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JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

PERFORMANCE EVALUATION OF NASA/KSC CAD/CAE GRAPHICS LOCAL AREA NETWORK

M394356

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Date:	July 1988
Contract No.:	University of Central Florida NASA-NGT-60002

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ABSTRACT

This study had as an objective the performance evaluation of the existing CAD/CAE graphics network at NASA/KSC. This evaluation will also aid in projecting planned expansions, such as the Space Station project on the existing CAD/CAE network.

The objectives were achieved by collecting packet traffic on the various integrated sub-networks. This included items, such as, total number of packets on the various subnetworks, source/destination of packets, percent utilization of network capactity, peak traffic rates, and packet size distribution.

The NASA/KSC LAN was stressed to determine the useable bandwidth of the Ethernet network and an average design station workload was also determined. The average design station workload was used to project the increased traffic on the existing network and the planned T1 link.

This performance evaluation of the network will aid the NASA/KSC network managers in planning for the integration of future workload requirements into the existing network.

LIST OF ILLUSTRATIONS

1. INTRODUCTION

The Computer Aided Design/Computer Aided Engineering (CAD/CAE) graphics network at the Kennedy Space Center is composed of several Local Area Networks (LAN). These LAN's are interconnected through either bridges or routers. There is also a broadband connection and a planned interconnect through a T1 link. The design/engineering workstations are various Intergraph products. The architectural philosophy is that the workstations are driven by a Digital Equipment VAX cluster (ref. 1) that is composed of a VAX 785 and a group of disks accessed through a Hierarchical Storage Controller (HSC). This cluster also has two other VAX's, a VAX 750 and a VAX 780. These VAX's support other functions.

The Intergraph workstations all use the VAX for their work environment, i.e., any command generated at the menu is sent to the VAX for an update of the opened drawing file and also displayed on the graphics monitor. This results in all, or nearly all, traffic being routed between the workstation and the VAX cluster.

The Intergraph workstations utilize the Xerox Network Standard (XNS) protocol residing in an of an Ethernet frame for the data link and physical layer. There are three other major protocols on the Ethernet link (ref. 2). They are Transport Control Protocol/Internet Protocol (TCP/IP), DecNet, and Address Resolution Protocol (ARP)(ref. 3). There is also traffic generated by other anciliary networks and protocols

The intent of this study is to obtain operating data on the packet traffic generated on the CAD/CAE graphics network, the distribution of packet size, the protocol distribution on the network, the destination/source traffic matrix; the amount of stress that can be put on the network while still being able to operate normally, and to determine the characteristics of the average workstation/designer load.

In the sections that follow, the following items will be discussed. A review of the NASA/KSC CAD/CAE graphics network configuration, Ethernet principles, experimental environment, performance evaluation under normal and stressed operating loads, and typical workstation environment.

2. NASA/KSC CAD/CAE GRAPHICS NETWORK CONFIGURATION

The NASA/KSC CAD/CAE graphics network configuration is composed of a VAX 785, an HSC 70, and several disks. This is one of three VAX's in the VAX cluster. This configuration is illustrated in Figure 1. This VAX is interfaced to the NASA

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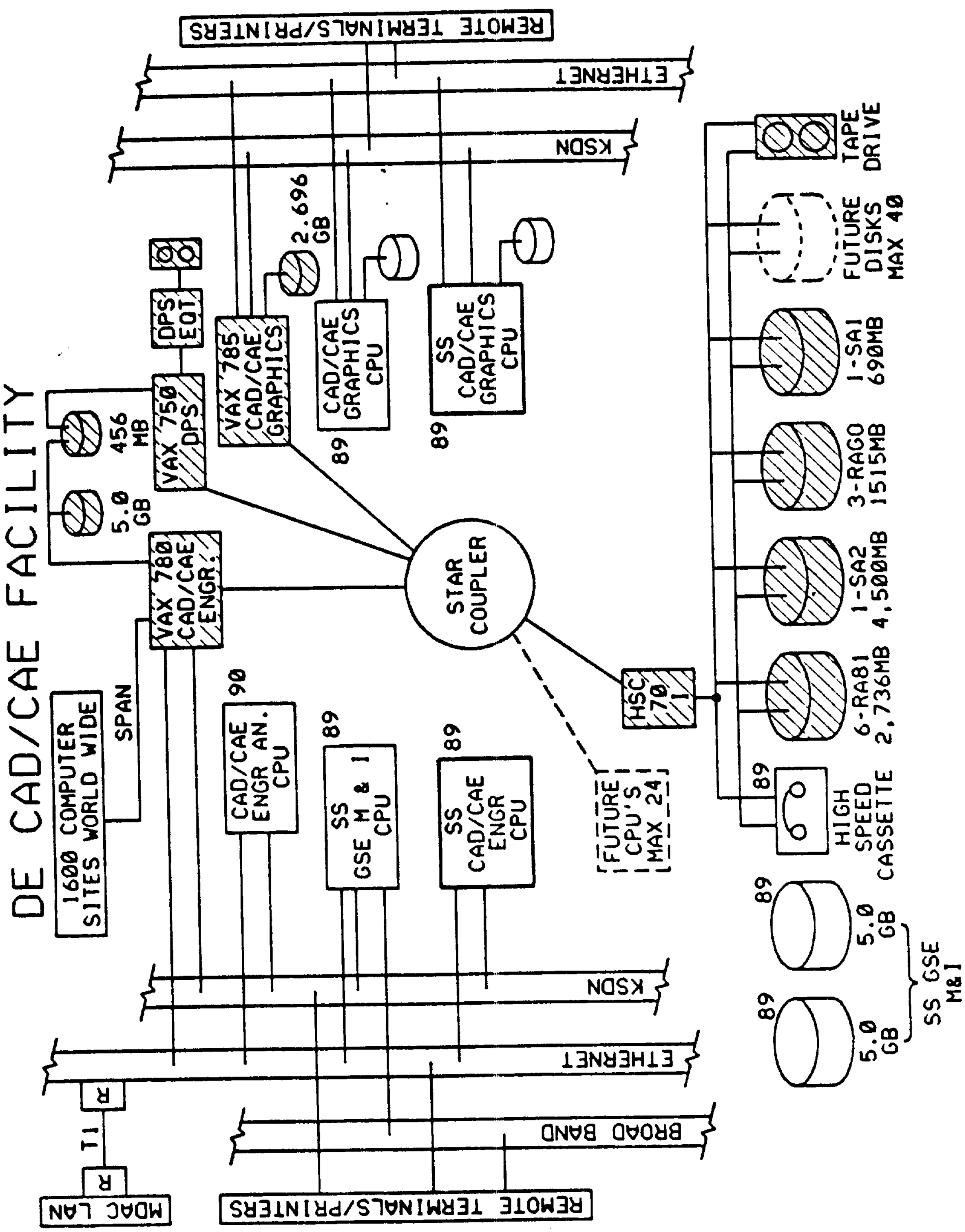

Figure 1 DE CAD/CAE Facility

Ethernet LAN which has fourteen (14) Intergraph workstations, a Versatec plotter, two bridges (one baseband and one broadband), and a router(ref. 4).

The NASA LAN is connected to a EG&G LAN through the baseband bridge and the O&C LAN through a router. The broadband bridge connects to a workstation in the O&C. There is only one workstation at present connected to the broadband bridge. The O&C Ethernet connected through the router has seven (7) Intergraph workstations connected to it and the EG&G LAN connected through a bridge has seven (7) workstations, a terminal server (which at present is inactive), and a VAX 250. There are two routers connected to the main router off the NASA LAN, one router serves the O&C LAN described above and the other router serves a workstation in the EDL building. The CAD/CAE graphics network architecture and the building configuration are shown in Figure 2 and 3, respectively.

It should be noted that the number and placement of workstations varies with time and this was a "snapshot" on a particular date.

The Intergraph workstations include various models. A description of these are given in Figure 4, while their placement is shown in Figure 2.

3. ETHERNET

Ethernet provides the services of the lower two layers in the International Standards Organization (ISO) Open Systems Interconnection (OSI) model for network protocols (ref. 3). There are seven layers in this model.

The layers and a brief description of their functions follow. The lowest layer is the Physical layer which is concerned with transmitting the bits over the transmitting medium, the next layer is the Data Link layer which is concerned with preparing the line for transmission and framing the packets so that their is a delineation of the packet boundaries, addressing, and error detection. This is the layer, along with the Physcial layer, for which Ethernet is used. The next layer is the Network layer, this layer determines how packets are routed through the sub-networks. Above this layer is the Transport layer, which mainly fragments the packet into smaller units, if needed, and insures that these fragments will be correctly put back together. The next layer is the Session layer, which is basically the user's interface to the network. The other two layers are the Presentation and Application layers. They are used for tasks, such as data compression and data distribution, respectively.

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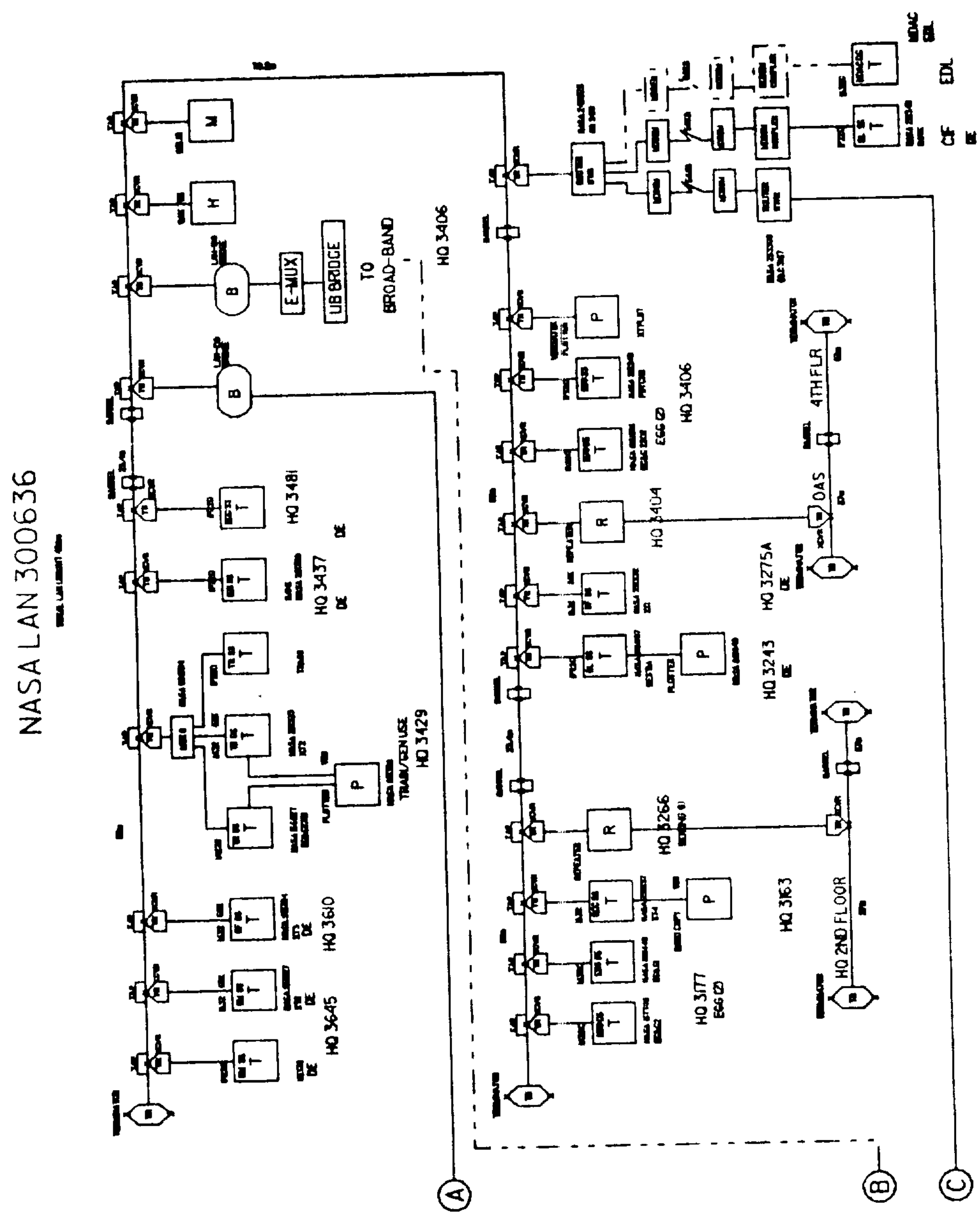

Figure 2 CAD/CAE Graphics Network Architecture

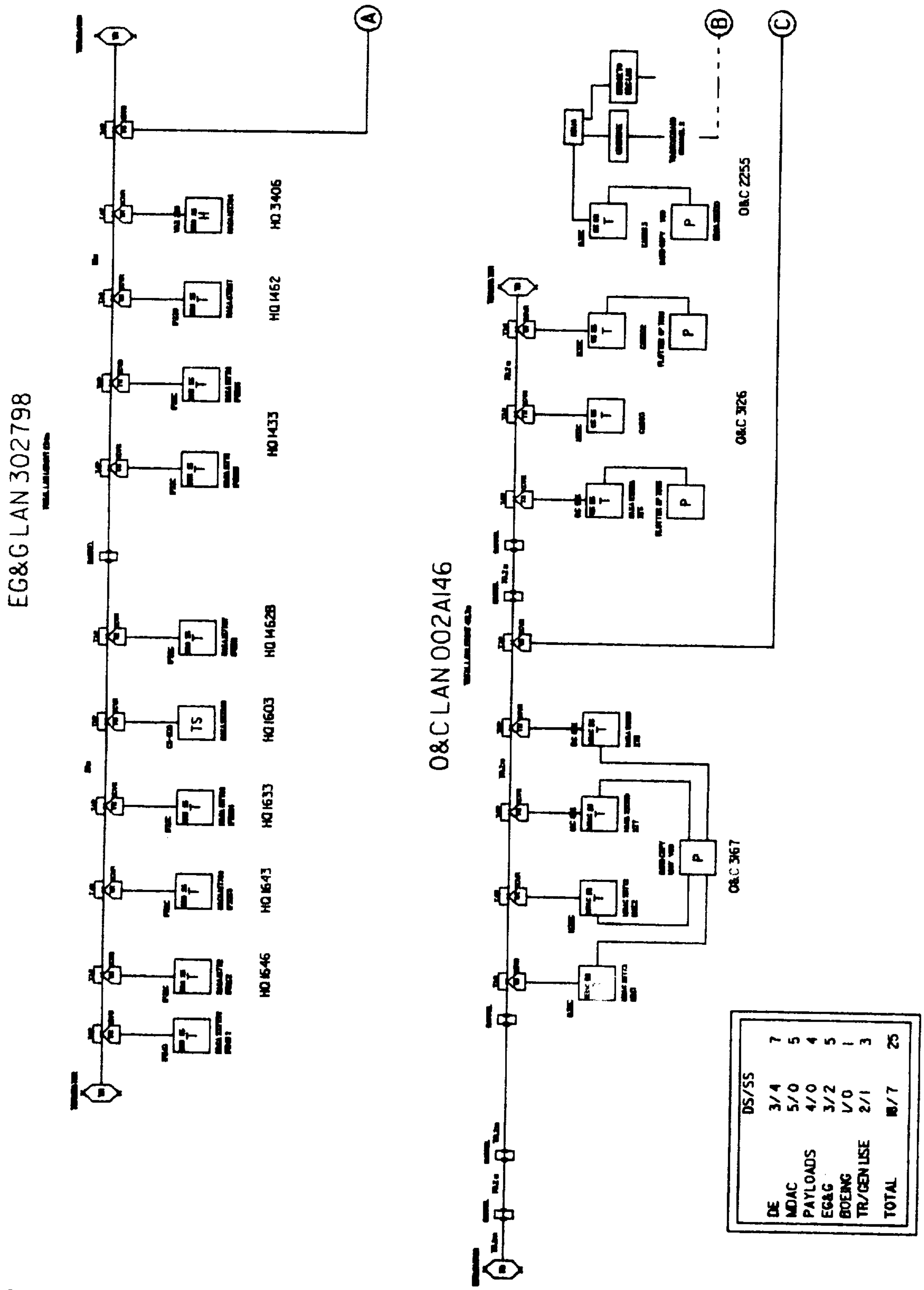

Figure 2 CAD/CAE Graphics Network Architecture (Continued)

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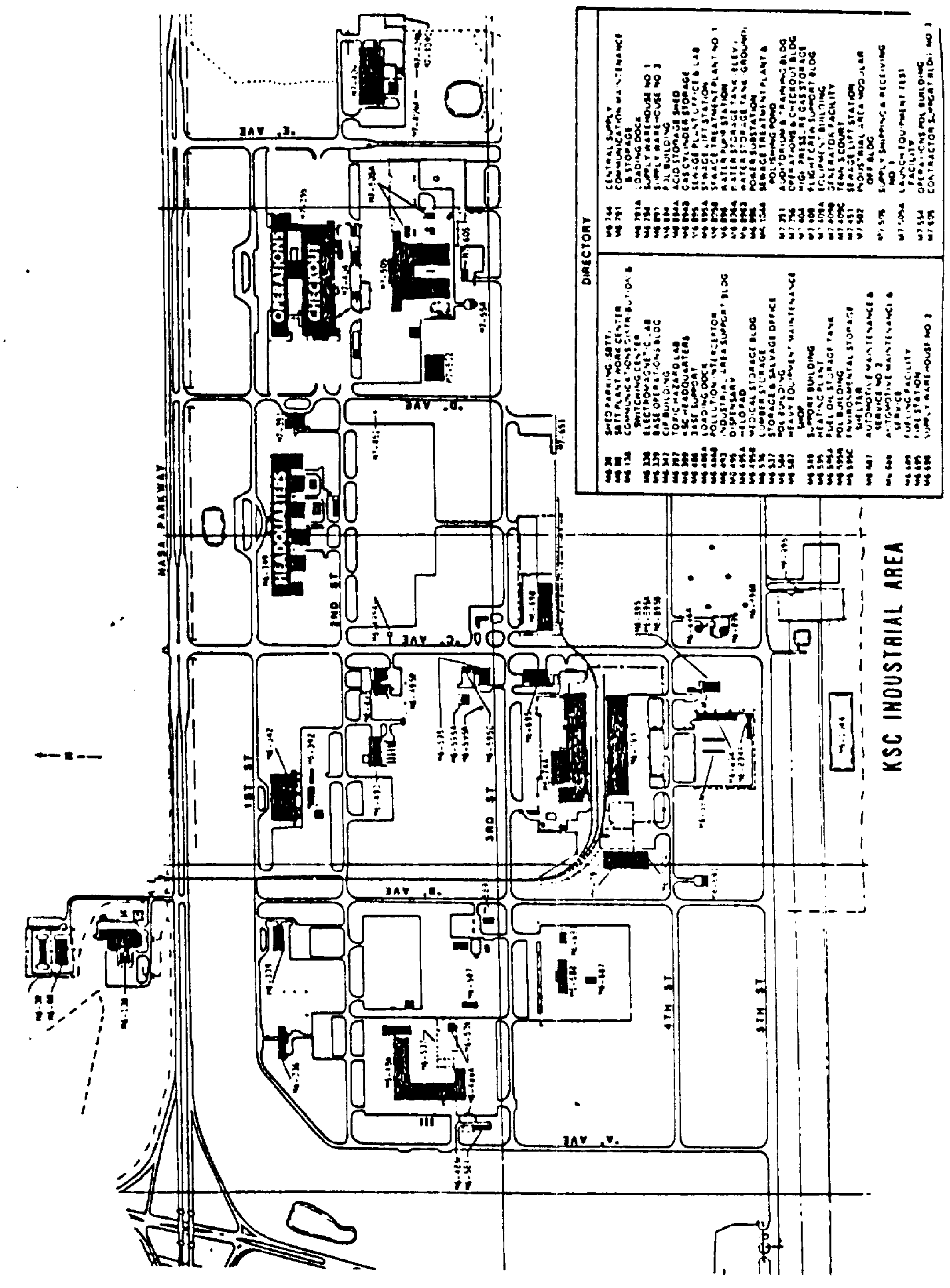

Figure 3 KSC Industrial Area

	Memory – Minimum/Maximum MB	Floating Point Engine	Standard Disk MB	Number of Optional 156 MB Disks	Tape Options 1/4" cartridge (60MB)	1/2" 1600/6250 BPI	Screen Size (inches) Standard/Optional	Display Colors	Palette	Menu Tablet	Digitizer Tablets
InterServe 200	16	n/a	156	6	external	external	n/a	n/a	n/a	n/a	n/a
InterServe 300	16/80	optional	156	6	external	external	n/a	n/a	n/a	n/a	n/a
InterPro 32C	6/16	n/a	80	6	external	external	15/19	32	4096	optional	optional
InterPro 220	8/16	n/a	156	6	external	external	19	32	4096	optional	optional
InterPro 240	8/16	n/a	156	6	external	external	19	512	16.7 million	optional	optional
InterPro 340	16/80	n/a	156	6	external	external	19	512	16.7 million	optional	optional
InterPro 360	16/80	standard	156	6	external	external	19	512	16.7 million	optional	optional
InterAct 32C	6/16	n/a	80	3	internal	n/a	2x19	32	4096	standard	standard
InterAct 340	16/80	n/a	156	3	internal	n/a	2x19	512	16.7 million	standard	standard
InterAct 360	16/80	standard	156	3	internal	n/a	2x19	512	16.7 million	standard	standard
InterView 32C	6/16	n/a	80	3	internal	n/a	2x19	32	4096	required option	required option
InterView 340	16/80	n/a	156	3	internal	n/a	2x19	512	16.7 million	required option	required option
InterView 360	16/80	standard	156	3	internal	n/a	2x19	512	16.7 million	required option	required option

Figure 4 Intergraph Workstation Descriptions

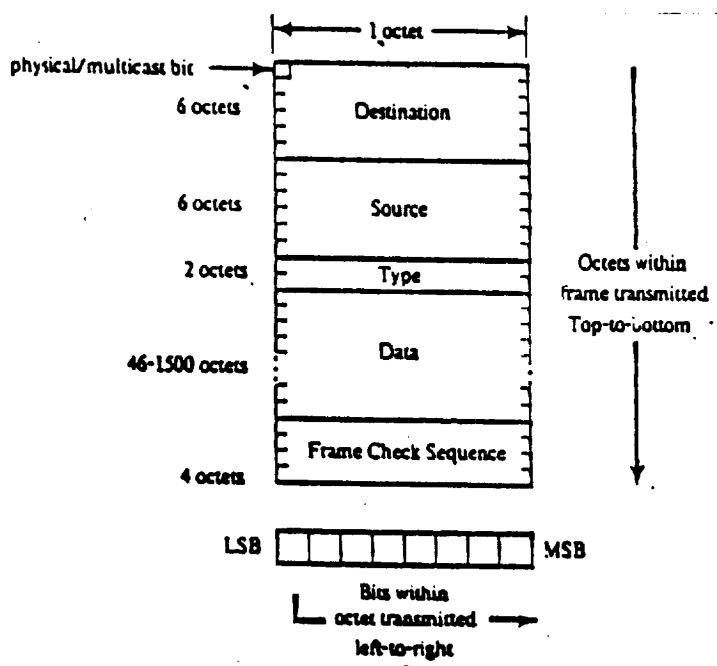

Figure 5 Ethernet Data Link Layer Frame Format

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The Physical layer characteristics for Ethernet (ref. 2) are:

- Data rate: 10 Million bits/second
- Maximum station separation: 2.5 Kilometers
- Maximum number of stations: 1024
- Medium: Shielded coaxial cable, base-band signalling
- Topology: Branching non-rooted tree

The Data Link characteristics are:

- Link control procedure: Fully distributed peer protocol, with statistical contention resolution
- Message protocol: Variable size frames, "best effort delivery"

Ethernet is a carrier sense protocol, i.e., all stations monitor the cable (the ether) during their transmission, terminating transmission immediately if a collision is detected. When an Ethernet station wishes to transmit a packet a carrier sense is performed forcing the station to defer if any transmission is in progress. If there is no station sensed to be transmitting then the sender can transmit immediately, otherwise the station waits until the packet has passed before transmitting. It is possible that two, or more, stations will sense the channel idle at the same time and begin transmitting. This has the possibility of producing a collision. The station will continue monitoring and sense this collision. When a collision is detected the station will stop transmitting and will reschedule a re-transmission at some later time. Retransmission time is random and is selected using a binary exponential backoff algorithm.

This mechanism is called "carrier sense multiple access with collision detection (CSMA/CD)". In a complete network architecture, suitable packet protocols are layered within this procedure. The Ethernet frame format is shown in Figure 5, while the TCP/IP headers are shown in reference 3, page 374. The data in Figure 5 is the packet formed by the TCP/IP protocol, or another suitable protocol. The packet contains the user generated data.

5. EXPERIMENTAL ENVIRONMENT

To enable collection of data concerning the traffic on the NASA/KSC CAD/CAE graphics network a network analyzer was used to characterize the traffic. Network analyzers are useful systems for monitoring, debugging, managing, and characterizing local area networks. Specifically, the analyzer can examine all packets transmitted on the network. The packets can be captured, timestamped, and stored based on user-defined criteria, which may include packet length, packet content, source/destination address, protocol type, and time.

They will also compute, display, and store statistics about network activity, such as network utilization, average and peak traffic rates, packet sizes, interpacket arrival times, and other items. They can also be used to generate network traffic by transmitting user-defined packets. The transmission rate and packet size can be controlled by the user.

There are also other functions which can be utilized, such as testing the Ethernet cable for opens and shorts; and decoding of protocols.

The network analyzer used for these tests was an Excelan LANalyzer EX 5000 Series Network Analyzer (ref. 5) installed on a WYSE PC286 computer. The user interface was through several screens. They are;

- Setup screen: Allows the user to specify test criteria
- Run screen: Displays results of test in progress
- Trace screen: Shows information about contents of packets collected during a test
- Statistics screen: Displays statistics about the packets collected
- Setup pattern screen: Allows the user to define patterns that the packet must match to be received

An example of each one of these screens is shown in Figures 6 -10.

The procedure used was to interface the network analyzer through an Ethernet tap into a particular sub-network. Since the networks only have their local traffic and traffic targeted for an Ethernet address on that network, the analyzer was moved to the EG&G subnetwork and the O&C subnetwork to be able to monitor the entire CAD/CAE graphics network. The EG&G network has a bridge separating it from the NASA LAN, therefore any local traffic would not be passed to the NASA LAN; while the O&C LAN interfaces to the NASA LAN through a router, hence the only interface address will be the router Ethernet address.

In a later section a traffic matrix will enumerate traffic patterns, both internet and intranet. Although, due to the Intergraph architecture the majority of the traffic is between workstations and the VAX host.

6. PERFORMANCE EVALUATION UNDER NORMAL OPERATING LOADS

6.1 PACKET TRAFFIC

The packet traffic on the Ethernet has been observed to be about 2,400,000 packets over 24 hours. This can be broke down

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```
                                                          Setup Test      13 43
+ -
---------------------------------- c:\lan\aveuser -----------------------------
RECEIVE                                                   Simple  Pattern Mode
Channel                    Packet__Size    Allow    Match    Collect  Start   Stop
Name       Active  Range                   Packets  Pattern  Stats.   Count   Count
promiscu   Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
xt4xxx     Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
eg2202xx   Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
psyc xxx   Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
xt4 vax    Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
e2202vax   Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
psycvax    Yes     >=0     <=Inf           All      Yes      Yes      Inf     Inf
           No      >=0     <=Inf           All      Yes      Yes      Inf     Inf

DATA COLLECTION
Performance Level: N/A
Start Collection After 00:00:00 Hr(s) Or   No Count
Stop  Trigger    After 99:00:00 Hr(s) Or   No Count
      Then collect additional                       0 Packets
Stop at buffer overflow No

1        2        3        4        5        6        7        8        9        10
load     save     mode     dspopt   pattrn            packet                     cmd
```

```
                                                          Setup Test      13 44
---------------------------------- c:\lan\aveuser -----------------------------
Trace File
Statistics File c:\lan\aveuserl
Collect Statistics Every 1800 Second(s)              Station Monitor Yes
Print Screen Every    0 Minute(s)

TRANSMIT
Collect Transmit Statistics No
                                       Transmission_____________Errors
Transmit                      Delay          Forced   Abnormal                    (Txall)
Name       Active   Count   (100us)  Crc    Collis   Preamble         Backoff   Rel.Freq
tx1        No           1        0   No     No       No   4 bytes     Yes             0
tx2        No           1        0   No     No       No   4 bytes     Yes             0
tx3        No           1        0   No     No       No   4 bytes     Yes             0
tx4        No           1        0   No     No       No   4 bytes     Yes             0
tx5        No           1        0   No     No       No   4 bytes     Yes             0
tx6        No           1        0   No     No       No   4 bytes     Yes             0

Txall      No           1        0   No     No       No   4 bytes     Yes Sequentially
Transmit After _      99:00:00 Hr(s) Or  _

1        2        3        4        5        6        7        8        9        10
load     save     mode     dspopt   pattrn            packet                     cmd
```

Figure 6   Setup Screen

```
42:32:53, Collecting ...                              Run    Counter   11:13
                          c:\lan\aveuser
   3803990 Packets Processed                Trace save in buffer
                                        Statistics save in file

   3803990 promiscu
    108931 xt4xxx
     55939 eg2202xx
      3363 psyc xxx
    107392 xt4 vax
     54383 e2202vax
         0 psycvax
         0

        17 Crc/Align   0    10   20   30   40   50   60   70   80   90   100
        72 Short                Channel Packets Distribution (%)
       N/A Collision
                                               0 Buffer Overflow
   3801900 Packets Not Saved                   0 Packets Not Processed
         0 Packets Transmitted                 0 Packets Deferred
         0 Packets Transmitted with Collisions

 1       2       3       4       5       6       7       8       9       10
 start   stop    globl   ctrs            stn     config          more    abort
```

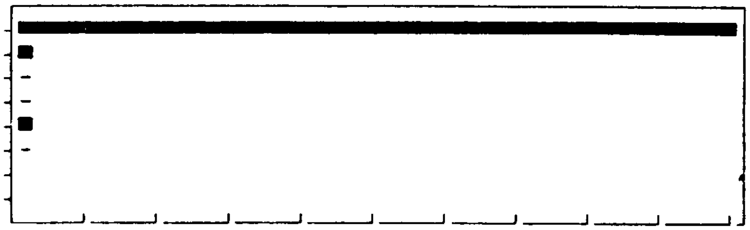

Figure 7 Run Screen

```
                                                        Trace Buffer   14:04
Created On 06/28/88 16:40:57    Elapsed Time 69:01:31   Total Packets    2642

Number    Len   Absolut_Timestmp Dest Addr    Source Addr  Ty/L Channels Err T
1        64   85:40:41.019.158 AA000400791C AA000400841C 6003 1....... ... .
2         64    85:40:41.023.007 AA000400841C AA000400791C 6003 1....... ... .
3         64    85:40:41.035.617 FFFFFFFFFFFF 00DD003C5E00 0806 1....... ... .
4         64    85:40:41.045.262 FFFFFFFFFFFF 00DD003C5E00 0806 1....... ... .
5         64    85:40:41.065.018 FFFFFFFFFFFF 00DD003C5E00 0806 1....... ... .
6         64    85:40:41.090.048 FFFFFFFFFFFF 00DD003C5E00 0806 1....... ... .
7         64    85:40:41.102.501 FFFFFFFFFFFF 00DD003C5E00 0806 1....... ... .
8         64    85:40:41.349.560 09002B010001 08002B061AA7 8038 1....... ... .
9         64    85:40:41.514.027 01DD01000000 00DD01013C47 7005 1....... ... .
10        64    85:40:41.515.028 01DD01000000 00DD00DCAD00 7005 1....... ... .
11        64    85:40:41.522.285 AA000400791C AA000400841C 6003 1....... ... .
12        64    85:40:41.526.171 AA000400841C AA000400791C 6003 1....... ... .
13        64    85:40:41.558.823 FFFFFFFFFFFF 00DD00442400 0806 1....... ... .
14        64    85:40:41.641.429 vax          hq1462       0600 1....... ... .
15        64    85:40:41.646.939 hq1462       vax          0600 1....... ... .
16        94    85:40:41.656.830 vax          xt1          0600 1....... ... .

1       2       3       4       5       6       7       8       9       10
load    find    buffr   savbf   goto    pktdat                  more    cmd
```

Figure 8 Trace Screen

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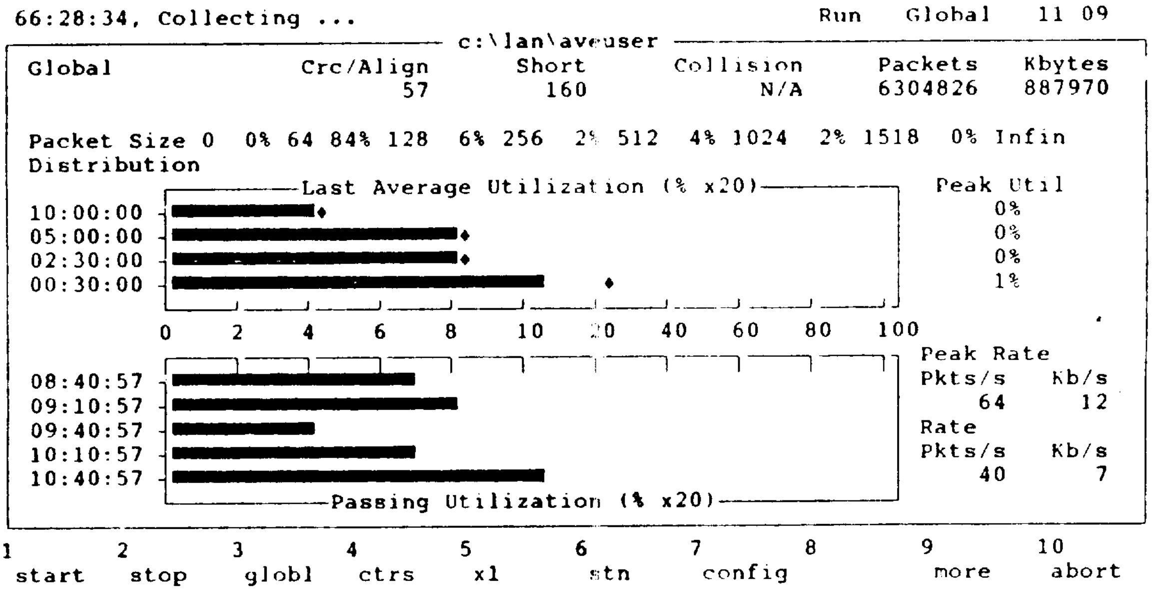


Figure 9 Statistics Screen

```
+ -                                                   Setup Pattern  13 57
                              c:\lan\aveuser
xt4 vax                                       Link Protocol Ethernet

Station vax               <---> xt4
Type     XXXX

Data:
Offset    Label                 Value
  0000    Version/IHL           XX
  0001    Type of Service       XX
  0002    Total Length          XXXXX
  0004    Identification        XXXXX
  0006    Flags/Frg Offset      XX XX
  0008    Time to Live          XXX
  0009    Protocol ID           XX
  000A    Header Checksum       XXXX
  000C    IPSource Address      XXX XXX XXX XXX
  0010    IPDest Address        XXX XXX XXX XXX
  0014    Source Port           XXXXX
  0016    Dest Port             XXXXX

1        2        3        4     5     6      7        8        9      10
promisc  xt4xxx   eg2202x  psyc  xx    xt4    vax      e2202va  psycvax  more  back
```

Figure 10 Setup Pattern Screen

into 1,670,000 packets during daylight and 730,000 packets during evening hours and as one suspects the majority of the packet traffic is generated during the daylight hours. This traffic totals about 340,000 Kilobytes. The Ethernet load versus time of day is shown in Figure 11.

6.2 UTILIZATION

The Ethernet utilization over a 24 hour period is shown in Figure 12, and is shown to range from negligible to a high of 0.88 %. This percentage is based on the Ethernet rate of 10 Million bits/second. As can be seen from the illustration most of the data communication tends to occur in bursts. A peak utilization of 3 % had been observed on other tests not presented.

6.3 PACKET LENGTH

The distribution of packet lengths over a 24 hour time period is shown in Figure 13 and reflects the kinds of applications that are present on the network. These would range from "handshakes" or acknowledgements, to transmittal of drawing commands between workstations and the VAX, to file transfers, to mail messages. One can see this reflected in the illustration, i.e., there is a concentration of packet lengths at the low end and the high end. The allowable distribution from the Ethernet frame is a minimum of 64 bytes to a maximum of 1518 bytes.

It should be noted that there is a reasonably high overhead on this Ethernet link. This is not unusual in an environment where most of the traffic is request/response with a server. The overhead in the Ethernet frame is 18 bytes and the overhead in TCP/IP is on the order of 40 bytes. No information was available on the XNS protocol overhead, but it can be assumed to be of the same order as TCP/IP.

6.4 SOURCE/DESTINATION TRAFFIC PATTERN

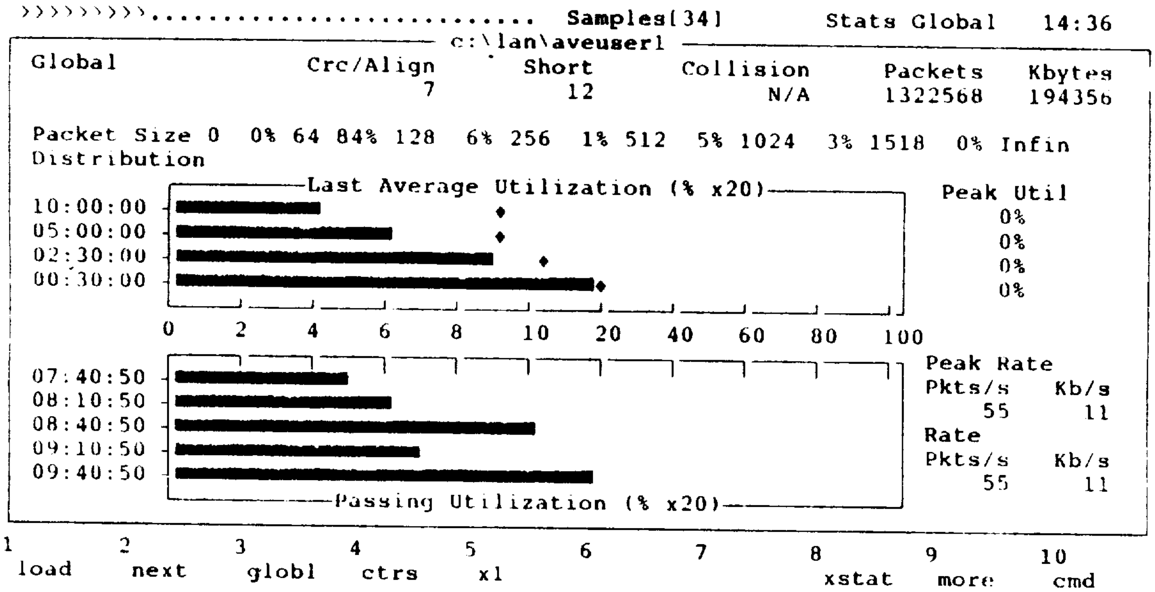
The internet source/destination traffic pattern is shown in Figures 14-16 for the traffic on the NASA, EG&G, and O&C LAN's, respectively. Figure 17 illustrates the intranet traffic between these LAN's. These figures illustrate that most of the traffic is between the workstations and the VAX cluster, since all drawing files reside at the VAX cluster site and commands are transmitted between the Intergraph workstations and the VAX. Figure 18 illustrates the protocol division on the Ethernet link for a typical day. For the CAD/CAE graphics architectural environment most of the protocol traffic is XNS, as one might suspect. This traffic

TIME PERIOD	PACKETS	KILOBYTES
7:40- 9:40	331227	51004
9:40-12:10	384975	72459
12:10-14:40	451500	67971
14:40-17:10	367386	47905
17:10-19:40	136636	12091
19:40-22:10	163580	18998
22:10-00:40	117989	9323
00:40- 3:10	115986	9210
3:10- 5:40	114880	9162
5:40- 8:10	252492	41272

Figure 11 Ethernet Load Versus Time

PACKET SIZE RANGE	GLOBAL DISTRIBUTION	SINGLE USER DISTRIBUTION
0 - 64 Bytes	0%	0%
64 - 128 Bytes	84%	78%
128 - 256 Bytes	6%	3%
256 - 512 Bytes	1%	0%
512 - 1024 Bytes	4%	11%
1024 - 1518 Bytes	2%	6%

Figure 13 Distribution of Packet Length



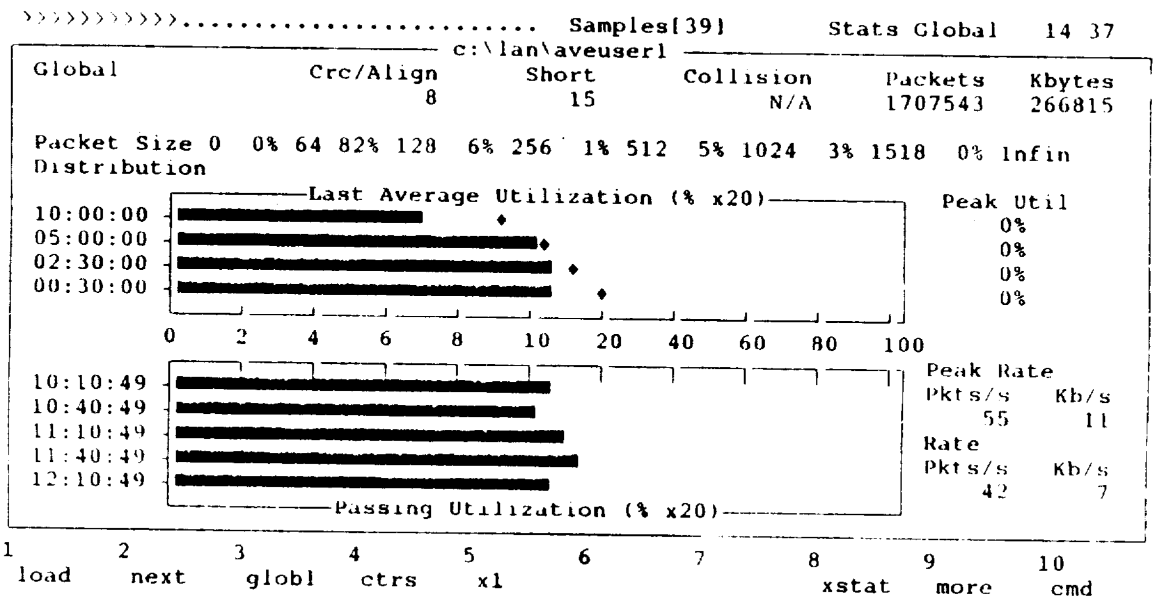


Figure 12 Ethernet Utilization

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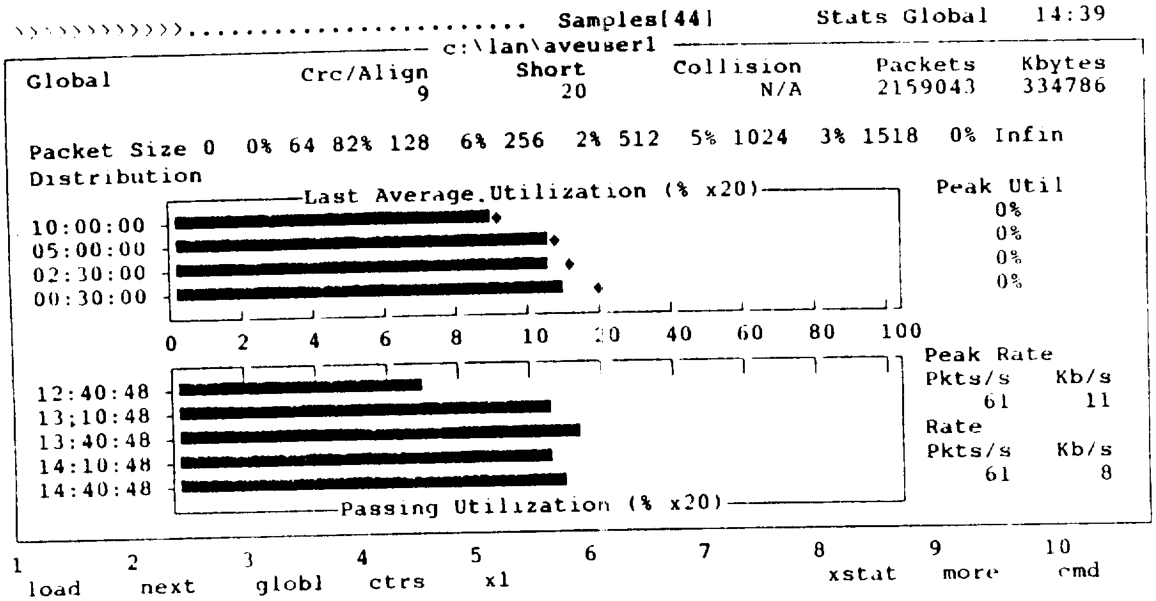


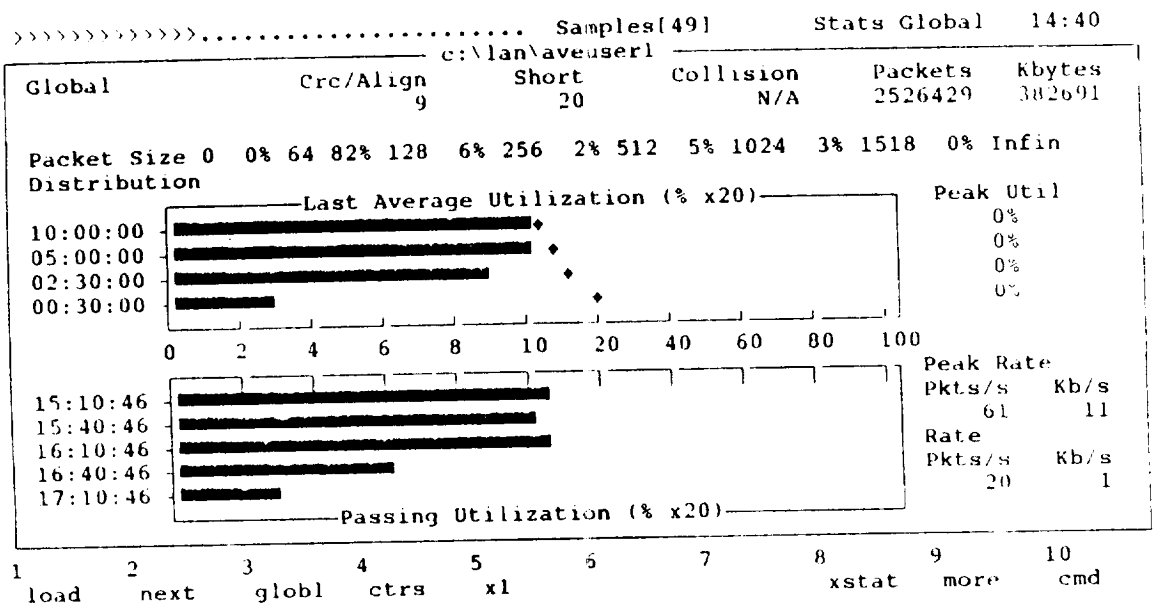
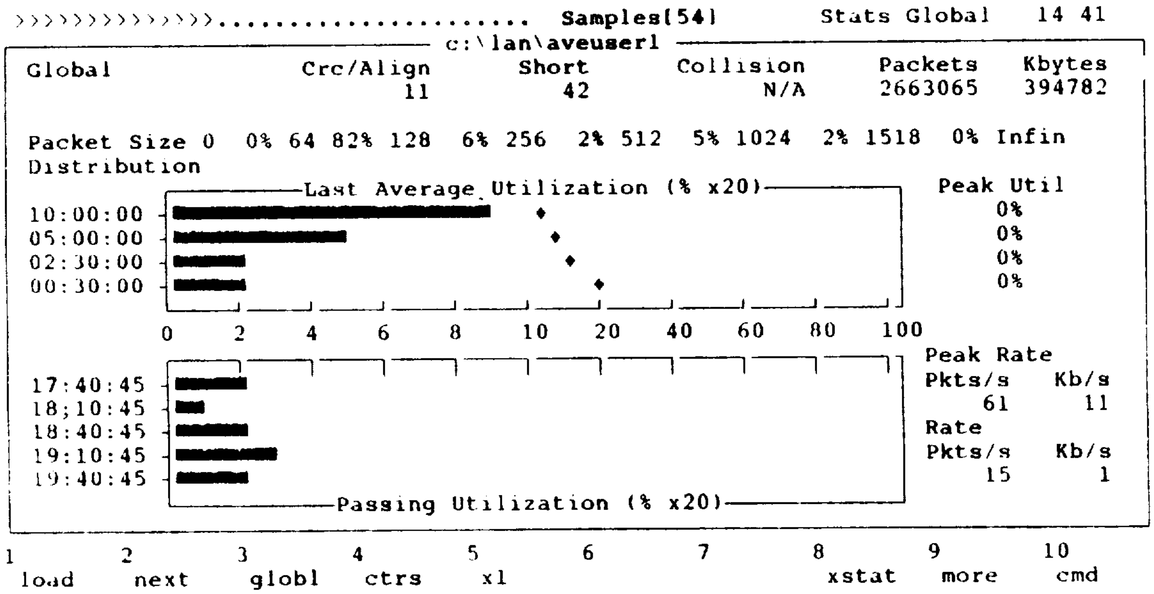


Figure 12 Ethernet Utilization (Continued)



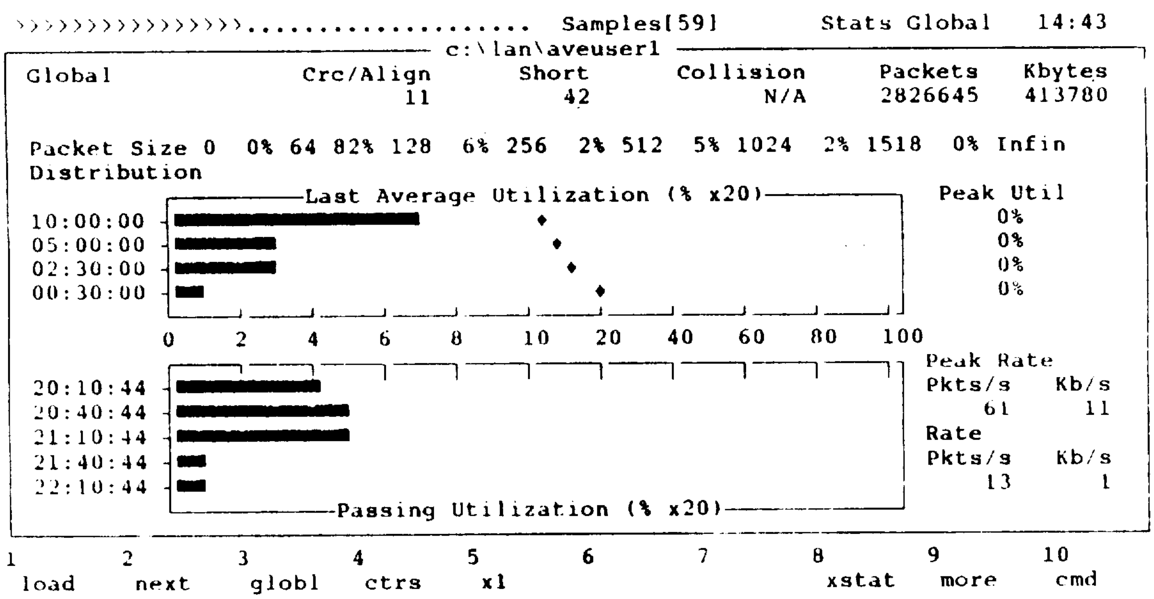
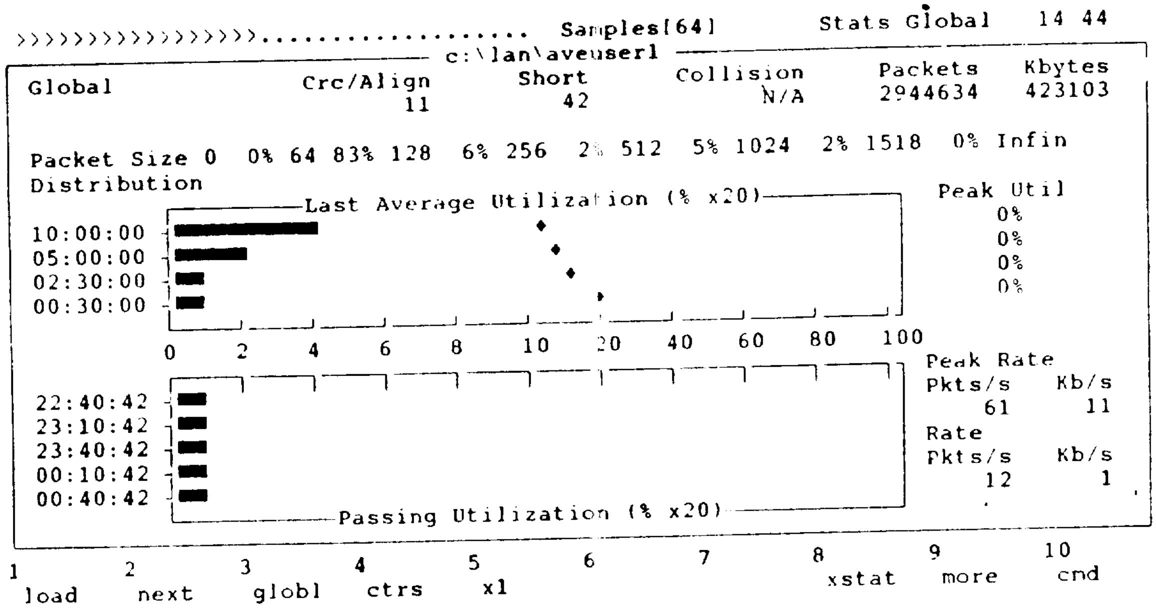


Figure 12 Ethernet Utilization (Continued)



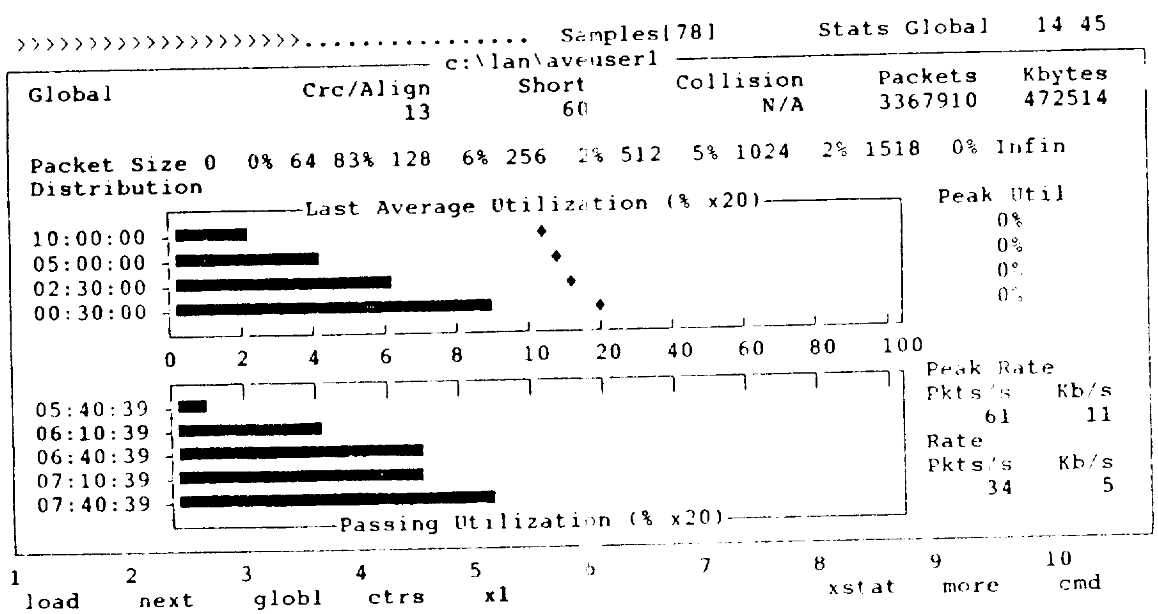


Figure 12 Ethernet Utilization (Continued)

	xxx	intergr	plotter	router1	vax250	eng vax	gr vax
intergr	193, 17	192, 17	2, 1	14, 3	10, 5	0, 0	193, 17
cargo3	* , *	* , *	0, 0	* , *	0, 0	0, 0	* , *
plotter	2, 1	2, 1	—	* , *	0, 0	0, 0	2, 1
router1	28, 5	14, 3	* , *	—	* , *	0, 0	28, 5
gr vax	192, 17	193, 17	2, 1	7, 1	2, 0	0, 0	—
vax250	7, 6	10, 5	0, 0	* , *	—	0, 0	11, 9

PEAK RATE LEGEND

XX, YY PACKETS/SEC; KBYTES/SEC

XXX ALL TRAFFIC

* LESS THAN 1 UNIT/SEC AVERAGE

Figure 14 Traffic Matrix for NASA LAN

	xxx	Intergr	vax250	gr vax
Intergr	—	79, 28	78, 28	0, 0
hq1462	*, *	—	11, 2	0, 0
hq1462b	*, *	—	4, 0	0, 0
hq1646	*, *	—	27, 4	0, 0
hq1643	*, *	—	13, 6	0, 0
hq1633	1, 0	—	19, 9	0, 0
hq1433c5	6, 0	—	7, 0	8, 0
hq1433c6	*, *	—	21, 1	0, 0
vax250	78, 28	78, 28	—	11, 9

PEAK RATE LEGEND

XX, YY PACKETS/SEC; KBYTES/SEC
XXX - ALL TRAFFIC
* - LESS THAN 1 UNIT/SEC AVERAGE

Figure 15 Traffic Matrix for EG&G LAN

	xxx	intergr	router2
intergr	41, 13	40, 13	40, 13
router2	40, 13	40, 13	—
mac1	—	—	0, 0
mac2	—	—	6, 2
xt7	—	—	8, 1
xt8	—	—	*, *
xt6	—	—	*, *
cargo1	—	—	*, *
cargo2	—	—	7, 1

PEAK RATE LEGEND

XX, YY PACKETS/SEC; KBYTES/SEC
XXX ALL TRAFFIC
* LESS THAN 1 UNIT/SEC AVERAGE

Figure 16 Traffic Matrix for O&C LAN

	router1	cargo3	vax250	engvax
xxx	10.64%	00.20%	7.62%	0.0004%
grvax	10.25%	00.13%	2.61%	0.0%
plotter	0.01%	0.001%	0.0%	0.0%
intergr	16.07%	0.14%	1.38%	0.0%

PACKET LEGEND

X.X	PERCENT OF TOTAL TRAFFIC
XXX	ALL TRAFFIC

Figure 17 Intranet Traffic Matrix

is given as a peak rate for both packets per second and in Kilobytes per second. One should note that these rates have an overhead associated with them, since if an Intergraph workstation is on, but idle then a "handshake" is reciprocated with the VAX at the rate of approximately 4 packets every 30 seconds. There is also traffic other than design traffic on the Ethernet link as illustrated by Figure 18.

6.5 COLLISIONS AND CRC ALIGNMENTS

There are very few packets lost through either collisions or from CRC alignments (ref. 6). The carrier sense before transmission feature of Ethernet should keep the collision rate low, especially during low utilization rates. The passive and shielded characteristics of the Ethernet link should maintain a low error rate in the data transmission. For a typical 24 hour day there were 13 CRC alignments. This particular network analyzer model did not collect collision data.

6.6 INTERPACKET ARRIVAL TIMES

Since the majority of the traffic on the Ethernet is request/response actions with a server, such as the VAX or a router, there will be a large interpacket arrival time. This is illustrated in Figure 19.

7. PERFORMANCE EVALUATION UNDER STRESS

The Excelan LANalyzer has the capability to create a test load on the Ethernet link by transmitting a large number of packets very rapidly. The load parameters can be varied to obtain different levels of utilization. This can be done by varying the data length and delay between successive packets. The primary purpose of this test is to determine how the hosts on the network respond to various percent utilization levels. The Ethernet link was stressed at 5%, 20%, 30%, 40%, and 75% utilization levels.

Figures 20 - 29 present the results of the stress tests at various levels of peak utilization. The Run Global Screen records the peak utilization and Statistics Transmission Screen records the number of collisions and deferred packets for the given number of packets transmitted during the test.

The test model used to generate packets and transmit them at the network analyzer station and then monitor workstation response at an adjacent Intergraph workstation is described below.

	x x x
x x x	709,521 100%
xns	491,317 69.25%
tcp	24 .0034%
Ip	28,565 4.03%
arp	1 0.0001%
dec	41,592 5.86%
other	148,022 20.86%

PACKET LEGEND

XX - NUMBER OF PACKETS COLLECTED
YY% - PERCENTAGE OF TOTAL COLLECTED

Figure 18 Protocol Division on Ethernet Link

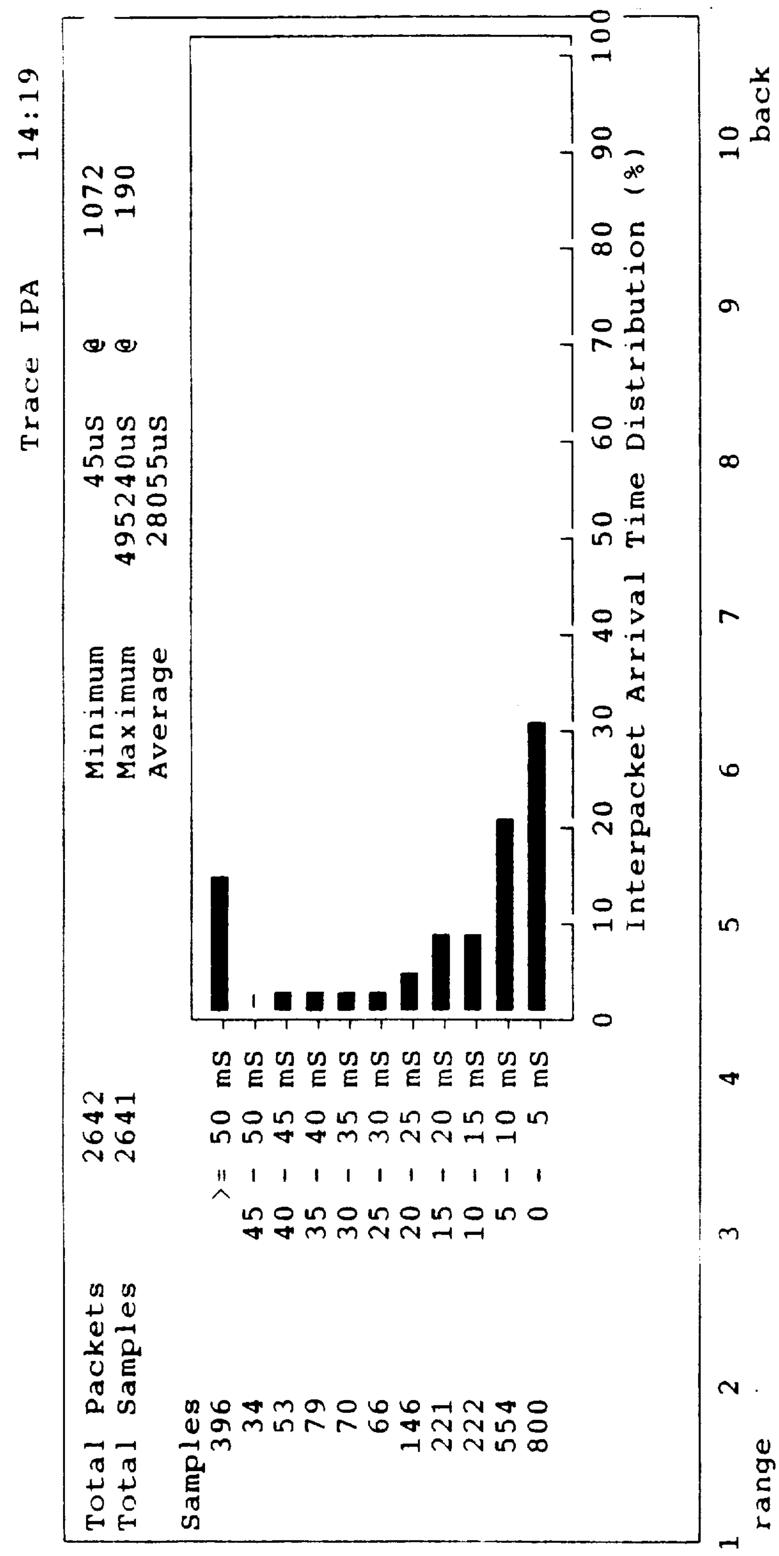


Figure 19 Intrapacket Arrival Times

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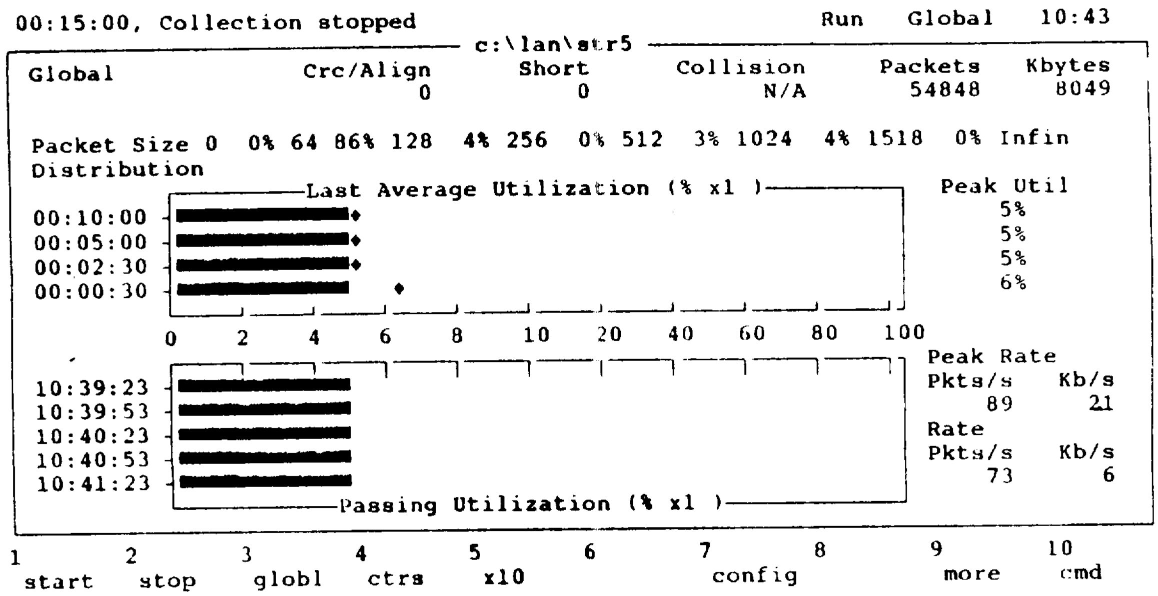

Figure 20 Run Global Screen for 5% Utilization

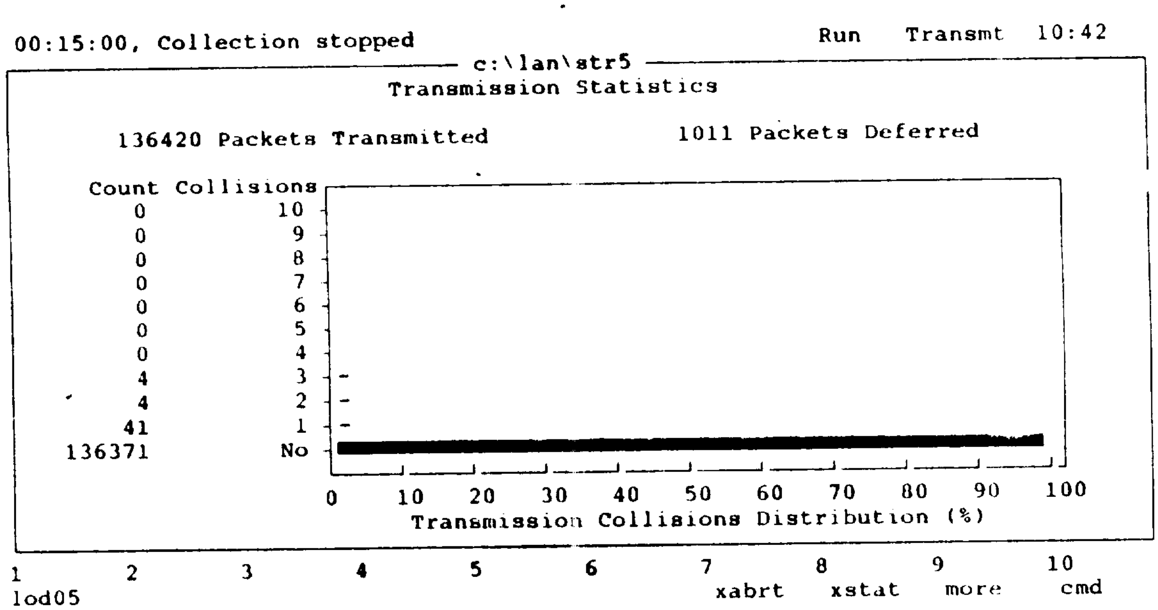

Figure 21 Statistics Transmission Screen for 5% Utilization

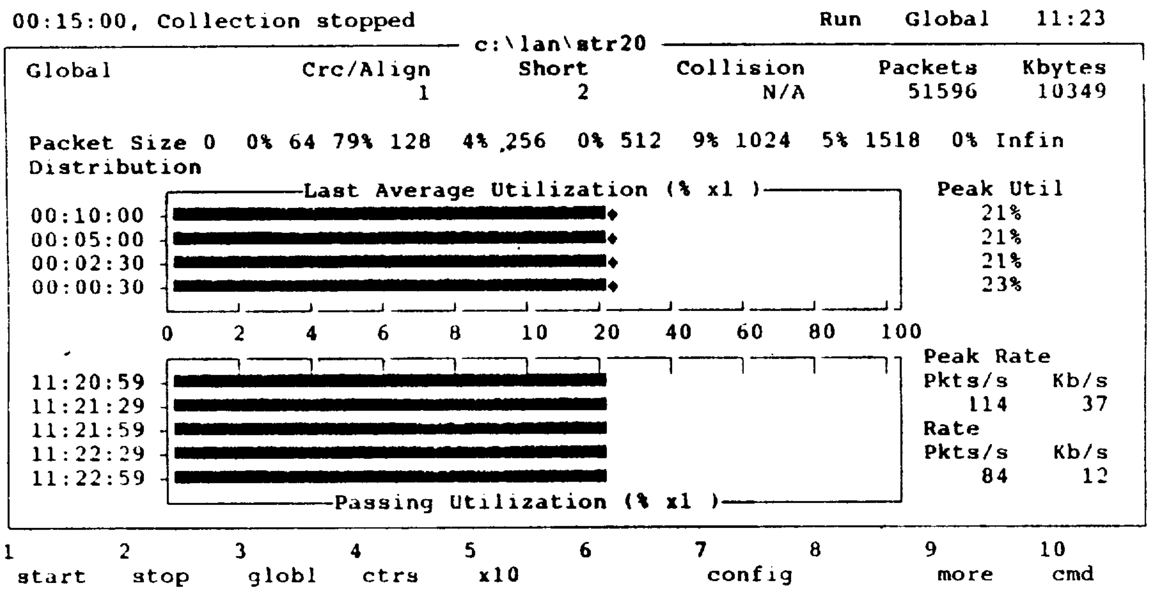

Figure 22 Run Global Screen for 20% Utilization

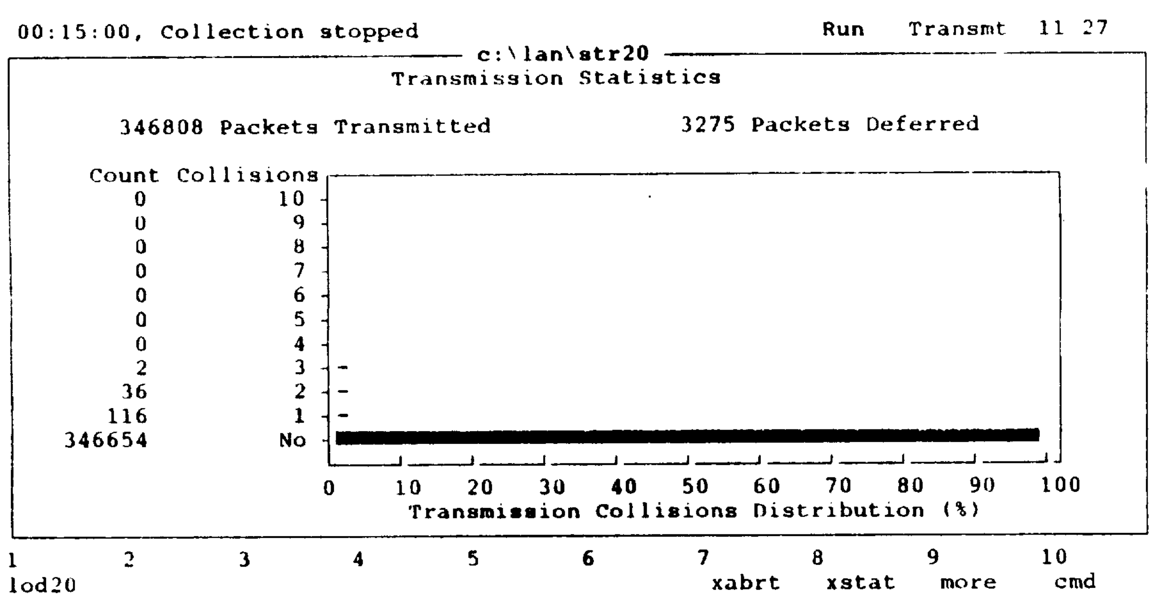

Figure 23 Statistics Transmission Screen for 20% Utilization

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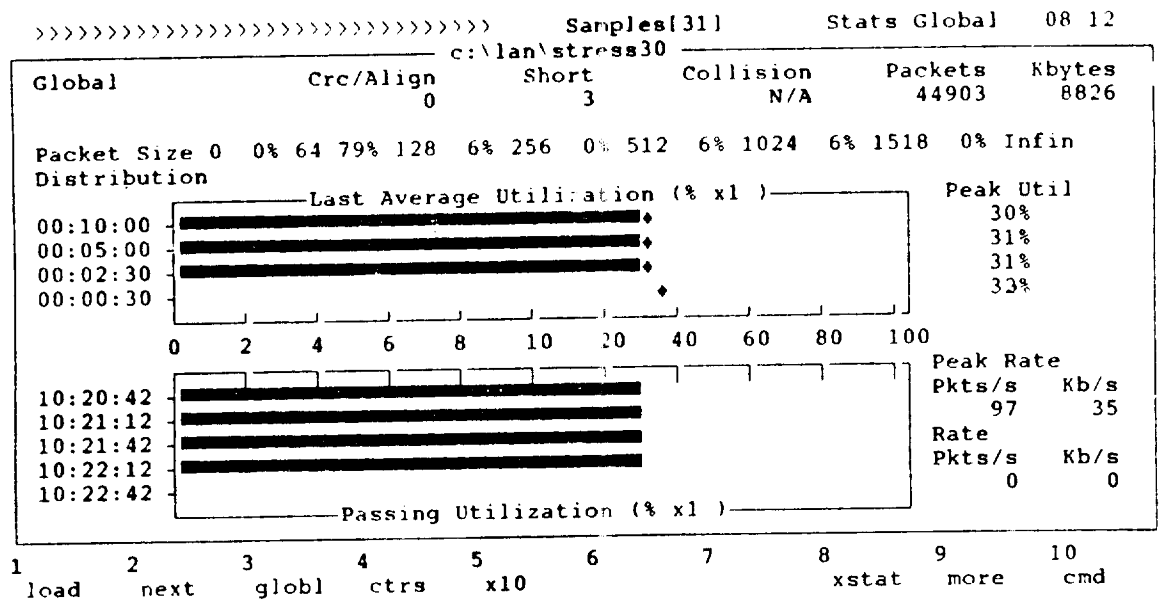

Figure 24 Run Global Screen for 30% Utilization

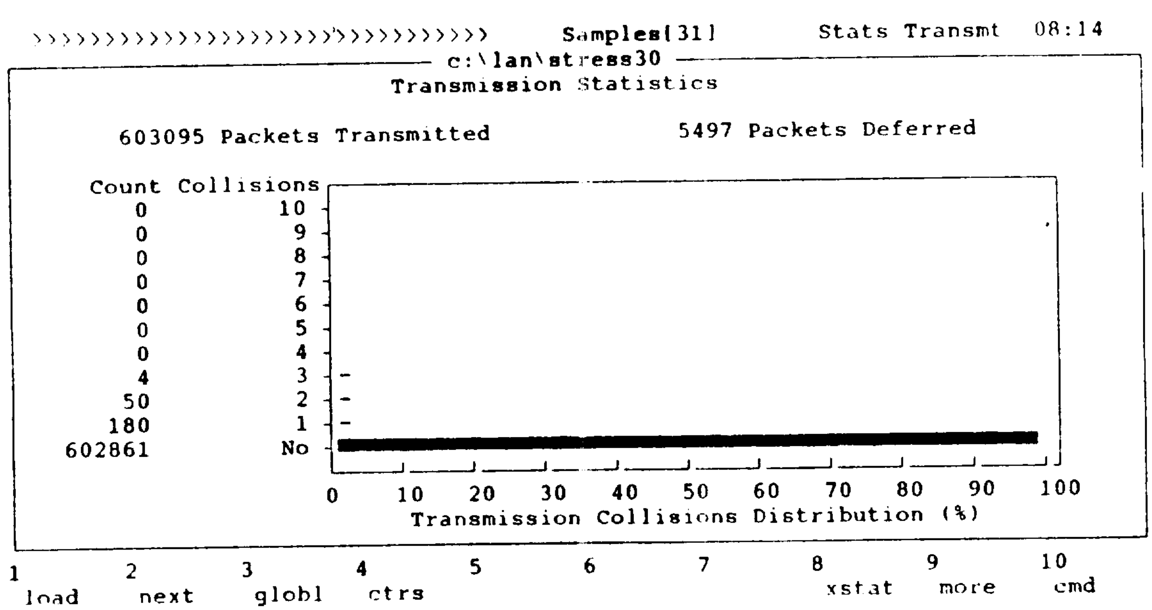

Figure 25 Statistics Transmission Screen for 30% Utilization

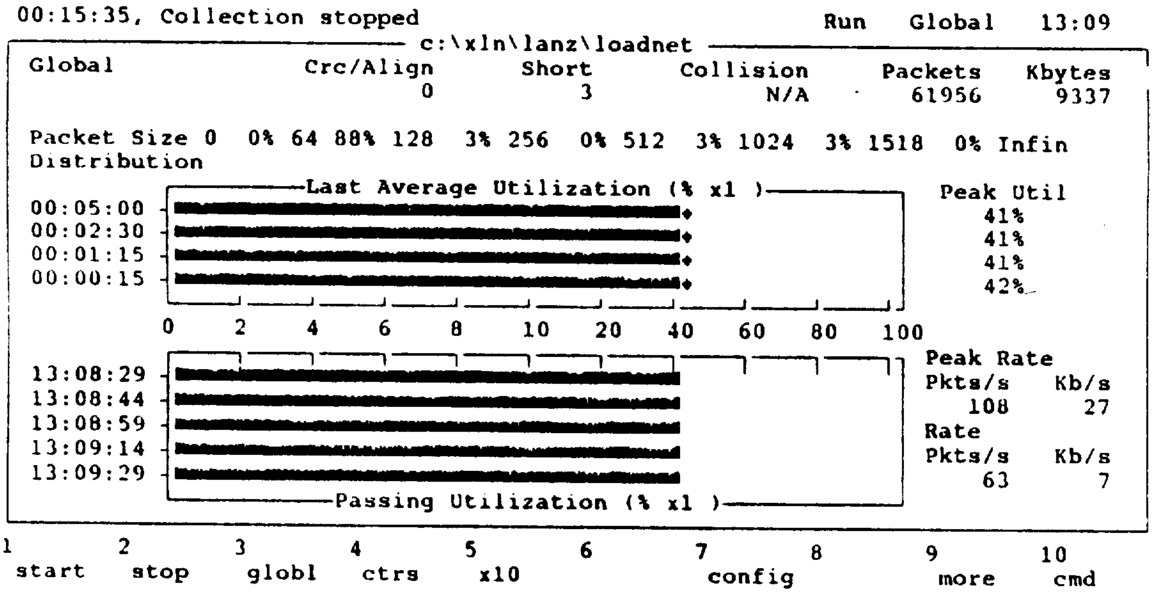

Figure 26 Run Global Screen for 40% Utilization

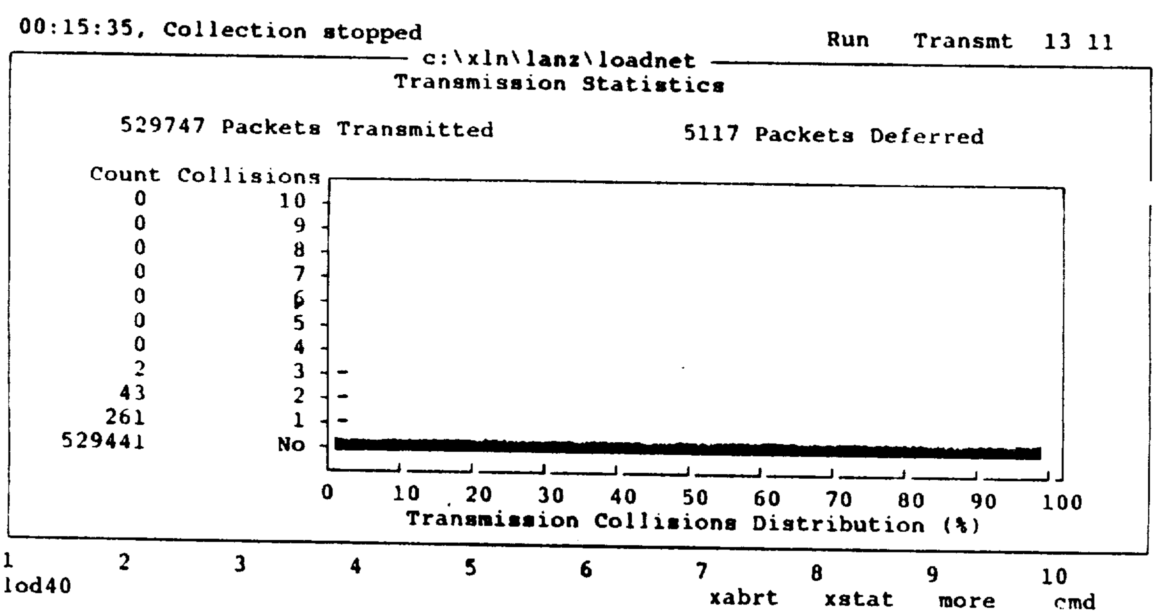

Figure 27 Statistics Transmission Screen for 40% Utilization

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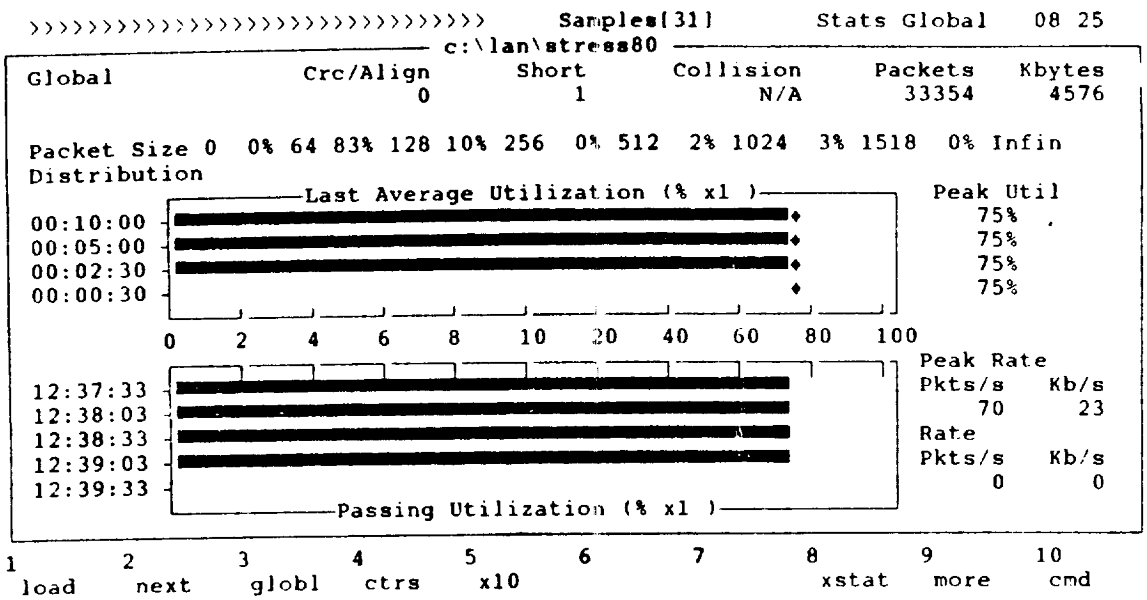

Figure 28 Run Global Screen for 75% Utilization

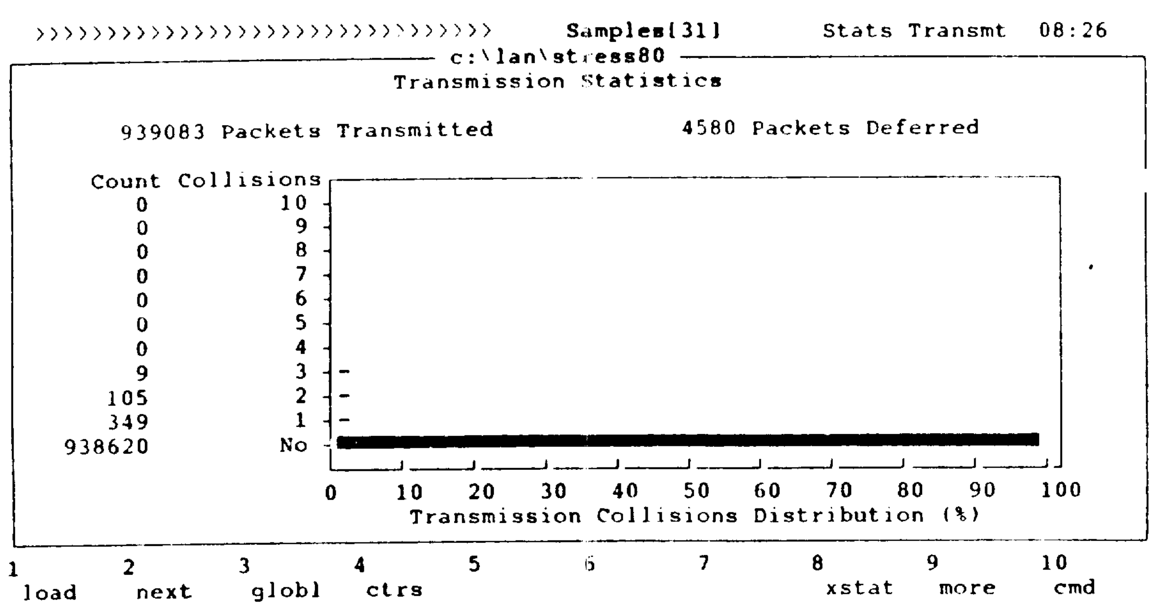

Figure 29 Statistics Transmission Screen for 75% Utilization

The packets transmitted had a destination address of 000000000000, this address will put packets on the Ethernet link, but no host will accept the packet. This test was run in the evening when there was minimal traffic on the Ethernet link. The designer was logged on while the Ethernet traffic stabilized at the various utilization levels, after stabilization attempts were made to shade a drawing, since this requires a reasonable amount of time and the transmission of numerous large packets from the VAX to the workstation. It was determined that the operational times were negligibly different through the 83% utilization level and the request/completion time was about 1 minute and 15 seconds for all utilization levels.

This test implies that the effective bandwidth is at least 83% and according to published data (ref. 7) should be 100% of the 10 Million bits/second Ethernet capacity. Although, the model used is a single source for the generated traffic, rather then using N sources each generating M packets/second to maintain N*M packets/second traffic, for which other results might be obtained.

There was also no attempt to vary packet length, while still maintaining a fixed load. This would come more closely to simulating the actual load on the network, if the packet size transmitted was the average packet size observed on the network.

8. TYPICAL WORKSTATION PROFILE

The determination of a typical workstation profile is very difficult, since there are many variable parameters. These parameters include whether the designer works in conjunction with an engineer who is supplying the work effort, thereby the designer can maintain a steady work effort as contrasted to the think-react mode; to the type of work being performed, i.e., file transfers, plot preparation, drawing file updates, new drawing generation, library creation, etc.

The following average parameters were obtained from collecting data on several workstations for three consecutive day/evening periods. The parameters obtained were,

- o Average packet size - 72 bytes
- o Peak traffic rate - 5 packets/second or
  0.64 Kilobytes/second

Additional data was taken for shading a drawing, which requires a relatively large peak packet/second rate. This resulted in the following parameters,

- o Average packet size - 385 bytes
- o Peak traffic rate - 87 packets/second or 33.5 Kilobytes/second

This information could then be used to project the amount of traffic on the T1 link due to N workstations.

8.1 USAGE ESTIMATE FOR SPACE STATION PROJECT

The Space Station CAD/CAE effort is targeted at a level of 63 workstations and it is assumed that the worst case environment would be for each workstation to have the drawing file reside on a host, rather than stand-alone systems. This would require all commands to be sent and acknowledged on the link.

Assuming another worst case scenario, where there is a peak rate burst of all workstations at same time, then utilizing the typical workstation load, it will result in a peak traffic on the link of 315 packets/second, or 22.70 Kilobytes/second.

8.2 PREDICTED T1 LINK UTILIZATION

The T1 link, which is the interface between the Space Station workstations and the NASA LAN, can support 1,544,000 bits/second and the average traffic generated is 181,600 bits/second. For the case of shading a drawing, which is a relatively file intensive operation, the T1 link should be able to support five (5) designers shading a drawing concurrently.

One can also reverse engineer the situation by determining how many packets/second the T1 link can support and then determine the relationship to the number of workstations on the Space Station project.

The 1.544 Million bit/second link can support a high of approximately 19500 packets/second for 64 byte packets to a low of 825 packets/second for 1518 byte packets. This is obtained by assuming a minimum Ethernet frame size of 64 bytes and a maximum frame size of 1518 bytes. This then results in each workstation generating between 13 and 309 packets/second as a maximum for 1518 and 64 byte packets, respectively. This is worst case, since one has assumed all traffic would be generated concurrently. The average packet length generated is 72 bytes, which results in each workstation having to generate, as a maximum, 275 packets/second concurrently with all other workstations, on the average.

9. SUMMARY AND CONCLUSIONS

The measurements reported reflect only the actual packet traffic on the Ethernet link, not the actual work effort in a design project. The workload in a design project is composed of tasks other than workstation interaction and the amount of interaction will depend upon the task.

The projected Space Station design effort, or any design effort, is not a superposition of N typical workstation efforts. Since, except in an unusual circumstance, the designers would not all be sending packet traffic on the link at the same instance. The projection is therefore a worst case scenario.

The stress test portion of the study should be expanded to include several other variations, these would be;

- o variation of packet length at various utilization levels
- o perform the test with N packet generating sources to achieve the same utilization level as with a single source
- o determine the effective bandwidth for different CAD/CAE workstation models
- o generate experimental test data on the T1 link utilization for average traffic and file intensive traffic

It would also be of interest to obtain packet information similar to that obtained on the CAD/CAE graphics sub-networks for all the NASA/KSC interconnected networks. This would reflect a system-wide utilization of the networking facilities.

From the test data obtained in this study one can conclude that there is considerable slack in the CAD/CAE graphics Ethernet network at present and it should be able to accomodate an expanded work effort. One can also conclude that the T1 link should support the planned Space Station effort with a reasonable response.

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