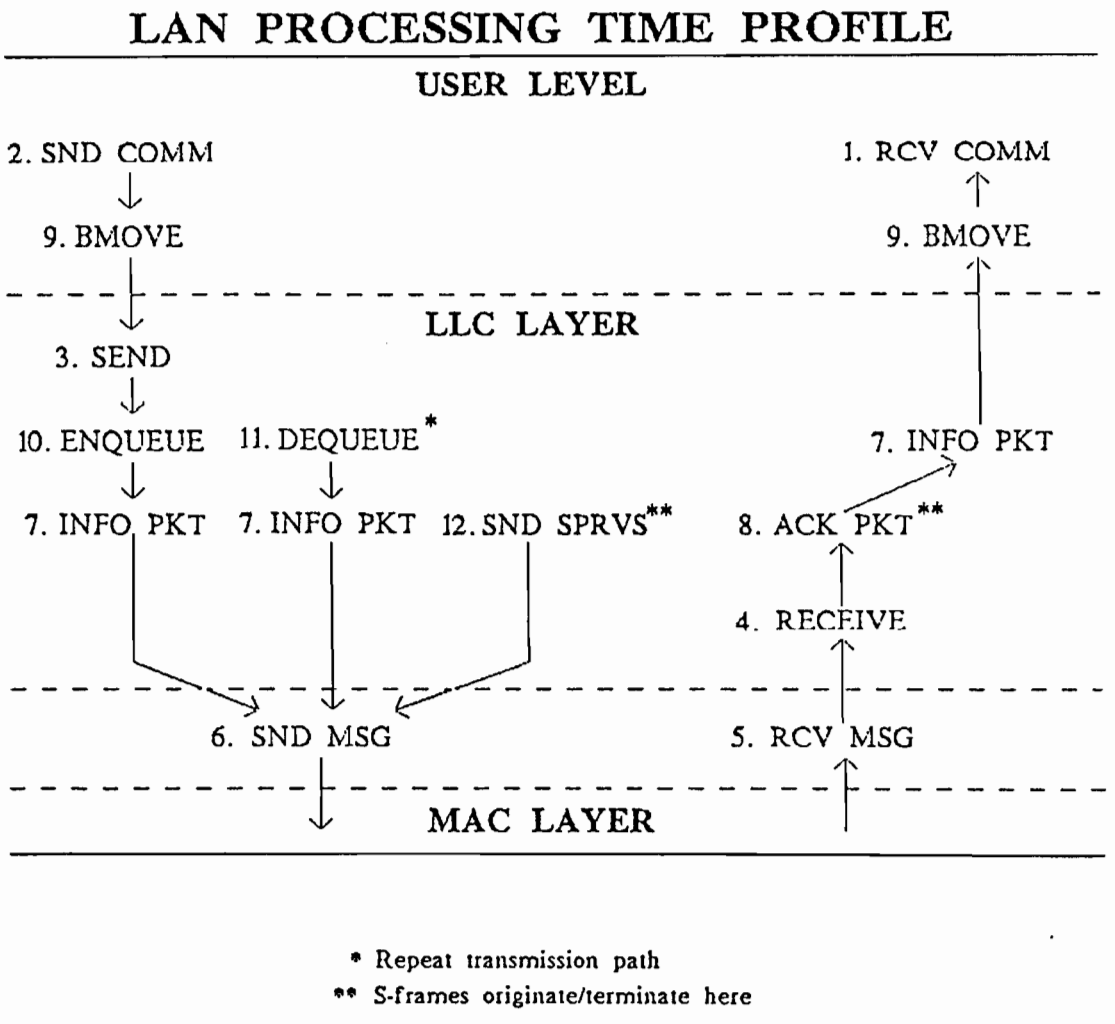

Figure 2 : Functions associated with LAN processing times

2.3 MAC CSMA-CD MODEL

The media access parameters for this particular protocol are described below and may be viewed on Table 2. Parameter #1 is the ratio of the velocity of the signal to the velocity of light in free space. This is used to specify the topology and link distances in the individual node specifications as distances in meters. Using this information, these distances can be converted into time delays to be used in the simulation. Parameter #2 is the line rate in megabits per second. Parameter #3 is the maximum number of collisions a packet can received before being discarded by the simulation. Parameter #4 is the maximum number to be used for this particular backoff scheme. Once a collision occurs, a random number is chosen from a uniform distribution. This distribution is from one to two to the power N. The value of N is increased as the number of collisions increases for that packet. The value of N may only increase until it reaches the specified backoff limit. Once this limit is reached, the packet is discarded. This scheme used to calculate the backoff time is known as binary exponential backoff which is random strategy to avoid repeat collisions as shown previously. Parameter #5 is the time a node waits to transmit after the node senses that the bus is done being used. Parameter #6 is the duration of the jam signal that is sent over the bus by a node that senses a collision on the bus. This signal is of the order of a few bits to indicate to other network nodes that a collision has occurred. Parameter #7 is the incremented time for the backoff that a node waits after a collision. This slot time should be at least twice the end to end bus propagation delay. Parameters #8 and #9 are the maximum and minimum packet sizes and are enforced after the overhead has been added. Packets that are too large are truncated and packets that are too small are padded. Parameter #10 is the number of overhead bits per packet.

Media Access Parameter

1	Velocity of media as fraction of light speed.	(real)
2	Line rate.	(μbps)
3	Maximum number of collisions.	(02)
4	Backoff limit	(integer)
5	Interframe spacing.	(μS)
6	Jam time.	(μS)
7	Slot time.	(bits)
8	Maximum packet size.	
9	Minimum packet size.	(bits)
10	number of overhead bits per packet.	(bits)

Media Access Protocol Processing Times

1	Sensing.	(μS)
2	Collision.	(μS)
3	Cyclic Redundancy Check (CRC).	(μS)

Table 2: Media Access Parameters for the MAC CSMA-CD Simulation

2.4 MAC TOKEN RING MODEL

The Media Access Parameters and Processing Times for the TOKEN RING Model can be viewed below in Table 3. The following parameters are in Table 3a. Parameter #1 is the ratio of the velocity of the signal to the velocity of light in free space. Parameter #2 is the line rate or channel bit rate which is specified in megabits per second. Parameter #3 is the probability of a bit being an error which allows the user to specify the channel bit error rate. Parameter #4 is the length of the MAC start of frame sequence in bits. This length is also the same for the end of frame sequence.

The "Address Field Length" or parameter #5 is the sum of the lengths of the source address, destination address, and access address. Parameter #6 is the length of a MAC packet's CRC field in bits. Parameter #7 is the length of a MAC token in bits as well as the size of the MAC latency buffer. This will be discussed briefly later. Parameter #8 allows specification of the MAC abort frame length in bits.

The "Maximum Packet Size", also parameter #9, is the maximum length of a packet once overhead has been added. If a packet is too large, it will be truncated to this specified size. The last three parameters set the timeout values of the various timers for the token ring MAC.

The processing times in Table 3b are for the TOKEN RING Simulation. The first processing time is the station hardware latency. This latency is the delay a bit experiences when passing through the hardware of a station on the ring in microseconds. The second latency is the amount of time required for a station to generate a free token after modifying its priority stacks in the TX ZEROS & MODIFY STACKS protocol state in microseconds.

Media Access Parameters

1	Velocity of media as fraction of light speed.	
2	Line rate.	(Mbps)
3	Probability of a bit being in error.	(real)
4	Start and end of frame sequence length.	(bits)
5	Address field length	(bits)
6	CRC field length.	(bits)
7	Token length.	(bits)
8	Abort frame length.	(bits)
9	Maximum packet size.	(bits)
10	Valid TX timer TVX timeout period.	(μS)
11	Return to repeat timer TRR timeout period.	(μS)
12	Token holding timer THT timeout period.	(μS)

Table 3a: Media Access Parameters for the MAC Token Ring

Media Access Protocol Processing Times

1	Station hardware latency.	(uS)
2	Priority modification latency.	(uS)

Table 3b: Media Access Processing Times for the MAC Token Ring.

2.5 MAC TOKEN BUS MODEL

The purpose of this section is to provide an overview of the GLAS model of the token bus. The ANSI/IEEE 802.4 token bus [IEEE85b] contains a complete description of this MAC protocol and will not be repeated here. The token passing bus includes provisions for establishment and re-establishment of the logical ring in the case of a catastrophic error. The GLAS model is concerned with only the steady state operation of the network where the logical ring has already been established. The GLAS model does allow for lost tokens due to errors. The optional priority mechanism is modeled. The MAC parameters for the token bus are given in Table 4a; the timer values and hardware latencies are shown in Table 4b.

The station hardware latency represents the time it takes a station to process and retransmit a received packet or token. The priority processing times represent the additional latency involved in handling each priority. The token bus priority algorithm requires four timer values. The high priority token holding time is the interval allocated to each station to send packets of the highest priority class. Each of the three lower classes are assigned a target-token-rotation time (TTRT). Each station measures the time it takes for the token to return to the lower priority queue; if this time is less than the TTRT for the lower priority packet, then the station is allowed to transmit packets of that priority class.

Media Access Parameters

1	Velocity of media as fraction of light speed.	(integer)	
2	Line rate.	(Mbps)	4.000
3	Probability of a bit being in error.	(real)	0.000
4	Start and end of frame sequence length.	(bits)	16
5	Address field length.	(bits)	40
6	CRC field length.	(bits)	32
7	Token length.	(bits)	24
8	Abort frame length.	(bits)	16
9	Maximum packet size.	(bits)	12144
10	Priority option?	(y/n)	N
11	Return to repeat timer TRR timeout period.	(uS)	10.00E+04

Table 4a: Media Access Parameters for the MAC Token Bus

Media Access Protocol Processing Times and Timer Values

1	Station hardware latency.	(uS)	0.000
2	High priority token hold time	(uS)	1.000E+3
3	Priority 4 token rotation time.	(uS)	4.000E+3
4	Priority 2 token rotation time.	(uS)	2.000E+3
5	Priority 0 token rotation time.	(uS)	1.000E+3
6	Packet Priority 6 processing time.	(uS)	0.000
7	Packet Priority 4 processing time.	(uS)	0.000
8	Packet Priority 2 processing time.	(uS)	0.000
9	Packet Priority 2 processing time.	(uS)	0.000

Table 4b: Media Access Protocol Processing Times and Timer Values

2.6 PRIORITY SPECIFICATION OPTION

The priority specification option is available for the token ring and token bus models. This option is specified in the node specifications and can be viewed in Table 5. The MAC models have the capability of specifying mixed message priorities. This entails specifying a certain percentage of packets generated to be at a given priority. The priorities available are 0, 2, 4, and 6. With this selection, every packet generated at that node will have that chosen priority.

The integrated token ring and bus models have only the node priorities. There is no option for specifying mixed message priorities. The choices available to the user are 0, 2, 4, and 6. As described, MAC models every packet generated at that node will be sent to the chosen priority. There will then be no message priority distribution window since the integrated models are said to have node priority.

Node # 1

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length before overhead.	(bits)	1024
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	10
5	Message priority	(MIXED, 0,2,4,6)	MIXED
6	LINK DISTANCE.	(METERS)	0.000
7	Bus distance to following node if appl.	(meters)	0.000
8	Interarrival time distribution.		EXPON (XMEAN)
9.	-- Mean interarrival time.	(uS)	4.266E+05

Message Priority Distribution for Node # 1

Field	Description		Value
6	Fraction of messages with high priority.	(real)	.6000
4	Fraction of messages with priority 4.	(real)	.3000
2	Fraction of messages with priority 2.	(real)	.1000
	Fraction of messages with lowest priority.	(real)	0.0000

Table 5: Priority Parameters for the Token Ring and Bus

2.7 INTEGRATED MODELS

The integrated protocols involve the LLC parameters and processing times for each of the integrated models. These LLC parameters and processing times are equivalent to those described in Section 2.2. The MAC parameters and processing times used in the simulation will be the same as the MAC values for the chosen model as explained above. One difference is that the Integrated CSMA-CD has MAC processing times, whereas this was not the case for the nonintegrated CSMA-CD. These processing times can be viewed in Table 6. All of the other models are a combination of the parameters and processing times for the integrated simulations. Some of the LLC parameters will be specified in the MAC parameters of the integrated versions. All of these specifications are listed in the above mentioned tables and are illustrated in Figure 2.

LAN topology of the integrated models is limited by the node pair requirements of the LLC model; all nodes must be connected in pairs to communicate. Therefore, all of the integrated models have paired nodes since these models use the LLC protocol.

Node characteristics may be specified as in the LLC model, except that the propagation delay is replaced by link and bus distances as in the MAC model.

Media Access Parameter

1	Velocity of media as fraction of light speed.	
2	Line rate.	(integer)
3	Maximum number of collisions.	(integer)
4	Backoff limit.	(integer)
5	Interframe spacing.	(uS)
6	Jam time.	(uS)
7	Slot time.	(uS)
8	Maximum packet size.	(bits)
9	Minimum packet size.	(bits)
10	Number of overhead bits per packet	(bits)

Media Access Protocol Processing Times

1	Sensing	(uS)
2	Collision.	(uS)
3	Cyclic Redundancy Check (CRC).	(uS)

Table 6: Media Access Parameters and Processing Times for the INTEGRATED LLC & CSMA-CD Simulation.

3.0 OPERATING THE USER INTERFACE

3.1 SIGN-ON

3.1.1 Referencing the Program

The executable file for the interface program is at the University of Kansas TISL Laboratory. This file may be run from any directory. If the user does not have write privileges to the current directory, then the program requests a directory name for input and output files; the user's home directory may be selected by default.

3.1.2 Protocol Selection

When the program is being run, the user is first prompted for the type of protocol to model. The choices are LLC, MAC CSMA-CD, MAC TOKEN RING, MAC TOKEN BUS, INTEGRATED LLC & CSMA-CD, INTEGRATED LLC & TOKEN RING, INTEGRATED LLC & TOKEN BUS as described in the previously sections.

3.1.3 Input File Selection

The program next requests a file name for default LAN parameters. This file should be one created by the program in a previous session. It defines the current LAN characteristics which may then be examined and altered. If this selection is defaulted, then the program uses the most recent LAN model (if it exists) or the internal program settings.

The files created by the program are described in the following section. Files for a particular LAN model are saved under one file name with different extensions. The parameter file referred to above is stored with the extension ".dat".

3.2 MAIN MENU

The main menu has five options for the user; they are described below. For normal use, the user will enter the main menu, change simulation parameters (option 1), return to the main menu, and exit the program (option 4). These parameters are saved when exiting using option 4.

3.2.1 Change current simulation parameters

This option allows the user to examine and alter the current LAN model parameters. When this option is selected, the user enters the 'page menu' which allows access to the parameters. This option is discussed further in section 3.3.

3.2.2 Save current simulation parameters

This option creates four files from the current LAN model parameters. Three of the files are prepared for the batch simulation run; one is a parameter listing for the user reference and for input to the user interface as described in section 3.1. The created files share a common file name but have different extensions.

When this option is selected, the user is informed of the expected traffic intensity of the LAN model. For the MAC simulation the offered load at the MAC level is reported. The packet lengths used in this calculation include the MAC overhead bits. For the LLC and the Integrated simulations, the offered load at the user level is reported. This figure does not include lower level overhead. For the LLC simulation, the offered load of each half duplex link is reported separately. The user is then given the choice of proceeding or revising the simulation parameters. If the expected traffic intensity is greater than one, then the user is forced to revise the LAN model.

After the offered load is approved, the user is informed of the average number of packets that will be generated by each network node during one simulation run. The user is then offered the chance to revise the simulation model. If too few packets will be generated during the simulation, then the user should increase the simulation time (section 3.3.1).

The user is next prompted for comments to insert in the parameter file. These comments appear at the top of the parameter file for the user reference. This option may be skipped if desired. If the old parameter file was used as input to the simulation, then the user is also given the option of copying comments from this file to the new parameter file.

Once the offered load and simulation time have been approved by the user and any desired comments have been entered, then the program creates four files from

the simulation parameters. The file name used is either 'lastlapllc', 'lastmaccsm', 'lastmacrng', 'lastmacbus', 'lastintcsm', 'lastintrng', or 'lastintbus' depending on the protocol model in use. For example, if the integrated CSMA-CD protocol was being used, the following files would be created:

lastintcsm.dat : parameter listing
lastintcsm.drv : SLAM driver file for simulation

The 'lastintcsm.dat' file would (by default) supply the program with initial LAN model parameters for the next session.

The user is next given the option of renaming current experiment's files. This option creates four files (as above) with a user specified file name. Since the 'last' files are overwritten whenever files are saved, this option is recommended. For example, if the user responds with the file name 'StarLan', then the files 'StarLan.dat', 'StarLan.com', 'StarLan.dvr', and 'StarLan.f' would be created. The user may create as many copies of the files as desired. When the user chooses not to create any more files, the program returns to the main menu.

3.2.3 Load new default parameter file

This option prompts the user for a new default parameter file as described in section 3.1. If any changes have been made to the current parameters, then the program first saves files as described above.

3.2.4 Exit program

This option simply ends the program. If any changes have been made to the current simulation, then the program first saves the files as described above. The program then gives a short set of instructions to run the simulation.

3.2.5 Exit program without saving model

This option also ends the program. The user is prompted once to verify that the current model will be lost.

3.3 PAGE MENU

Option #1 of the main menu, 'Change current simulation parameters', activates the page menu. The parameters of the simulation are grouped into pages which are accessed through this menu. The first page of parameters is always 'General Simulation Controls' and the last page is always 'Individual Node Specifications'. These two pages are listed in Tables 7 and 8.The other pages on the menu list parameters particular to the protocol model being used. These pages are listed in Tables 1 through 6. To change LAN simulation parameters, see section 3.4.

3.3.1 General Simulation Controls

The general simulation parameters are listed in Table 7. Parameters #1 and #2 are used for the simulation output heading. This heading may be used to help identify output files, in addition to the file names used. Parameters #3, #4, #5, and #6 are currently set to generate concise output and suppress long listings of statistics. Parameter #8 defines the number of identical runs performed by the simulation to obtain statistics. Ten runs are considered sufficient; twenty is maximum number allowed. Parameter #9 should be set to allow the LAN nodes to generate sufficient traffic during the simulation. Parameter #10 defines the set-up time for each subrun. During the set-up time, no statistics are recorded to avoid misleading results from initial conditions in the LAN. For a more detailed description of these controls, see [4]. (These parameters are used to form the SLAM II 'GEN' statement.)

3.3.2 Individual Node Specifications

The first option lists an overview of the LAN nodes and their parameters. Nodes are listed in numerical order according to their place on the LAN bus. Options #3 through #7 facilitate adding or deleting nodes.

Option #2 allows direct access to the parameters of the individual nodes. The program requests the number of the node to examine. If this node does not exist, then a node is created and added to the system. The nodes' parameters are displayed and may be altered as described in the following section.

Options #8 and #9 are used to set up homogeneous systems. When option 8 is selected, the user may change the default specifications for the system nodes. Option

#9 allows any or all of these parameters to be applied to the system nodes. For example, option #8 could be used to set the default message length to 4096 bits. Option #9 could then be used to set all nodes' message length to 4096 bits.

3.4 CHANGING PARAMETER VALUES

Parameters may be changed when a specific page or node is viewed. First, type the field number of the parameter to change in response to the program's prompt. The program will then request the new value for the parameter. Enter the new value and type return. If the new value is valid, the program re-displays the current page or node. If an invalid parameter value is entered, then the program prints an explanation and waits for a correct value.

Note that in all cases, the program gives you the option of canceling the current operation. (A carriage return is always a safe entry.) Once a parameter's value has been changed, however, the old value is not recoverable. The example session in section 6.0 demonstrates how to interactively change parameter values.

General Simulation Controls

Field	Description		Default
1	Analyst's Name	(up to 20 characters used)	U of K TISL
2	Project title.	(up to 20 characters used)	Lapd Model
3	Print SLAM input listing?	(y/n)	N
4	Print SLAM echo summary report ?	(y/n)	N
5	Attempt execution?	(y/n)	Y
6	Print SLAM summary report?	(y/n)	N
7	Confidence interval for output tabulation.	(%)	95
8	Number of simulation subruns.	(Integer)	10
9	Time for each subrun.	(uS)	15.00E+06
10	Set-up time as percent of run-time.	(%)	10.00
11	Abort if an application layer queue fills?	(y/n)	N

Table 7: General Simulation Controls

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Table 8: Individual Node Specifications.

4.0 INTERPRETING SIMULATION OUTPUT

4.1 STATISTICS

The reported statistics for each performance measure are its average value, the confidence interval of the mean, and the standard deviation of the mean. The average value is the mean of the measurements from all simulation subruns. The confidence interval and the standard deviation refer to the accuracy of this average. The confidence interval is calculated according to the value specified for 'Confidence Interval for Output Tabulation' on the 'General Simulation Controls' page of parameters. The default is a 95% confidence interval.

Statistics are calculated as 'average' or 'total' measures. 'Average' measures are averaged over the number of measurements taken. 'Total' measures report the sum of measurements during the simulation. For example, the MAC performance measure 'Avg Packet Transmission Time' is averaged over the number of packets transmitted during the simulation. The MAC performance measure 'Total Collisions' reports the total number of collisions during the simulation. Unless described with the word 'total', all performance measures are 'average' measures.

Statistics are further divided into 'global' and 'node' measurements. The first output page lists global performance measures for the network; following pages list measurements for the individual nodes. 'Global' measures are taken over all system nodes during the simulation; these results are averaged for the final output as described above. 'Node' measures are taken for a specific node during the simulation.

For example, the MAC performance measure 'Total Collisions' listed under 'MAC GLOBAL NETWORK PERFORMANCE' reports the average over the simulation of the total number of collisions experienced by all of the LAN nodes. The 'Total Collisions' measure listed under 'NODE #1 MAC NETWORK PERFORMANCE' reports the average over the simulation of the total number of collisions experienced by node #1. The confidence interval and standard deviation reported for both these measures refer to the accuracy of the reported means.

4.2 PERFORMANCE MEASURES

The simulation results are presented in tables of performance measures as described above. An example of the Integrated CSMA-CD simulation output for the 'GLOBAL NETWORK PERFORMANCE' and 'NODE #1 NETWORK PERFORMANCE' is shown in Figure 4 and 5, respectively.

Definitions of the performance measures are given below. Refer to Figure 3 for delay related measures. As described above, the measures reported for the individual nodes are measured over packets generated by those nodes. Measures appearing on the 'GLOBAL NETWORK PERFORMANCE' page are measured over all packets. Definitions for the performance measures are as follows:

LAN PERFORMANCE MEASURES PROFILE

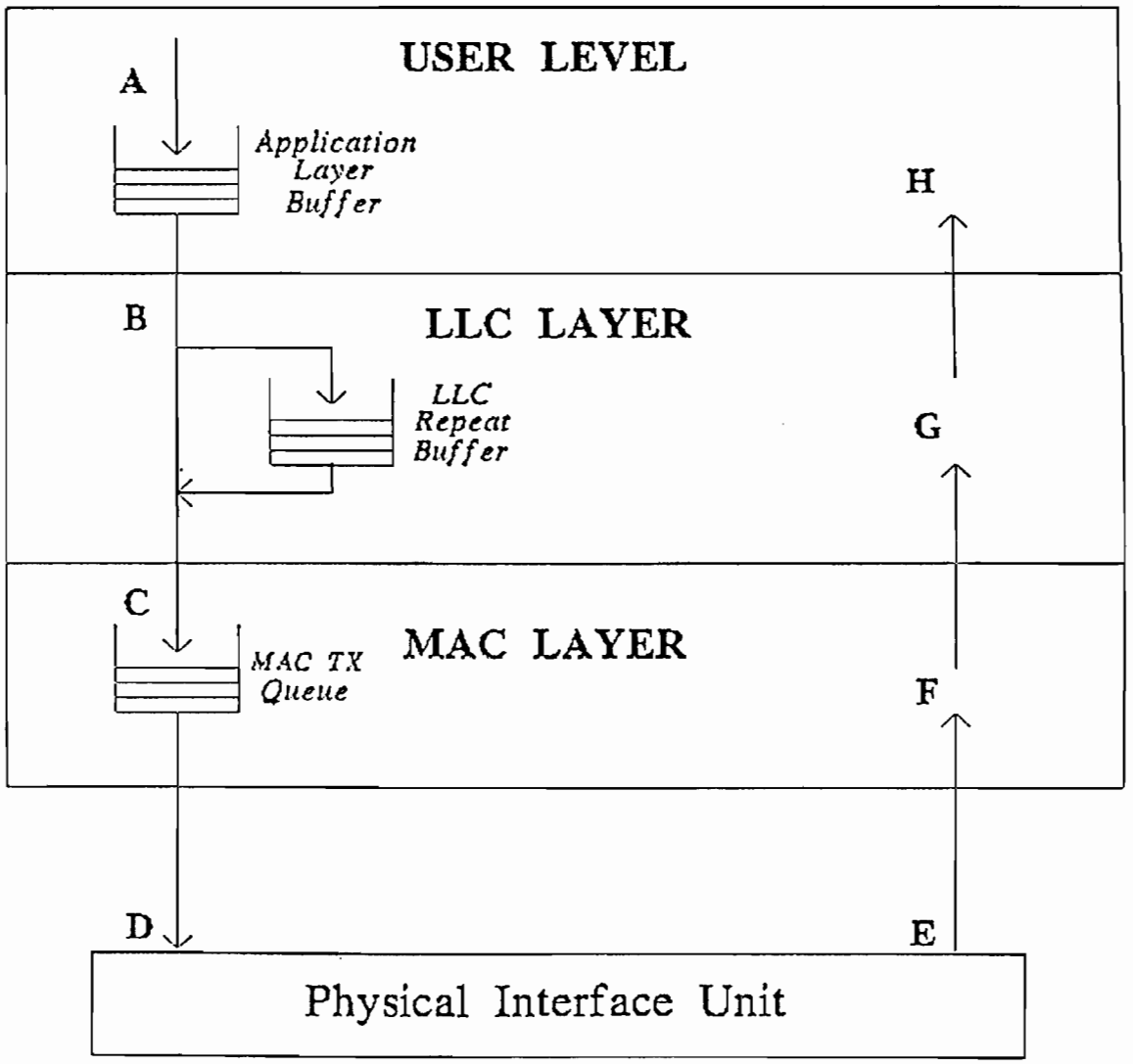

Figure 3 : Schematic of LAN Layers for definitions of output measures. Note that the Application Layer Buffer and LLC Repeat Buffer are of user-specified length; the MAC TX Queue has infinite capacity.

LLC PERFORMANCE MEASURES

End-to-End Delay	: Average end-to-end delay at the user level. Measured for I-Frame only. (from A to H in Figure 4.)
User to LAP Queue Delay	: Average time from I-Frame creation to arrival at the LLC layer. (from A to B in Figure 4.)
User to MAC Queue Delay	: Average time from I-Frame creation to arrival at the MAC layer. (From A to C in Figure 4.)
Avg Total LAP Delay	: Average end-to-end delay at the LLC layer. Measured for I-Frames only. (from B to G in Figure 4.)
Repeat Buffer Holding Time	: Average time that an I-Frame is stored in the LLC repeat queue waiting for a positive acknowledgment to be received.
Avg # of Packets in System	: Average number of packets in the system.
Average Message Size	: Average number of bits per I-Frame.
Total Packets Transmitted	: Total number of transmitted packets and also includes re-transmissions.
Total Packets Generated	: Total number of original information packets only. Number of packets entering A in Figure 3.
Total Re-transmitted I-Frames	: Includes re-transmissions due to timeouts and out-of-sequence packets.
Total Timeouts Resulting in Re-transmissions	: Total times that a timeout occurred and the RR polling mechanism determines that a re-transmission was necessary.
Total Out-of-Sequence Packets	: Total number of packets received out-of-sequence.
Total Packets Discarded due to Transmission Errors	: Total number of CRC errors.

Total RR-Frames Transmitted : Includes non-piggybacked acknowledgments and error recovery polling frames.

Total REJ-Frames Transmitted : Total number of reject frames transmitted.

Total Timeouts : Total number of timeouts summed over all nodes.

Total LLC Throughput : Fraction of time sending successful (error free, in sequence) information bits. This includes LLC overhead, but does not include any retransmissions, etc.

MAC PERFORMANCE MEASURES for the CSMA/CD

Avg Total MAC Delay : Average end-to-end delay in the MAC layer. Reported for I-Frames, S-Frames, and all frames.(from C to F in Figure 4.)

Avg MAC Access Time : Average delay from entry to the MAC layer to the start of a successful transmission. Includes delays from collisions. Reported for I-Frames, S-Frames, and all frames.(from C to D in Figure 4.)

Avg Packet Transmission Time : Average frame transmission time. Includes all frames. Note that I-Frame or S-Frame transmission time can be calculated from average packet lengths and the line rate. (from D to E in Figure 4.)

Total Collisions : Number of collisions experienced by the packets transmitted by a node. For 'GLOBAL NETWORK PERFORMANCE', this quantity is summed over all the network nodes.

Total Discarded Packets : Packets discarded due to excessive collisions.

Total Media Throughput : Fraction of time sending bits that did not experience collisions. This includes time for packets with transmission errors since error recovery is in a Link Level function.

MAC PERFORMANCE MEASURES for the TOKEN RING

(Note all performance statistics are defined

both on a global and per priority class basis)

Avg Total MAC Delay	: Average end-to-end delay in the MAC layer. Includes MAC queuing delay and transmission time. Reported for all frames. (from C to F in Figure 4.)
Avg MAC Queue Delay	: Amount of time packets spend in the MAC queue. Reported for all frames.
Avg Effective Service Time	: Amount of time that elapses from a packet's removal from the MAC queue until the packet has arrived at the destination station. Reported for all frames.
Total Media Throughput	: Fraction of time sending bits that did not experience collisions. This includes time for packets with transmission errors since error recovery is in a Link Level function.
Total Correct Transmissions	: Number of packets transmitted without receiving bit errors.
Total CRC Errors	: Total number of packets that arrived at the destination address and were marked as having a CRC error.
Total Address Errors	: Indicates how many packets had destination address errors.
Total Packets Left in Queues	: Indicates the number of packets still queued in the MAC layer after the simulation is completed.
Total Packets Offered to MAC	: Total number of packets offered to the MAC layer from the application layer.
Total Timer THT Delayed TX	: Indicates the number of times the token holding timer, THT, caused a data transmission to be terminated.

Total Timer TVX Expirations	: Number of times the TVX expires.
Total Tokens Claimed for TX	: Number of times a node claims the token to transmit.
Total Tokens Claimed for Priority Modification	: Number of times the token is claimed to make priority modifications.
Total Token Errors	: Total number of token errors throughout the network during the simulation.
Total MAC Purge Frames TX	: Number of MAC purge frames sent to clean up the token in the network.

MAC PERFORMANCE MEASURES for the TOKEN BUS

(Note all performance statistics are defined

both on a global and per priority class basis)

Avg Total MAC Delay	: Average end-to-end delay in the MAC layer. Includes MAC queueing delay and transmission time. Reported for all frames (from C to F in Figure 4.
Avg MAC Queue Delay	: Amount of time packets spend in the MAC queue. Reported for all frames.
Avg Effective Service Time	: Amount of time that elapses from a packet removal from the MAC queue until the packet has arrived at the destination station. Reported for all frames.
Total Media Throughput	: Fraction of time sending bits that got through the MAC layer. This includes time for packets with transmission errors since error recovery is in a Link Level function.
Total Packets Offered to MAC	: Total number of packets offered to the MAC layer from the application layer.
Total Packets Thrown Away by MAC	: Total number of packets thrown away as the buffers were full at times when packets were offered to MAC.
Total Packets Taken by MAC	: Total number of packets taken in by the MAC layer which is the difference of the

number of packets offered to MAC and the number of packets thrown away.

Total Correction Transmissions: : Number of packets transmitted without receiving bit errors.

Total Packets Left in Queues : Indicates the number of packets still queued in he MAC layer after the simulation is completed.

Total Tokens Claimed for TX : Number of times the token is claimed by a node to transmit packets.

Total CRC Errors : Total number of packets that arrived at the destination address and were marked as having a CRC error.

Total Token Errors : Number of times the Token has been in error and had to be regenerated at a node throughout the network during a simulation.

U of K TISL
Example Output

Global Network Performance
Mac Performance Measures

Parameter	Average	C.I.	S.D.
Avg. Total MAC Delay: All Pkts	324.2 uS	±1.590	4.371
Avg. Total MAC Delay: I-Frames	542.9 uS	±1.912	5,256
Avg. Total MAC Delay: S-Frames	105.5 uS	±1.795	4.934
Avg MAC Access Time: All Pkts	58.17 uS	±1.520	4.179
Avg MAC Access Time: I-Frames	62.02 uS	±1.759	4.835
Avg MAC Access Time: S-Frames	54.32 uS	±1.795	4.934
Avg Packet Transmission Time	266.0 uS	±3.710	.0000
Total Collisions	125.7	±3.710	10.20
Total Discarded Packets	0.000	±.0000	.0000
Total Media Throughput	102.2 E-3	±.8280 E-3	2,277 E-3

Lap Performance Measures
(I-Frames only unless otherwise specified.)

Parameter	Average	C.I.	S.D.
END-to-END Delay	542.9 uS	±1.912	5.256
User to LAP Queue Delay	0.000 uS	±.0000	.0000
Avg. Total LAP Delay	542.9 uS	±1.912	5.256
Repeat Buffer Holding Time	648.4 uS	±3.180	8.743
Average # Packets in System	830.9 E-3	±762.1 E-3	2095. E-3
Average Message Size (bits)	4.984 E+3	±.0240 E+3	.0650 E+3
Total Packets Transmitted	2.593 E+3	±.0200 E+3	.0550 E+3
Total Packets Generated	2.593 E+3	±.0200 E+3	.0550 E+3
Total Re-transmitted I-Frames	0.000	±.0000	.0000
Total Timeouts Resulting in Re-transmissions	0.0000	±.0000	.0000
Total Out-of-Sequence Packets	0.0000	±.0000	.0000
Total RR-Frames Transmitted	2.583 E+3	±.0200 E+3	.0550 E+3
Total REJ-Frames Transmitted	0.0000	±.0000	.0000
Total Timeouts	0.0000	±.0000	.0000
Total LLC Throughput	87.44 E-3	±.7220 E-3	1.986 E-3

Figure 4: Example of Global Output Page for the Integrated CSMA-CD Simulation

NODE # 1 Network Performance

MAC Performance Measures

Parameter	Average	C.I.	S.D.
Avg. Total MAC Delay: All Pkts	326.0 uS	±9.780	26.89
Avg. Total MAC Delay: I-Frames	547.4 uS	±16.66	45.79
Avg. Total MAC Delay: S-Frames	112.8 uS	±3.917	10.77
Avg. MAC Access Time: All Pkts	63.40 uS	±6.620	18.20
Avg. MAC Access Time: I-Frames	64.87 uS	±11.10	30.50
Avg. MAC Access Time: S-Frames	61.61 uS	±3.917	10.7
Avg. Packet Transmission Time	262.6 uS	±5.259	14.46
Total Collisions	76.10	±6.143	16.89
Total Discarded Packets	0.000	±.0000	.0000
Total Media Throughput	4.152 E- 3	±.1610 E- 3	.4430 E- 3

Lap Performance Measures
(I-Frames only unless otherwise specified.)

Parameter	Average	C.I.	S.D.
END-to-END Delay	547.4 uS	±16.66	45.79
User to LAP Queue Delay	0.000 uS	±.0000	.0000
Avg. Total LAP Delay	547.4 uS	±16.66	45.79
Repeat Buffer Holding Time	658.2 uS	±22.58	62.07
Average Message Size (bits)	4.924 E+ 3	±.1770 E+ 3	.4860
Total Packets Transmitted	104.7	±3.907	10.74
Total Packets Generated	104.7	±3.907	10.74
Total Re-transmitted I-Frames	0.000	±.0000	.0000
Total Timeouts Resulting in Re-transmissions	0.000	±.0000	.0000
Total Out-of-Sequence Packets	0.0000	±.0000	.0000
Total Packets Discarded Due to Transmission Errors	0.000	±.0000	.0000
Total RR-Frames Transmitted	108.5	±3.078	8.462
Total REJ-Frames Transmitted	0.0000	±.0000	.0000
Total Timeouts	0.0000	±.0000	.0000
Total LLC Throughput	3.541 E- 3	±.1480 E- 3	.4060 E- 3

Figure 5: Example of Node Output Page for the Integrated CSMA-CD Simulation

4.3 ANALYTICAL MODELS

When the save model option is invoked from the main menu an estimate of load and number of packets at each node is given. If the user is setting up a mac level only simulation a prompt appears asking the user if an analytical estimate of delay is desired. If the question is answered no the model is saved, if the question is answered yes an estimate of the total delay (see 4.2 Performance Measures) is given along with an estimate of of the standard deviation of the total delay of a packet. The option of returning to revise parameters is then given, if answered no a copy of of the analytic estimate will eventually be written to a file with the same name as the parameter file but with the extension .est.

The analytical model can be used to help determine if a network needs to be simulated in complete detail. The analytical model considers many of the parameters used by GLAS but not all of them. If complete detail is desired a simulation must be run, but a first approximation using the analytical model may eliminate the need to simulate some of the networks being considered. The modeling parameters used in the analytical estimate as well as the assumptions made are described below. The token ring and token bus use almost identical models and will be described together. The CSMA/CD analytical model will be described first.

The CSMA/CD analytical estimate is determined by considering the total traffic, calculating delays due to collisions, and adding queue delay, transmission time, and propagation time. Specifically, the calculations make use of the aggregate arrival rate of packets to the network, the overall average message length, the over head bits added, the line rate, the hardware constants: sensing time and jam time, the propagation time, and the inter frame spacing. Differences in individual nodes are used only in the calculation of the second and third moments of message length, but certain homogeneous assumptions are made. The arrival distributions are assumed to be exponential and the stations are assumed to be equally spaced along the bus. No consideration is given for blocking, or truncation to maximum packet lengths. The total delay estimate given by the user interface should match the total delay given in the output statistics for homogeneous networks with exponential packet lengths and interarrival times. It should be noted that the standard deviation given by the analytical model will not match the standard deviation listed in the output

parameters. This is because the analytic model gives the standard deviation of the delay for a packet, while the output lists the standard deviation of the mean after multiple subruns.

The token ring and token bus analytical models both use the same parameters for delay estimation. Both use the line velocity, the bit rate, the over head bits, the hardware latency, the moments of message length, the distance from each node to the ring/bus, the distance from each node to the next, and the aggregate arrival rate. The average queue delay is found by considering the entire network to be one queue with each node waiting to begin service. The queue delay for each packet is added to an average value of transmission time and an average value of propagation time. It is assumed for these models that all arrival rate distributions are exponential, no blocking occurs, and all packets travel halfway around the ring to their destination. GLAS simulates priority, but the analytic estimate does not take this into consideration, nor are different delays for different nodes reported. The analytical estimate is again useful for homogeneous networks, with exponential packet lengths, and interarrival times, with out priority. When these conditions are met the estimate should match the simulation total delay output statistic.

4.4 VARIANCE REDUCTION OUTPUT STATISTICS

The following should be added to 4.2 Performance measures under the titles MAC PERFORMANCE MEASURES for the CSMA-CD, TOKEN RING, and TOKEN BUS:

VR. / Avg Total MAC Delay	: This is an alternate estimate for Avg Total MAC Delay described above, available only in MAC only simulations. It is useful for obtaining smaller confidence intervals at high loads, but should be ignored for loads <0.5. See section ??? for a more complete description.
VR. \ Avg MAC Access Time	: An alternate estimate for Avg MAC Access Time described above, available only in MAC only simulations. It is useful for obtaining smaller confidence intervals at high loads, but should be ignored for loads less than 0.5.

4.5 DESCRIPTION OF VARIANCE REDUCTION PERFORMANCE MEASURES

For MAC only simulations of the CSMA-CD, Token Ring, and Token Bus protocols two estimates are given for Average Total Delay and Average MAC Access Time. The first one listed in the outputs is found by averaging the delays for individual packets in the network. The second value, denoted by VR for Variance reduction, is a hybrid estimate using some analytical calculations and some simulated values. This estimate provides a smaller confidence interval for these statistics when heavily loaded networks are simulated. The standard estimates should be used when the confidence interval from the variance reduced estimate is wider than the normal confidence interval. This will generally occur when the total network load is less than 0.5.

The hybrid simulation is best with exponentially distributed interarrival times and a homogeneous network. If non-exponential interarrival distributions are used the variance reduction estimate will only be valid for large networks. In general, if the variance reduction estimates are within the confidence interval of the standard estimates the variance reduced estimates will be valid and will provide a more accurate estimate of delays. If the variance reduced estimates lie outside of the confidence interval of the standard estimates the simulation should probably be rerun with a longer simulation time. Generally, the rerun will show the standard estimate has moved closer to the variance reduced estimate for high load homogeneous networks.

It is possible for the simulation output to report, Variance Reduction not available, rerun with longer simulation time. This message occurs when the hybrid estimate was unable to be computed because of an insufficient number of observed idle cycles, the remedy is to increase the simulation run time. Finally, it should be noted that variance reduction estimates are not valid when priority operation is occurring (Token Ring and Token Bus only).

5.0 MODELING CONSIDERATIONS

The GLAS has been extensively used and tested at the University of Kansas during its development period. Some LAN models have produced unexpected simulation results. These 'errors' were attributed to poorly modeled systems. The primary causes of these types of errors are discussed below.

5.1 UNSTABLE SYSTEMS

The application layer transmission buffer for each network node is modeled with user-specified capacity and blocking. This buffer fills only when the LLC layer blocks incoming packets. For a reasonable buffer size and a stable system, this blocking should have no effect on the simulation results. For an unstable system, this blocking will not be represented in the simulation results, although system performance measures will indicate high delays.

An option on the first page of the simulation parameters (section 3.3.1) allows the simulation to be aborted if the application layer buffer ever blocks a packet. Since a stable system may experience enough random variation to cause some blocking at the application layer, this option is usually not used. This option may be useful to limit the waste of resources in the case of a modeling error. For example, if one specifies a 0.9 offered load when a 0.09 offered load is desired.

5.2 INSUFFICIENT SAMPLING

The first page of LAN model parameters (see section 3.3.1) defines the number of simulation subruns to perform and the time to collect statistics during each run. If too few subruns are averaged by the simulation, then output performance measures may not be accurate. Errors of this type will be indicated by the confidence intervals listed with each performance measure.

Errors resulting from an insufficient observation time (the parameter 'Time for each subrun' in section 3.3.1) may not be evident from the confident intervals of the performance measures. The primary guideline for selecting the simulation time is the number of packets that will be generated by each network node. These quantities are reported by the interface before the LAN models are stored.

Delays in the system should also be considered. For example, if a two node LLC simulation is proposed with a one second delay between nodes, a ten second simulation is not expected to produce accurate results.

Insufficient sampling can usually be detected by observing the trend of performance measures for different simulations. For example, a plot of end-to-end delay versus load should follow a known pattern. These problems may be avoided by selecting a simulation time that is large relative to time-related functions

of the modeled system. The performance trade-off is in computing costs.

5.3 TRANSIENT RESPONSE

The parameter 'Set up time as percent of run-time' (see section 3.3.1) should be long enough so that output measures will represent steady state conditions. A set-up time of one-tenth the simulation time is usually more than sufficient. If the simulation is long enough, transient effects will be minimum, regardless of the specified set-up time. Any significant problems with transient will be apparent in the confident intervals of the output performance measures.

6.0 LAN MODELING EXAMPLES

A sample interactive LAN modeling sessions are shown below. The example demonstrates how to reference the program and create a LAN model. User inputs will be followed by comments inside three asterisks. Other comments will also be in this form.

The example first shows how to run the program and access the LAN parameters. The integrated LLC & CSMA-CD protocol is selected for this example. Pages of LAN parameters are viewed and some parameters are changed. The system nodes are then examined and all program functions to aid in specifying the node parameters and LAN topology are illustrated. Next, the sign-off procedure is demonstrated. Files are created to simulate the LAN model after the user has approved the current model parameters. The program is run again to show how to revise an existing LAN model.

LAN models are created in this example and stored in the file names 'sample' and 'sample2'. The files 'sample.dat' and 'sample2.dat' contain listings of LAN parameters; 'sample.dat' is listed following the example session.

$glas

Telecommunications and Information Sciences Laboratory

General LAN Analysis System

GLAS
Contact : Victor S. Frost, Associate Professor
University of Kansas
(913) 864-4833

Type <CR> to continue

Enter the number corresponding to the desired simulation model.

1. LAP LLC
2. MAC CSMA-CD
3. MAC TOKEN RING
4. MAC TOKEN BUS
5. INTEGRATED LLC & CSMA-CD
6. INTEGRATED LLC & TOKEN RING

6

Select model for simulation.

Enter the file name (without extension) for default values, or
<CR> to default the selection.

The program provided the default values.

Type <CR> to continue.

***Carriage return defaults the file selection; since this is the first run, the program chose its internal default LAN parameters. ***

MAIN MENU

Field	Description
1	Change current network parameters.
2	Save current network parameters.
3	Load new default parameter file.
4	Exit program.
5	Exit program without saving model.

Enter the field number of the desired action.

1

Access page menu to view/alter LAN parameters.

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications.

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.

1

Select page 1 to view General Simulation Controls.

General Simulation Controls

Field	Description		Default
1	Analyst's name.	(up to 20 characters used)	U of K TISL
2	Project title.	(up to 20 characters used)	LAPMAC Model
3	Print SLAM input listing?	(y/n)	N
4	Print SLAM echo summary report?	(y/n)	N
5	Attempt execution?	(y/n)	Y
6	Print SLAM summary report?	(y/n)	N
7	Confidence interval for output tabulation.	(%)	95
8	Number of simulation subruns.	(Integer)	10
9	Time for each subrun.	(uS)	15.00E+06
10	Set-up time as percent of run-time.	(%)	10.00
11	Abort if an application layer queue fills?	(y/n)	N

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

2

Change project title.

Enter new value for: Project title. (up to 20 characters used),or
<CR> to return to the menu.

Sample Run

New project title; a carriage return would have preserved the old project title

General Simulation Controls

Field	Description		Default
1	Analyst's name.	(up to 20 characters used)	U of K TISL
2	Project title.	(up to 20 characters used)	Sample Run
3	Print SLAM input listing?	(y/n)	N
4	Print SLAM echo summary report?	(y/n)	N
5	Attempt execution?	(y/n)	Y
6	Print SLAM summary report?	(y/n)	N
7	Confidence interval for output tabulation.	(%)	95
8	Number of simulation subruns.	(Integer)	10
9	Time for each subrun.	(uS)	15.00E+06
10	Set-up time as percent of run-time.	(%)	10.00
11	Abort if an application layer queue fills?	(y/n)	N

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

+

View the following page of parameters.

Media Access Parameters

Field	Description		Default
1	Velocity of media as fraction of light speed.		880.0E-03
2	Line rate.	(Mbps)	4.000
3	Start and end of frame sequence length.	(bits)	16
4	Address field length.	(bits)	40
5	CRC field length.	(bits)	32
6	Token length.	(bits)	24
7	Abort frame length.	(bits)	16
8	Maximum packet size.	(bits)	12144
9	Valid TX timer TVX timeout period.	(μS)	12.50E+03
10	Return to repeat timer TRR timeout period.	(μS)	2.500E+03
11	Token holding timer THT timeout period.	(μS)	10.00E+03

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

1

Enter new value for: Velocity of media as fraction of light speed, or
<CR> to return to the menu.

Change the velocity of the media.

1.5

Invalid entry; upper bound is .100E+01.

Illegal entry; upper bound is 1.0

Enter new value for: Velocity of media as fraction of light speed, or
<CR> to return to the menu.

1

A carriage return would still have preserved the old value.

Media Access Parameters

Field	Description		Default
1	Velocity of media as fraction of light speed.		1.000
2	Line rate.	(Mbps)	4.000
3	Start and end of frame sequence length.	(bits)	16
4	Address field length.	(bits)	40
5	CRC field length.	(bits)	32
6	Token length.	(bits)	24
7	Abort frame length.	(bits)	16
8	Maximum packet size.	(bits)	12144
9	Valid TX timer TVX timeout period.	(μS)	12.50E+03
10	Return to repeat timer TRR timeout period.	(μS)	2.500E+03
11	Token holding timer THT timeout period.	(μS)	10.00E+03

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

+

Media Access Protocol Processing Times

Field	Description		Default
1	Station hardware latency.	(µS)	0.000
2	Priority modification latency.	(µS)	0.000

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

1

Enter new value for: Station hardware latency. (µS), or
<CR> to return to the menu.

0.4e3

Media Access Protocol Processing Times

Field	Description		Default
1	Station hardware latency.	(uS)	400.0
2	Priority modification latency.	(uS)	0.000

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

2

Enter new value for: Priority modification latency.(uS), or
<CR> to return to the menu.

0.2E3

Media Access Protocol Processing Times

Field	Description		Default
1	Station hardware latency.	(μS)	400.0
2	Priority modification latency.	(μS)	200.0

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

+

Link Access Parameters

Field	Description		Default
1	Window size (sequence number range).	(integer)	8
2	Timeout period.	(uS)	1.000E+06
3	Probability of a bit being in error.	(real)	0.000
4	Number of network nodes.	(even integer)	10
5	Overhead bits per pkt, also S-frame size.	(bits)	48
6	Acknowledgment timeout period at receiver.	(μS)	0.000

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

+

Chose not to change these parameters; view next page.

Link Access Protocol Processing Times

Field	Description		Default
1	Appl. layer receiving commands from LLC.	(μS)	0.000
2	Appl. layer sending commands to LLC.	(μS)	0.000
3	Transmission of any frame.	(μS)	0.000
4	Reception of any frame.	(μS)	0.000
5	Receive packet from media access layer.	(μS)	0.000
6	Send packet to media access layer.	(μS)	0.000
7	Information frame processing or decoding.	(μS)	0.000
8	Process received acknowledgments.	(μS)	0.000
9	Block movement of data within memory.	(μS)	0.000
10	Enqueue packet to the repeat buffer.	(μS)	0.000
11	Dequeue packet from the repeat buffer.	(μS)	0.000
12	Prepare/send supervisory frame.	(μS)	0.000

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

+

Choose not to change these parameters; view next page.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
1

List LAN nodes in ring order with some parameters.

Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
2	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
3	8	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
4	7	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
5	6	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
6	5	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
7	4	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
8	3	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
9	2	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
10	1	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

LAN contains ten nodes connected in pairs as shown. (1 to 10, etc.) Packet lengths are exponentially distributed with 4096 bits average. Interarrival times are exponential; means are not shown. Link distances are 220 meters.

Individual Node Specifications

Field	Description

1 View node directory.
2 Create/examine a node.
3 Insert a node.
4 Insert several nodes.
5 Create copies of a node.
6 Delete a node.
7 Delete several nodes.
8 Change/examine default node specifications.
9 Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.

2

Enter the number of the node to create/examine, or
"0" to exit to the menu.

3

Examine node #3. If less than 3 nodes existed, then one would have been created.

Node # 3

Field	Description		Value
1	Message length distribution.(CONSTANT, EXPON)		EXPON (XMEAN)
2	-- Average message length before overhead.(bits)		4096
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		EXPON (XMEAN)
9	--Mean interarrival time.	(μS)	5.850E+04

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

2

Enter new value for: -- Average message length before overhead.(bits),or
<CR> to exit to the menu.

2500

Node # 3

Field	Description		Value
1	Message length distribution.(CONSTANT, EXPON)		EXPON (XMEAN)
2	-- Average message length before overhead.(bits)		2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		EXPON (XMEAN)
9	--Mean interarrival time.	(μS)	5.850E+04

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

8

Change interarrival time distributions.

Interarrival Time Distributions

Field	Function	Description
1	CONSTANT	A constant time period.
2	EXPON (XMEAN)	Exponential distribution with mean XMEAN.
3	UNFRM (ULO,UHI)	Uniform distribution on the interval ULO to UHI.
4	TRIAG(XLO,XMODE,XHI)	Triangular distribution on the interval XLO to XHI with mode XMODE.
5	RNORM (XMN,STD)	Normal distribution with mean XMEAN and standard deviation STD.
6	RLOGN (XMN,STD)	Lognormal distribution with mean XMEAN and standard deviation STD.
7	ERLNG (EMN,XK)	Erlang distribution which is the sum of XK exponential samples, each with mean EMN.
8	GAMA (BETA,ALPHA)	Gamma distribution with parameters BETA and ALPHA.
9	BETA (THETA,PHI)	Beta distribution with parameters THETA and PHI.
10	NPSSN (XMN)	Poisson distribution with mean XMEAN.

Enter the field number of the desired distribution, or
"0" to exit the selection.

5

Select Gaussian interarrival.

Node # 3

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length before overhead.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0 7
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		RNORM (XMN,STD)
9	--Mean interarrival time.	(μS)	5.850E+04
10	--Standard deviation from the mean.	(μS)	5.850E+04

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.
10

Change new parameter: standard deviation.

Enter new value for: -- Standard deviation from the mean. (μS), or
<CR> to exit to the menu.
5000

Node # 3

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length before overhead.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		RNORM (XMN,STD)
9	--Mean interarrival time.	(μS)	5.850E+04
10	--Standard deviation from the mean.	(μS)	5.000E+04

Enter the field number of the value to change, or
"+" to create/examine the next node, or
"-" to examine the preceding node, or
"0" to exit menu.
10

Selecting the same parameter for typing error.

Enter new value for: -- Standard deviation from the mean. (μS), or
<CR> to exit to the menu.
500

Node # 3

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		RNORM (XMN,STD)
9	--Mean interarrival time.	(μS)	5.850E+04
10	--Standard deviation from the mean.	(μS)	500.0

Enter the field number of the value to change, or
"+" to create/examine the next node, or
"-" to examine the preceding node, or
"0" to exit menu.
5

Choosing node priority for all messages.

Enter new value for: Message priority (MIXED, 0 - 7), or
<CR> to exit to the menu.
2

Node # 3

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	8
5	Message priority.	(MIXED, 0 - 7)	2
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		RNORM (XMN,STD)
9	-- Mean interarrival time.	(μS)	5.850E+04
10	-- Standard deviation from the mean.	(μS)	5.00

Enter the field number of the value to change, or
"+" to create/examine the next node, or
"-" to examine the preceding node, or
"0" to exit menu.
0

Return to page of node options.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
3

Enter the number of the new node, or
"0" to exit to the menu.
4

Insert node at position 4 on ring with default parameters.
Node inserted into position 4.

Type <CR> to continue.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
4
Enter the number of nodes to insert, or
"0" to exit to the menu.
4
Enter the number of the first new node, or
"0" to exit to the menu.
2
Node inserted into positions 2 to 5.

Type <CR> to continue.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
1

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
2	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
3	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
4	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
5	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
6	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
7	8	EXPON (XMEAN)	4096	RNORM (XMN,STD)	.2200E+03
8	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
9	7	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
10	6	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
11	5	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
12	4	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
13	3	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
14	2	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
15	1	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

Notice 4 nodes were inserted into positions 2 to 5 with invalid node destinations; we may correct these or let the program handle it as will be shown later. Node inserted at position 4 was pushed up to position 8 with others. Notice changes previously made to node #3, now node #7.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.

5

Enter the number of nodes to create, or
"0" to exit to the menu.

1

Enter the number of the model node, or
"0" to exit to the menu, or
<CR> to view the node directory.

6

Create one node with same parameters as node #6.

Node # 16 created from node # 6.

Type <CR> to continue.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.

1

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
2	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
3	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
4	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
5	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
6	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
7	8	EXPON (XMEAN)	4096	RNORM (XMN,STD)	.2200E+03
8	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
9	7	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
10	6	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
11	5	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
12	4	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
13	3	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
14	2	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
15	1	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
16	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

Node #16 is new node with parameters of node #6.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
7
Enter the number of the first node to delete, or
"0" to exit to the menu, or
<CR> to view the node directory.
3
Enter the number of the last node to delete, or
"0" to exit to the menu, or
<CR> to view the node directory.
7
Delete nodes 3 to 7? (N)
y
Nodes 3 to 7 deleted.

Delete nodes 3 through 7.

Type <CR> to continue.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
1

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
2	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
3	0	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
4	7	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
5	6	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
6	5	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
7	4	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
8	3	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
9	2	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
10	1	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
11	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

Notice that an odd number of nodes remain, and they are not paired correctly. We can fix this or let the program handle it.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
0

Choose to exit node parameter page; program will correct error.

Node # 11 deleted to evenly match message destinations.

Message destination for node # 2 corrected.
Message destination for node # 3 corrected.

Type <CR> to continue.

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
2	9	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
3	8	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
4	7	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
5	6	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
6	5	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
7	4	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
8	3	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
9	2	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03
10	1	EXPON (XMEAN)	4096	EXPON (XMEAN)	.2200E+03

Type <CR> to continue.

Nodes were paired with old destinations preserved as much as possible. If we chose to, we could change these destinations by altering individual node parameters.

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications

Enter the page number of parameters to view or change, or "0" to exit to the main menu.

6

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
8

Examine the default node parameters to apply to new nodes.

Default Node Specifications

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length before overhead.	(bits)	4096
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	0
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		EXPON (XMEAN)
9	-- Mean interarrival time.	(μS)	5.850E+04

Enter the field number of the value to change, or
"0" to exit to the menu.
2
Enter new value for: -- Average message length before overhead.(bits),or
<CR> to exit to the menu.
2500

Change default message lengths.

Default Node Specifications

Field	Description		Value
1	Message length distribution. (CONSTANT, EXPON)		EXPON (XMEAN)
2	-- Average message length before overhead.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	0
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		EXPON (XMEAN)
9	-- Mean interarrival time.	(μS)	5.850E+04

Enter the field number of the value to change, or
"0" to exit to the menu.

8

Interarrival Time Distributions

Field	Function	Description
1	CONSTANT	A constant time period.
2	EXPON (XMEAN)	Exponential distribution with mean XMEAN.
3	UNFRM (ULO,UHI)	Uniform distribution on the interval ULO to UHI.
4	TRIAG(XLO,XMODE,XHI)	Triangular distribution on the interval XLO to XHI with mode XMODE.
5	RNORM (XMN,STD)	Normal distribution with mean XMEAN and standard deviation STD.
6	RLOGN (XMN,STD)	Lognormal distribution with mean XMEAN and standard deviation STD.
7	ERLNG (EMN,XK)	Erlang distribution which is the sum of XK exponential samples, each with mean EMN.
8	GAMA (BETA,ALPHA)	Gamma distribution with parameters BETA and ALPHA.
9	BETA (THETA,PHI)	Beta distribution with parameters THETA and PHI.
10	NPSSN (XMN)	Poisson distribution with mean XMEAN.

Enter the field number of the desired distribution, or
"0" to exit the selection.

1

Change default interarrival time distribution.

Default Node Specifications

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	0
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		CONSTANT
9	-- Constant interarrival time.	(μS)	5.850E+04

Enter the field number of the value to change, or
"0" to exit to the menu.

0

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.

9

***Apply some or all of the default parameters to all nodes. ***

Default Node Specifications

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	0
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		CONSTANT
9	-- Constant interarrival time.	(μS)	5.850E+04

Enter the field number of the parameter to apply to all nodes, or
"a" to affect all parameters of all nodes, or
"0" to exit to the menu.

2

***Set all nodes' average message length to 2500 bits. ***

Field # 2 of all nodes set.

Default Node Specifications

Field	Description		Value
1	Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
2	-- Average message length.	(bits)	2500
3	Application layer buffer size.	(messages)	20
4	Message destination node.	(integer)	0
5	Message priority.	(0 - 7)	7
6	Link distance.	(meters)	220.0
7	Ring distance to next node.	(meters)	0.000
8	Interarrival time distribution.		CONSTANT
9	-- Constant interarrival time.	(μS)	5.850E+04

Enter the field number of the parameter to apply to all nodes, or
"a" to affect all parameters of all nodes, or
"0" to exit to the menu.

A

***Set all nodes with the above specification. ***

All nodes set to default specifications.
Message destination for node # 1 corrected.
Message destination for node # 2 corrected.
Message destination for node # 3 corrected.
Message destination for node # 4 corrected.
Message destination for node # 5 corrected.
Message destination for node # 6 corrected.
Message destination for node # 7 corrected.
Message destination for node # 8 corrected.
Message destination for node # 9 corrected.
Message destination for node # 10 corrected.

Type <CR> to continue.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
1

Node	Destination Node	Message Length Distribution	Avg Message Length	Interarrival Time Distribution	Link Dist. (meters)
1	10	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
2	9	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
3	8	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
4	7	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
5	6	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
6	5	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
7	4	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
8	3	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
9	2	EXPON (XMEAN)	2500	CONSTANT	.2200E+03
10	1	EXPON (XMEAN)	2500	CONSTANT	.2200E+03

Type <CR> to continue.

Notice that destination nodes were reset.

Individual Node Specifications

Field	Description
1	View node directory.
2	Create/examine a node.
3	Insert a node.
4	Insert several nodes.
5	Create copies of a node.
6	Delete a node.
7	Delete several nodes.
8	Change/examine default node specifications.
9	Apply default node specifications.

Enter the field number of the desired action, or
"0" to exit to the page menu.
0

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.
0

MAIN MENU

Field	Description
1	Change current network parameters.
2	Save current network parameters.
3	Load new default parameter file.
4	Exit program.
5	Exit program without saving model.

Enter the field number of the desired action.
4

Exit program; save LAN model.

Offered Load at User Level = .10684

Do you wish to revise the simulation parameters? (N)
y

***Choose to revise parameters to get a lower load. ***

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.
2

Change media access parameters.

Media Access Parameters

Field	Description		Default
1	Velocity of media as fraction of light speed.		1.000
2	Line rate.	(Mbps)	4.000
3	Start and end of frame sequence length.	(bits)	16
4	Address field length.	(bits)	40
5	CRC field length.	(bits)	32
6	Token length.	(bits)	24
7	Abort frame length.	(bits)	16
8	Maximum packet size.	(bits)	12144
9	Valid TX timer TVX timeout period.	(μS)	12.50E+03
10	Return to repeat timer TRR timeout period.	(μS)	2.500E+03
11	Token holding timer THT timeout period.	(μS)	10.00E+03

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.
2

Enter new value for: Line rate. (Mbps),or
<CR> to return to the menu.
5

Media Access Parameters

Field	Description		Default
1	Velocity of media as fraction of light speed.		1.000
2	Line rate.	(Mbps)	5.000
3	Start and end of frame sequence length.	(bits)	16
4	Address field length.	(bits)	40
5	CRC field length.	(bits)	32
6	Token length.	(bits)	24
7	Abort frame length.	(bits)	16
8	Maximum packet size.	(bits)	12144
9	Valid TX timer TVX timeout period.	(μS)	12.50E+03
10	Return to repeat timer TRR timeout period.	(μS)	2.500E+03
11	Token holding timer THT timeout period.	(μS)	10.00E+03

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

0

PAGE MENU

Page	Description
1	General Simulation Controls
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6	Individual node specifications

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.

0

MAIN MENU

Field	Description
1	Change current network parameters.
2	Save current network parameters.
3	Load new default parameter file.
4	Exit program.
5	Exit program without saving model.

Enter the field number of the desired action.

4

Offered Load at User Level = .08547

Do you wish to revise the simulation parameters? (N)

n

Accept this load.

Node	Expected # of Packets
1	230.8
2	230.8
3	230.8
4	230.8
5	230.8
6	230.8
7	230.8
8	230.8
9	230.8
10	230.8

Do you wish to revise the simulation parameters? (N)

no

Do you wish to enter new comments for the parameter file? (N)

Creating files; please wait.

Two files have been created.
Parameter file: lastintrng.dat
SLAM driver file: lastintrng.dvr

Do you wish to rename the current experiment's files? (N)
y

Naming files with appropriate names.

Enter a file name (without extension), or
"0" to exit the selection.
Sample

Creating files; please wait.

Two files have been created.
Parameter file: Sample.dat
SLAM driver file: Sample.dvr

Do you wish to rename the current experiment's files? (N)

To execute the SLAM run, type at system level:

batch <CR>
simulate file name <CR> e.g. simulate lastlapllc
control-D

The simulation output will be stored in: "filename.out"
You will be notified by mail when the output is ready.

Type <CR> to continue.

$

Sign-off message explains how to generate results. When the program is run again, the file 'lastintrug.dat' will provide the initial LAN model parameters. The following session demonstrates this capability. The current model is revised by decreasing the time per simulation subrun. The effect of this change is reflected in the sign-off listing of the expected number of packets to be generated by each node.

$glas

Telecommunications and Information Sciences Laboratory

General LAN Analysis System

GLAS
Contact : Victor S. Frost, Associate Professor
University of Kansas
(913) 864-4833

Type <CR> to continue

Enter the number corresponding to the desired simulation model.
1. LAP LLC
2. MAC CSMA-CD
3. MAC TOKEN RING
4. MAC TOKEN BUS
5. INTEGRATED LLC & CSMA-CD
6. INTEGRATED LLC & TOKEN RING
7. INTEGRATED LLC & TOKEN BUS

6

Enter the file name (without extension) for default values, or
<CR> to default the selection.

lastintrng.dat provided the default values.

Type <CR> to continue

The previous LAN model may not be viewed.

MAIN MENU

Field	Description
1	Change current network parameters.
2	Save current network parameters.
3	Load new default parameter file.
4	Exit program.
5	Exit program without saving model.

Enter the field number of the desired action.
1

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.
1

General Simulation Controls

Field	Description		Default
1	Analyst's name.	(up to 20 characters used)	U of K TISL
2	Project title.	(up to 20 characters used)	Sample Run
3	Print SLAM input listing?	(y/n)	N
4	Print SLAM echo summary report?	(y/n)	N
5	Attempt execution?	(y/n)	Y
6	Print SLAM summary report?	(y/n)	N
7	Confidence interval for output tabulation.	(%)	95
8	Number of simulation subruns.	(Integer)	10
9	Time for each subrun.	(μS)	15.00E+06
10	Set-up time as percent of run-time.	(%)	10.00
11	Abort if an application layer queue fills?	(y/n)	N

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

9

Enter new value for: Time for each subrun (μs), or
<CR> to return to the menu.

10e6

General Simulation Controls

Field	Description		Default
1	Analyst's name.	(up to 20 characters used)	U of K TISL
2	Project title.	(up to 20 characters used)	Sample Run
3	Print SLAM input listing?	(y/n)	N
4	Print SLAM echo summary report?	(y/n)	N
5	Attempt execution?	(y/n)	Y
6	Print SLAM summary report?	(y/n)	N
7	Confidence interval for output tabulation.	(%)	95
8	Number of simulation subruns.	(Integer)	10
9	Time for each subrun.	(μS)	10.00E+06
10	Set-up time as percent of run-time.	(%)	10.00
11	Abort if an application layer queue fills?	(y/n)	N

Enter the field number of the parameter to change, or
"+" to view the next page, or
"-" to view the preceding page, or
"0" to exit to the page menu.

0

PAGE MENU

Page	Description
1	General Simulation Controls
2	Media Access Parameters
3	Media Access Protocol Processing Times
4	Link Access Parameters
5	Link Access Protocol Processing Times
6	Individual node specifications

Enter the page number of parameters to view or change, or
"0" to exit to the main menu.

0

MAIN MENU

Field	Description
1	Change current network parameters.
2	Save current network parameters.
3	Load new default parameter file.
4	Exit program.
5	Exit program without saving model.

Enter the field number of the desired action.
4

Offered Load at User Level = .08547

The change in simulation time has no effect on the offered load.

Do you wish to revise the simulation parameters? (N)
n

Node	Expected # of Packets
1	153.8
2	153.8
3	153.8
4	153.8
5	153.8
6	153.8
7	153.8
8	153.8
9	153.8
10	153.8

The expected number of packets is lower for this version of the LAN model due to the shorter simulation time.

Do you wish to revise the simulation parameters? (N)
n

Do you wish to copy the input file's comments to the parameter file? (N)
n

Do you wish to enter new comments for the parameter file? (N)
y

Enter new comments for parameter file;
Enter a line with only a "$" to stop.

This is an example of how to create LAN models and change parameters.
These comments will appear at the top of the .dat file.

This model may be revised by running the program again as shown.
$

Creating files; please wait.

Two files have been created.
Parameter file: lastintrng.dat
SLAM driver file: lastintrng.dvr

Do you wish to rename the current experiment's files? (N)
y

Enter a filename (without extension), or
"0" to exit the selection.
Sample2

Creating files; please wait.

Two files have been created.
Parameter file: Sample2.dat
SLAM driver file: Sample2.dvr

Do you wish to rename the current experiment's files? (N)

To execute the SLAM run, type at system level:

batch <CR>
simulate file name <CR> e.g. simulate lastlapllc
control-D

The simulation output will be stored in: "filename.out"
You will be notified by mail when the output is ready.

Type <CR> to continue.

$

$	Media Access Protocol Processing Times	
Station hardware latency.	(μS)	200.0E-03
Priority modification latency.	(μS)	200.0
$	Link Access Parameters	
Window size (sequence number range).	(integer)	8
Timeout period.	(uS)	1.000E+06
Probability of a bit being in error.	(real)	0.000
Number of network nodes.	(even integer)	10
Overhead bits per pkt., also S-frame size	(bits)	48
Acknowledgement timeout period at receiver.	(uS)	0.000
$	Link Access Protocol Processing Times	
Appl. layer receiving commands from LLC.	(μS)	0.000
Appl. layer sending commands to LLC.	(μS)	0.000
Transmission of any frame.	(μS)	0.000
Reception of any frame.	(μS)	0.000
Receive packet from media access layer.	(μS)	0.000
Send packet to media access layer.	(μS)	0.000
Information frame processing or decoding.	(μS)	0.000
Process received acknowledgements.	(μS)	0.000
Block movement of data within memory.	(μS)	0.000
Enqueue packet to the repeat buffer.	(μS)	0.000
Dequeue packet from the repeat buffer.	(μS)	0.000
Prepare/send supervisory frame.	(μS)	0.000
$ Node #1		
Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
-- Average message length.	(bits)	2500
Application layer buffer size.	(messages)	20
Message destination node.	(integer)	20
Message priority.	(0 - 7)	7
Link distance.	(meters)	220.0
Ring distance to next node	(meters)	0.000
Interarrival time distribution		CONSTANT
-- Constant interarrival time.	(μS)	58.50E+03

$ Node #10		
Message length distribution.	(CONSTANT, EXPON)	EXPON (XMEAN)
-- Average message length.	(bits)	2500
Application layer buffer size.	(messages)	20
Message destination node.	(integer)	1
Message priority.	(0 - 7)	7
Link distance.	(meters)	220.0
Ring distance to next node	(meters)	0.000
Interarrival time distribution		CONSTANT
-- Constant interarrival time.	(μS)	58.50E+03

7.0 FILE STRUCTURE AND INSTALLATION

7.1. FILE STRUCTURE

The GLAS file structure is pictured below. Each group of files represents a directory with the corresponding name underlined at the top of the group. The GLAS directory, which may be placed below any directory that the user chooses, is the top level directory; the five others are subordinate to this directory.

event	lap	mac	user_interface	bin
event.f	dummy.dat	csmacd.dat	Ex_mom.f	glas
general.dat	dummy.f	csmacd.f	Hx_mom.f	lapllc.exe
ot_intbus.f	ev_dummy.f	dummy.dat	Te_mom.f	maccsm.exe
ot_intcsm.f	ev_lapd.f	dummy.f	Tex_mom.f	macrng.exe
ot_intrng.f	in_dummy.f	ev_csmacd.f	Ti-mom.f	macbus.exe
otlib.f	in_lapd.f	ev_dummy.f	Tr_mom.f	intcsm.exe
userf.dat	init_cs.f	ev_tokbus.f	Tv_mom.f	intrng.exe
userf.f	init_lap.f	ev_tokrng.f	blnkps.f	intbus.exe
	init_tb.f	icsmacd.f	calctf.f	
	init_tr.f	in_csmacd.f	chkdst.f	
	lapd.dat	in_dumy.f	chkhst.f	
	lapd.f	in_tokbus.f	chkpri.f	
	ot_lapd.f	in_tokrng.f	chkval.f	
		init_tb.f	comvar.dat	
		init_tr.f	csmacd_apr.f	
		ot_csmacd.f	cval.f	
		ot_tokbus.f	defprm.f	
		tot_tokrng.f	distrb.f	
		tbparams.dat	do_bus.f	
		tokbus.dat	do_csm.f	
		tokbus.f	do_llc.f	
		tokrng.dat	do_rng.f	
		tokrng.f	doanal.f	
		trparams.dat	dodvr.f	
			dohelp.f	
			domenu.f	
			donode.f	
			dopage.f	
			dopram.f	
			doranf.f	
			engfmt.f	
			filchk.f	
			getblk.f	

user interface

getfil.f
getpri.f
getprm.f
getran.f
indrct.f
init_llc.f
init_node.f
inmain.f
intype.f
ival.f
llc_csm.f
llc_rng.f
llcapr.dat
main.f
mean.f
noddef.f
noddir.f
opnfil.f
priority_q.f
prmchk.f
prompt.f
pval.f
retx_est.f
rrf_est.f
rval.f
savfil.f
setndf.f
signon.f
tokring.f
traffic.f
tval.f
valtyp.f
wrtblk.f
xval.f

The files may have .for extensions rather than .f on some systems. Also, in addition to these files, three files (PARAR.INC, main.f, and slam.f) and the corresponding object code should be kept in a directory named slam. This directory may appear anywhere in the directory structure; it is necessary only that the shell variable SLAM in the make file (described in section 7.2) points to this slam directory.

7.2 INSTALLATION

After the code has been placed into the proper directories, ensure that the makefile which resides in the GLAS directory is updated. This process involves, first, setting the shell variable SLAM within the makefile so that it points to the correct directory. If, for instance, the slam files reside in /u/jones/slam, then the SLAM variable should be set as SLAM=/u/jones/slam. Next, the shell variables SMAIN and SLIB should be set to the object code files for main.f and slam.f respectively. For example, if the main.f object code is in main.o, then set SMAIN=$(SLAM)/main.o, and similarly for slam.o. The compiler commands should be changed next so that they are correct for the FORTRAN compiler being used. The variable COMP should be set to the FORTRAN compile command which generates only object code but does not link. In SVSFORTRAN, for instance, this command is "svsfort -c". Also, the LD command for loading the code should be set to the local FORTRAN link command. In SVSFORTRAN this command is "svsfort -o". Finally, if the local FORTRAN compiler requires source code files with .for extensions rather than .f, change all of the occurrences of .f to .for within the makefile.

Once the makefile is configured correctly, executables can be made by changing directory to the GLAS directory and executing the makefile. To make all of the executables, type "make all". To make only certain executables, type"make <name>", where <name> is glas, lapllc, maccsm, intcsm, etc. The executable will be placed in the bin directory.

8.0 REFERENCE

1. "A Combined LAP-D/CSMA-CD Simulation Model for the Study of Local Area Networks" by V. S. Frost, M. S. Kashefipour, W. Larue, and R. Ananthanpillai, ICC'87.

2. "A Performance Evaluation of Local Area Networks" by B. J. Wood, Telecommunications and Information Sciences Laboratory, Unversity of Kansas, Technical Report TISL-6731-3.

3. "A Combined LAP-D/CSMA-CD Simulation Model for the Study of Local Area Networks" by M. S. Kashefipour, Telecommunications and Information Sciences Laboratory, University of Kansas, Technical Report TISL 6731-4.

4. "Introduction to Simulation and SLAM II" by A. Alan and B. Pritsker, Halsted Press, 1984.

5. McKee, Alan, "LANSIM Token Ring LAN Simulation," Master's Project Report, Telecommunications and Information Sciences Laboratory, Technical Report 6731-9, January 1989.

6. Patnam, Kishore, "Token Bus Simulation Model," Telecommunications and Information Sciences Laboratory Technical Report TR#6731-10.