UQNET First Annual Report

December 1990

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Prentice Computer Centre

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Contents

Introduction

Network facilities being shared by departments at the University of Queensland are managed by the Network Management Group within the Prentice Computer Centre. The group is responsible for day-to-day operation of the network, expansion work and providing information for long term planning. This report is a review of all of these activities with particular emphasis on the latter aspect. It presents information on the performance of the network during the year and examines some trends that have developed.

For the benefit of readers who are not familiar with the technical details of the university's computer networks, the report starts by taking a brief look at how networks are used and the configuration of the networks at The University of Queensland.

There has been considerable activity in networking this year. Analysis of statistics have shown exponential growth occurring in parts of the network. To cope with the growth this year a number of significant improvements were made to the network. These achievements are summarized in the section on network activity during 1990. An enormous effort was put into management of the network and an overview of the approach being taken toward network management is also included in this document.

The Network Configuration

The computer networks being used at the University of Queensland are quite complex. To explain the configuration of the networks, it is necessary to first have an understanding of how computer systems use the networks in general.

Computers utilize networks to communicate with other computers. Communication is necessary to perform such tasks as transferring files, sending and receiving electronic mail, logging in to a remote computer system or printing on a remote printer.

Computer communications requires communication lines to physically connect the computers together and protocols to define how the computers will talk to each other over those lines. Figure 1 shows the relationship between computers, protocols and physical networks.

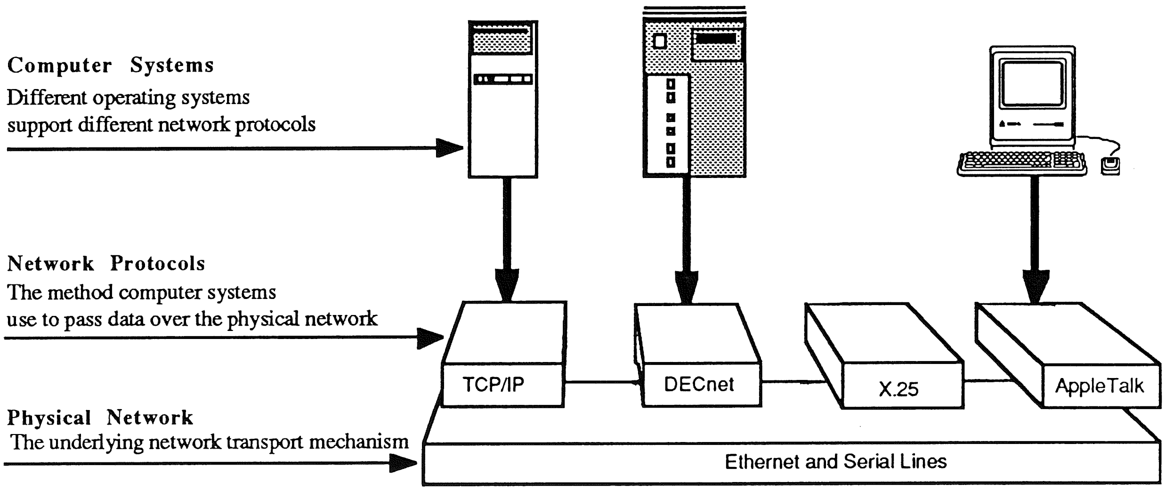

Figure 1
Network Configuration

At the lowest level are the physical networks. These are the wires, cables and electronic equipment that provide the connections between computers. At the University of Queensland there are two main types of physical networks being used, one is the serial line and the other is ethernet. Serial lines are used for lower speed links over long distances. Speeds used on serial lines are in the range of 9600 bps (bits per second) to 2Mbps. Ethernet is used for high speed communications on campus. It has a theoretical bandwidth of 10 Mbps.

Computer systems use standard methods of passing data over the physical networks. These standards are called network protocols. Quite a number of protocols have been developed for computer communication. Which one you use depends on the computer system and the physical network you are using. Different computer operating systems (eg. Unix or VMS) generally support different networking protocols, although many now support multiple protocols. Examples of network protocols currently being used on campus are TCP/IP, DECnet, X.25, AppleTalk and IPX.

A typical example of how computers communicate over the campus network is shown in figure 2. In the figure the uVAX II is using the AppleTalk protocol to communicate with the Apple Macintosh. They are using an ethernet network to make the physical connection. At the same time the IBM - RT is communicating with the Sun 3/50 workstation using the TCP/IP protocol over the same physical ethernet network.

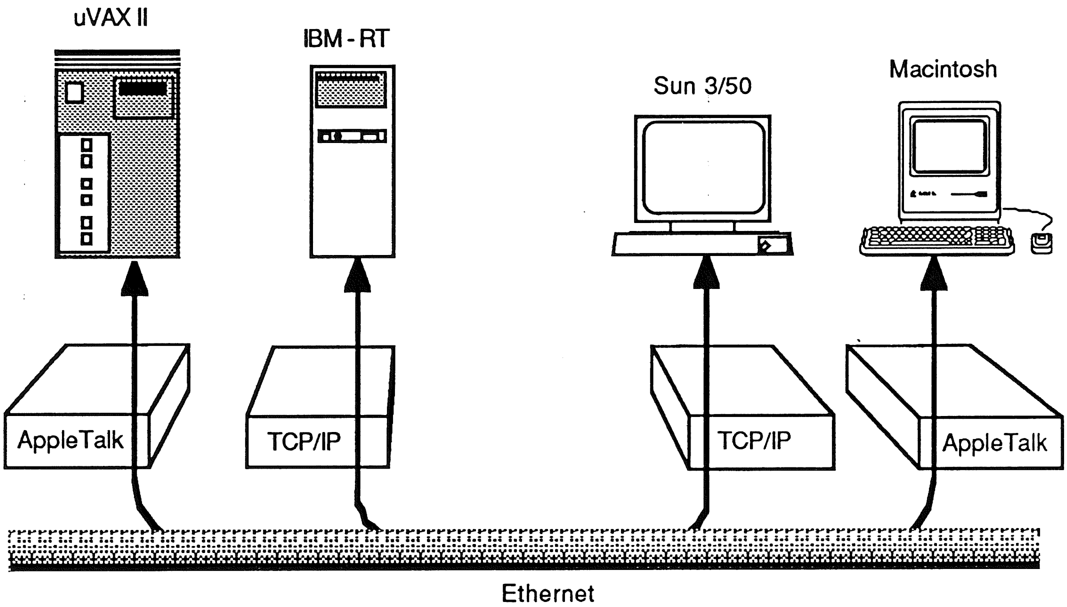

Figure 2
How Computer Systems use the Network

The networks at the University are designed around the use of a number of network protocols over a number of different physical networks. Sometimes networks are described by the protocol being used and sometimes they are described by their physical connections. We use a combination of both methods to describe the configuration of the networks used at the University of Queensland. The following sections give a brief overview of those networks.

UQNET

The name UQNET is used to refer to all the network facilities at the University of Queensland. Figure 3 shows a map of UQNET. The map is a simplified representation of the network. It uses lines to show physical connections and groups computers into areas according to the network protocols they use.

Serial lines are shown as dashed lines and ethernet is represented by the thick black line that snakes through the various protocol areas. Ethernet is the preferred method of connection to UQNET because it is a high speed physical network that supports many network protocols. Departmental ethernet segments are connected to the campus backbone ethernet by the device labelled WALLABY. It is a device called a Bridge/Router which can make the physical connection between ethernet segments but it also interprets network protocols so it helps to control the flow of traffic at the protocol level. Because WALLABY is such a useful network device it is playing a central role in current ethernet expansion work.

The UQNET map attempts to show the protocols being used by grouping computers according to protocol. Computers that support two protocols are placed on the boundary of the appropriate two areas. Unfortunately for the map drawers, computers have recently started to support many protocols. For example UQVAX now supports DECnet, TCP/IP, X.25, LAT and AppleTalk. So this type of diagram will not be used for much longer.

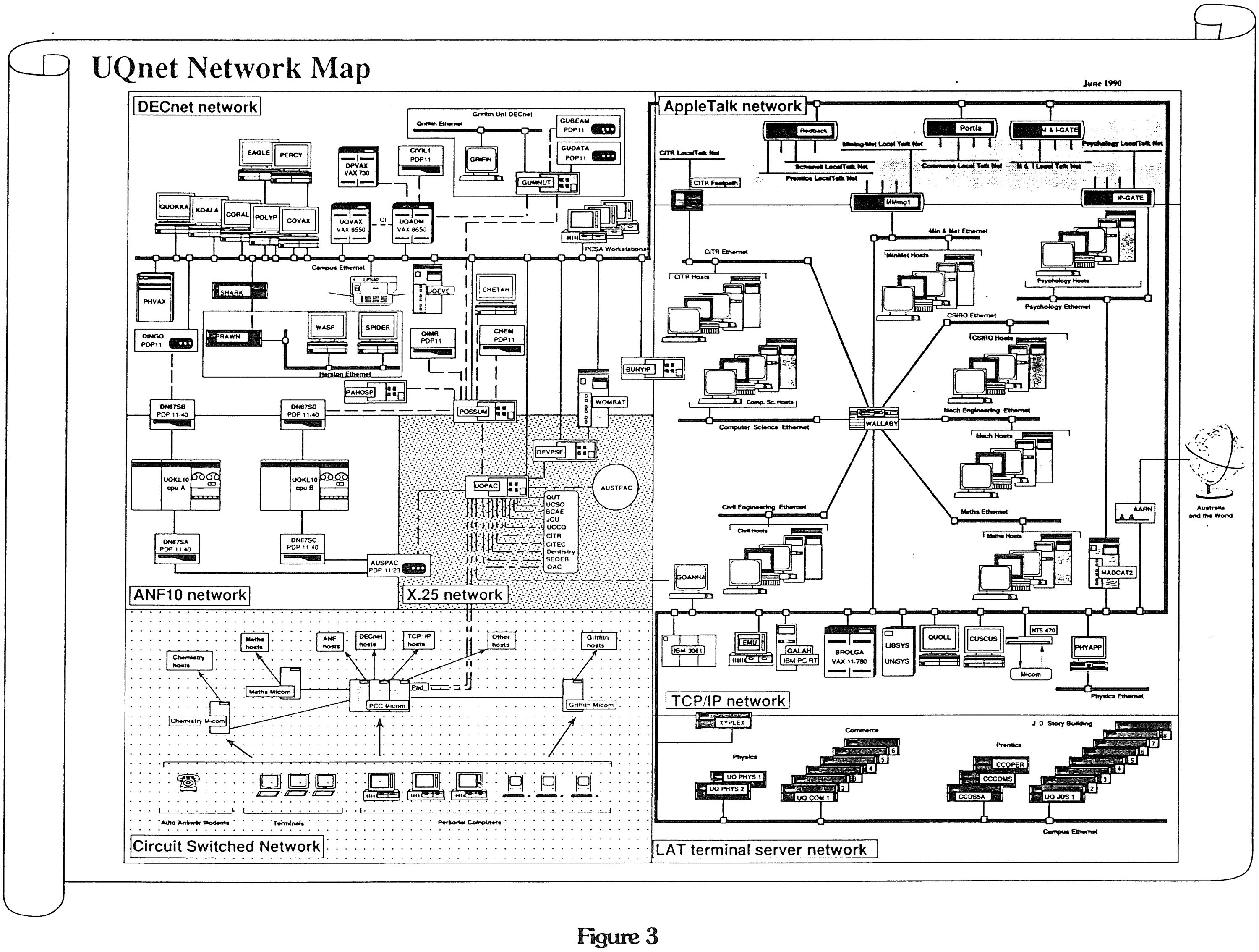

Figure 3
Network Map

QUESTnet

The UQNET network has connections to other tertiary institutions in Queensland. The network formed by these connections is called QUESTnet. Figure 4 shows the topology of QUESTnet. It has serial communication lines operating at 48Kbps to institutions at Townsville, Rockhampton and Toowoomba. QUESTnet also has 2Mbps serial lines in Brisbane linking QUT and Griffith University to the network.

The network supports three protocols in its current configuration, they are DECnet, TCP/IP and X.25. This gives all the tertiary institutions in Queensland ready access to computer facilities at each other's sites. For example, administration staff at James Cook University in Townsville can interrogate the QTAC database that resides on the IBM 3081 at the University of Queensland.

At the bottom of figure 4 is an arrow pointing to Melbourne. This arrow represents a 48Kbps serial line that connects QUESTnet to the Australia-wide network described in the next section.

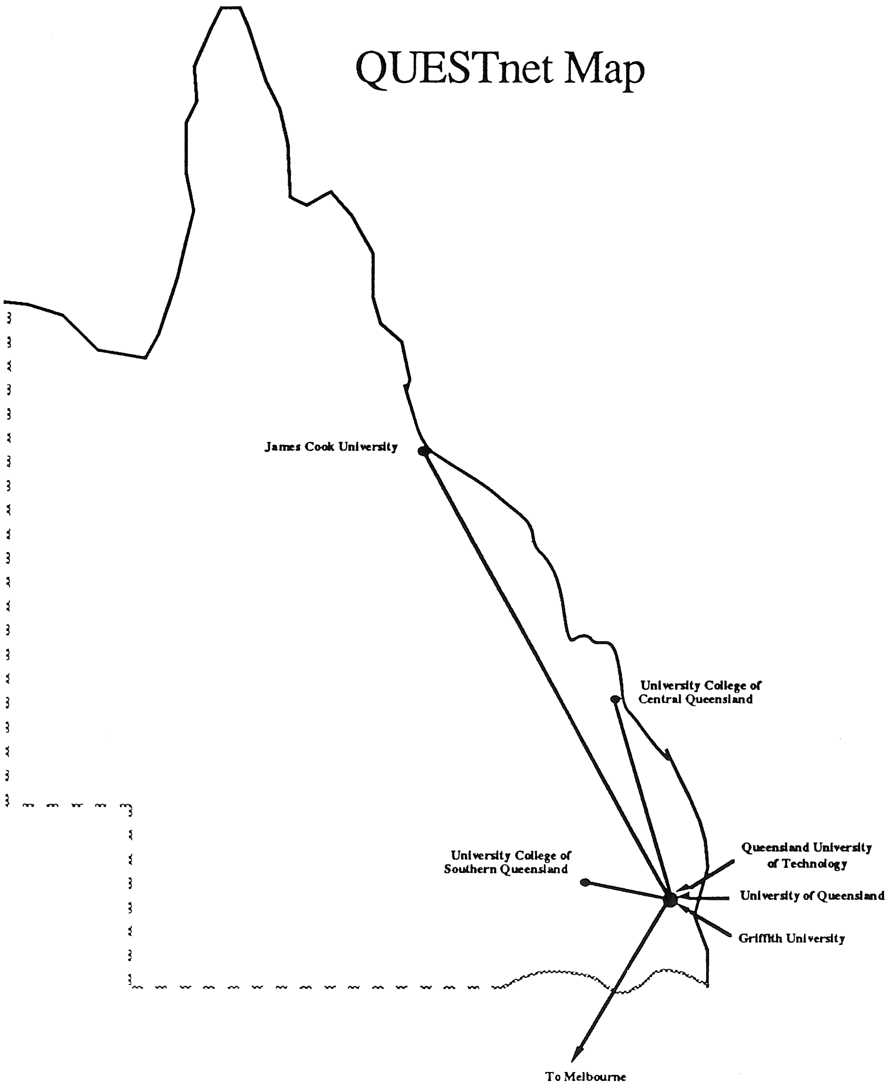

Figure 4
QUESTnet Configuration

AARNet

In May this year the Australian Academic and Research Network (AARNet) was commissioned. AARNet connects tertiary institutions in all Australian states to form a national network. The network uses a star topology for the backbone links as shown in figure 5. The star is centred on Melbourne with serial lines connected to each state capital city. In each state region institutions are connected back to the point where the backbone line terminates by more serial lines. The QUESTnet network discussed in the previous section is an example of how a state region of AARNet is configured.

AARNet has a line that connects the network to international networks. The line is a permanently leased satellite link running at 128Kbps. The other end of the satellite link is on the West coast of the USA where it is connected to a network that encompasses all of the American government agencies' networks. This large international network (of which AARNet is a part) is called the Internet.

A number of protocols are now supported over AARNet. Initially the network was configured with TCP/IP only. This protocol is supported by many computer systems and AARNet sites have been using TCP/IP to work with computer systems inside and outside Australia. DECnet was added to the network during the year. It is being used mainly for communication between Digital Equipment Corporation VAX/VMS systems within Australia. There are no plans to extend DECnet outside Australia at this stage.

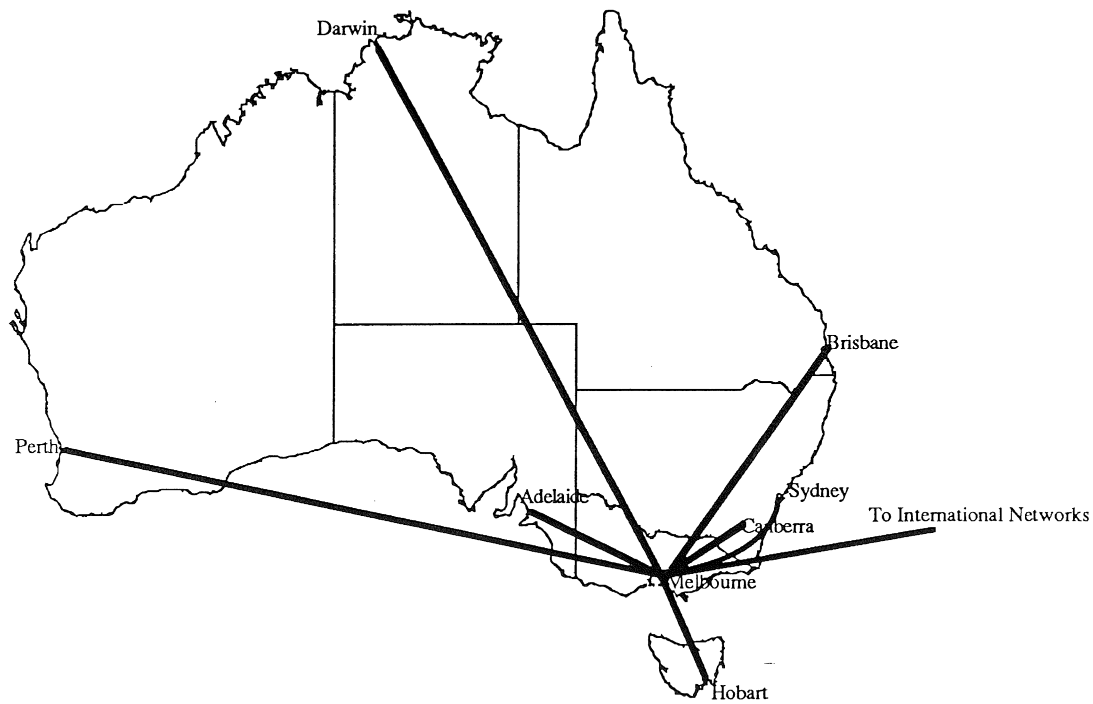

Figure 5
AARNet Configuration

Network Activity during 1990

There was an overall growth of the network during 1990. To cope with this growth a number of improvements were made to the constituent networks and their management.

Overall Growth

An indication of the overall growth of the network can be gained by looking firstly at the growth in the underlying physical network and secondly by looking at the growth in traffic for a particular protocol being used over that network.

There are a number of parameters that could be used to measure the growth of the physical network. You might measure the total length of cable on campus or the total number computers connected to the network. Both of these parameters would be extremely difficult and expensive to measure, and they would still only give a simplistic view of growth because they do not account for the types of physical network being used.

While it may not be a definitive method, another way of assessing the growth in the physical network is to look at the amount of money being spent in that area. The Prentice Computer Center performs a lot of the network installation work for university departments and records show that this year there was a 38% increase on 1989 spending. It can therefore be assumed that the physical network has experienced a similar level of growth in 1990.

Some indication of the overall growth in the use of the network can be gained from measurements of the amount of traffic on the network. The analysis section of this report gives details of this sort of information for each part of the network, but an idea of the overall growth can be gained by an examination of traffic using a particular protocol.

On the next page figure 6 shows how the DECnet network has grown in 1990. It can be seen that total traffic measured on a monthly basis has experienced an exponential rise. The line showing the transfer rate is an indicator of the performance of the network. This transfer rate is affected by traffic using other protocols in addition to DECnet, however there was a general trend indicating that as DECnet traffic increased, performance decreased. Transfer rates decreased from a high in February a consistently lower level in July. An ethernet expansion in August brought the performance back up to earlier levels for the latter months of the year.

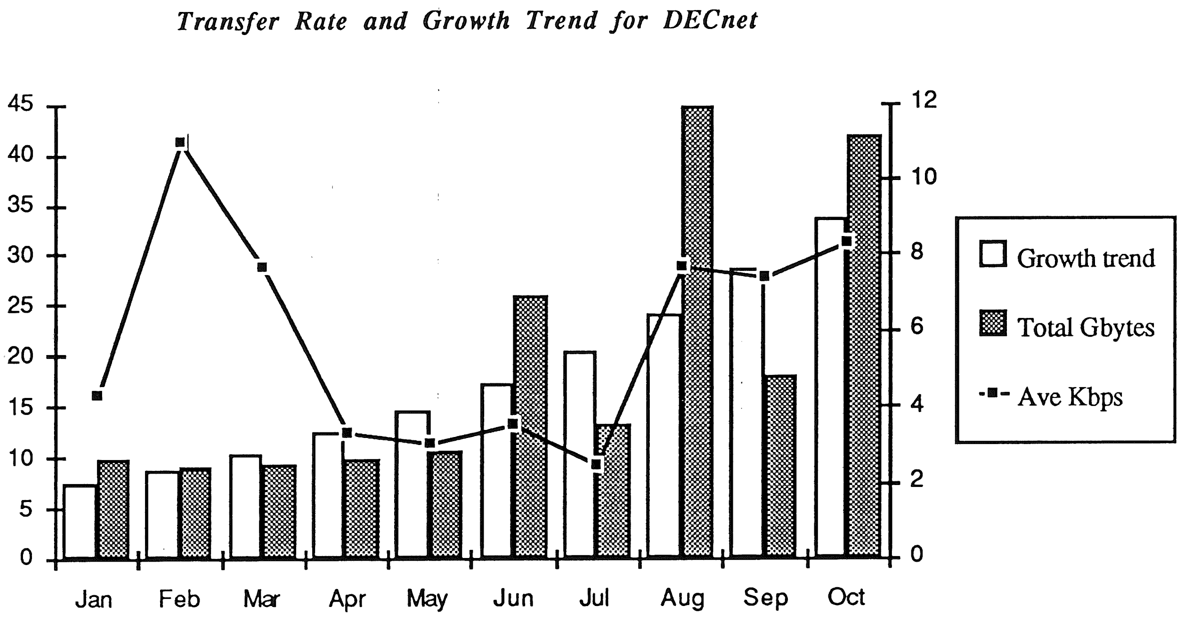

Figure 6
DECnet Growth in 1990

The cycle of traffic growth, followed by network expansion, followed by further traffic growth was obvious in 1990. This trend is expected to continue into 1991 necessitating the installation of faster physical networks and higher performance computers.

Development

Development activity during the year focused on expanding the physical network, improving network management and increasing connectivity to state and national networks. Some of the major milestones in these areas are discussed here.

The Physical Network

May - Bridge/Router installed in network.
This device was installed to provide a more versatile method of connecting departmental computer networks to the campus backbone ethernet.

August - Ethernet repeater equipment installed in Joyce Ackroyd building.
A major upgrade to the campus ethernet network provided services to departments in this new building.

September - 2Mbps equipment installed.
High speed serial lines were installed between The University of Queensland, QUT and Griffith University. This was the first equipment installed as part of the plan to interconnect the four universities in South East Queensland with high speed computer networks. This work is being performed for a project called *The Technology Quadrangle*, which aims to provide researchers with ready access to the resources at each of these universities.

Network Management

January - Network Management computer commissioned.
A VAXstation 3100 workstation was installed to perform network management tasks using specialized software.

October - Network Operator started work.
A network operator was recruited into the network management group to improve service.

QUESTnet/AARNet developments

March - X.25 Packet Switch Exchange upgraded.
The uVAX I computer used to switch X.25 traffic was replaced by a uVAX II. This upgrade more than doubled the speed of the packet switch exchange, allowed more lines to be connected and improved hardware maintenance support.

July - UQ nodes in national DECnet.
Two VAX/VMS systems at Prentice Computer Centre were reconfigured to use DECnet protocols over AARNet.

September - Library working over AARNet.
The library on-line catalog system successfully implemented the TCP/IP protocol allowing access from AARNet.

Managing the Network

Network management at the University of Queensland is performed by the Network Management Group at Prentice Computer Centre. The group consists of a Manager and an Assistant Manager and a Network Operator.

This group performs numerous tasks but to understand the nature of these tasks they can be classified into five major categories:-

1. Monitoring
2. Diagnosing and repairing
3. Security management
4. Configuration management
5. Statistical analysis

These five categories are examined in more detail in the sections that follow.

Monitoring

Any problems that might occur in the network need to be detected as quickly as possible if disruptions to network services are to be minimized. Ideally problems should be fixed before users become aware of them. To achieve something close to this ideal, the network is monitored for fault conditions.

Most of the monitoring is performed using special programs running on computers dedicated to network management. These programs will raise an alarm if certain network parameters exceed preset thresholds or when a data link in the network fails completely.

Diagnosing and Repairing

When a problem is detected by monitoring it then must be diagnosed and repaired. Diagnosing is done using specialized software and equipment. Once the exact nature of a fault is understood it will be either repaired immediately or equipment might be re-configured to isolate the fault. It can then be repaired at a more convenient time.

Security Management

Security issues often arise in the management of a computer network. One area of concern is that of unauthorized capture of sensitive data transmitted on the network and another is the threat of a computer network virus attack.

When designing a computer network thought needs to be given to how secure the network is against unauthorized access. If the network is carrying sensitive data, equipment can be chosen to minimize the risk of someone "tapping" the network. An example of this type of sensitive data is that used for payroll, personnel, and university administration. To improve the security of that data on the university network, the Network Management Group initiated a major modification to the configuration of the campus network.

Computer viruses can attack computer networks. To guard against such an attack on the university network, the group keeps up to date with the latest information on viruses and anti-viral software. As another measure the group is represented on the Prentice Computer Centre's Security Committee which meets fortnightly to discuss ways of ensuring computer systems are safe from hackers.

Configuration Management

Computer networks require databases of information about computers in the network and about how the network is connected together. It is therefore part of the network management task to maintain these databases. Network management staff have established and now maintain network configuration databases for the university.

To keep track of all the network connections a series of network configuration drawings have been produced and these drawings are continually updated by network management personnel. The drawings are kept on a computer for ease of maintenance. They provide details of all network equipment configurations and are essential for diagnosing faults and making changes to the network configuration.

Statistical Analysis

Planning for the growth of the university's computer network relies on statistics that show details of how heavily the network is being used. Network management staff collect statistics on the volume of data being transferred over each part of the network. The statistics are then analysed to calculate utilization figures for communications lines and to graph trends in usage levels. The information is then used to identify bottlenecks in the flow of data around the network.

The software used for analysis of the network was developed by network management staff from a combination of standard commercial products, programs written by communications programmers and programs written by the network management staff themselves. The method of collection and analysis of statistics is frequently changed and new methods are developed as the network grows.

Other Related Work Performed by the Network Management Group

The network management staff do more than perform the key network management functions. They are involved in consulting for university departments, training other Prentice Computer Centre staff and doing evaluations of networking hardware and software.

Consulting

The network management staff spends a considerable amount of time advising departments on the most cost effective and reliable methods of configuring their networks. Issues such as methods of connecting them to the campus-wide network and what potential conflicts might arise with existing network equipment, need to be discussed. This type of consulting ensures that university money is not wasted on the purchase and installation of equipment that is not compatible with the existing network.

Training

Network management staff provide training for other sections of the Prentice Computer Centre. In particular the computer operations staff have been participating in a training program conducted by the network managers. They learn what the network is, how it operates and how it is managed. As operations personnel staff the HELP desk, this training is essential to answer user enquiries on network related matters. Now that operations staff have received suitable training help the network management group by monitoring the network outside normal working hours.

Further training is performed on an ad hoc basis as required. Network management personnel give talks at various seminars and workshops when network management issues are raised.

Technical evaluation

As new networking hardware and software is required for the expansion or upgrading of the network, its performance and suitability for the university's network is evaluated by the Network Management Group. This ensures that the equipment purchased for the immediate and future need of the network, is compatible with existing equipment, cost effective and above all reliable.

Network Analysis

The aim of network analysis is to identify potential overload conditions in the network before such problems are encountered. With this aim in mind, graphs are produced for the volume of traffic or the percentage of available bandwith being used depending on what is applicable. The following sections present this information on a protocol by protocol basis and the text gives an explanation of what can be interpreted from the graphs.

The DECnet Network

Used predominantly for communications between Digital Equipment Corporation VAX/VMS computers.

The Network Management group is using a VAXstation 3100 to monitor the network. This VAXstation (named Quokka) has been running the NMCC DECnet monitoring software since January. Using this program, statistics for the DECnet network have been collected for most of 1990.

Data

Figure 7 shows the volume of traffic over the DECnet network for the year to date. The figures shown are for the total amount of data in Gigabytes. It can be seen that there has been an increase of approximately 400% since January. The growth profile appears to be exponential however the November and December figures are needed to confirm whether that is really the trend or not.

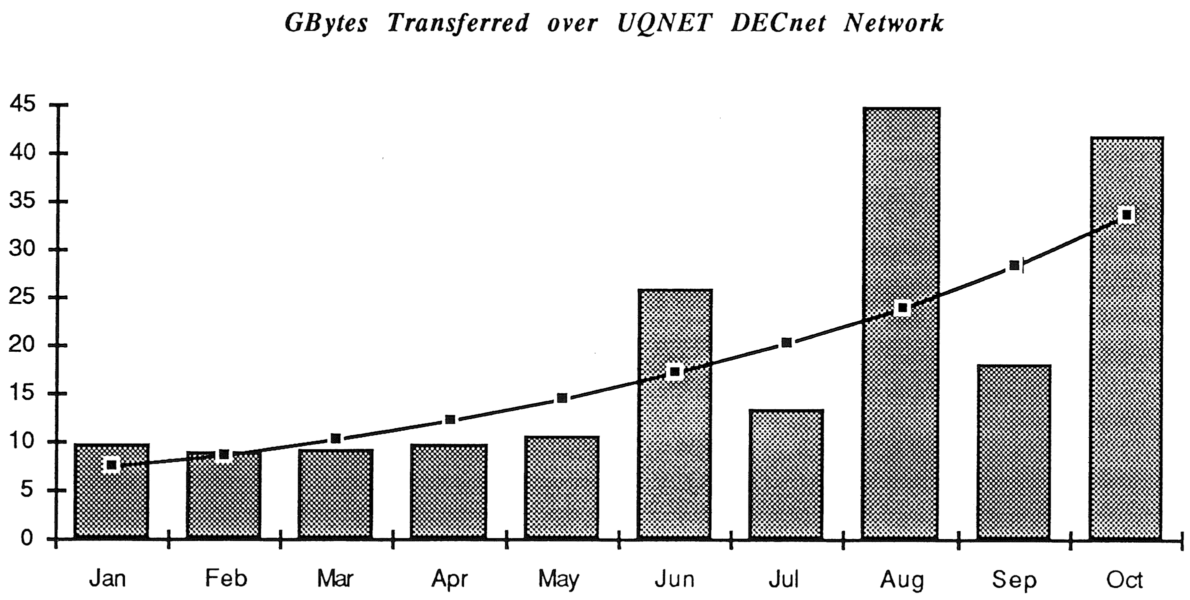

Figure 7
DECnet Traffic

The traffic statistics shown in figure 7 were further analyzed to determine the amount of traffic being generated by Prentice Computer Centre VAX/VMS systems. That analysis showed that UQVAX and UQADM were by far the busiest systems. Figure 8 displays the information graphically.

MBytes Sent or Received over DECnet by Prentice Computer Centre VAX/VMS Systems

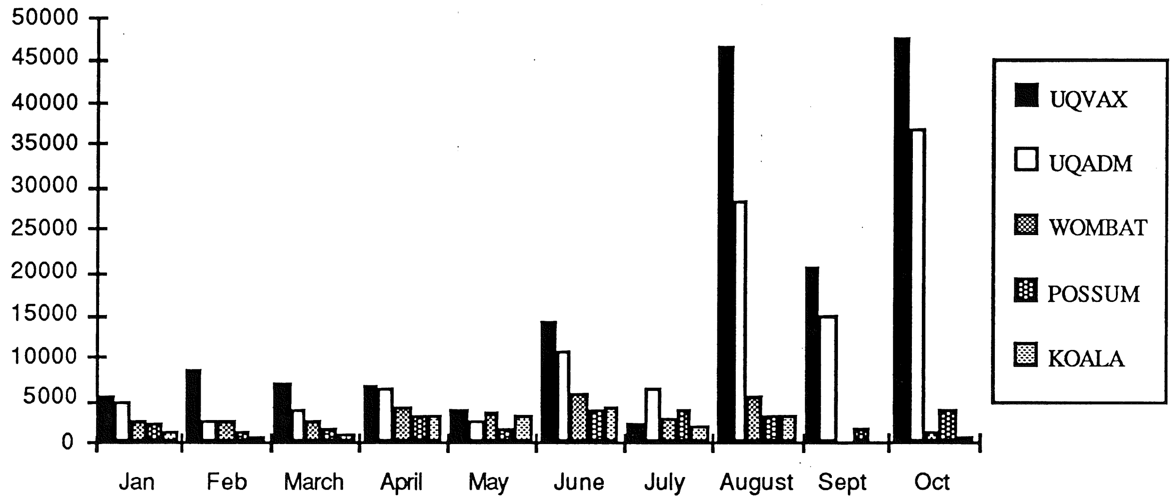

Figure 8
PCC DECnet Traffic

Network performance can be ascertained from the average transfer rate. This is a measure of the speed of a data transfer from one VAX/VMS system to another measured in KBytes/second. Figure 9 shows the plot of transfer rates for the year overlaid on the graph of the total traffic. As stated in the *overall growth* section of this report, performance dropped during the year as the traffic load increased. Traffic from other protocols does affect the performance of DECnet, but the general trend is fairly clear. The increase in performance in August resulted from expansion of the ethernet when a new ethernet bridge was installed. DECnet performance improvements can be gained by upgrading either the physical network, the VAX/VMS system hardware or the system software.

Transfer Rate and Growth Trend for DECnet

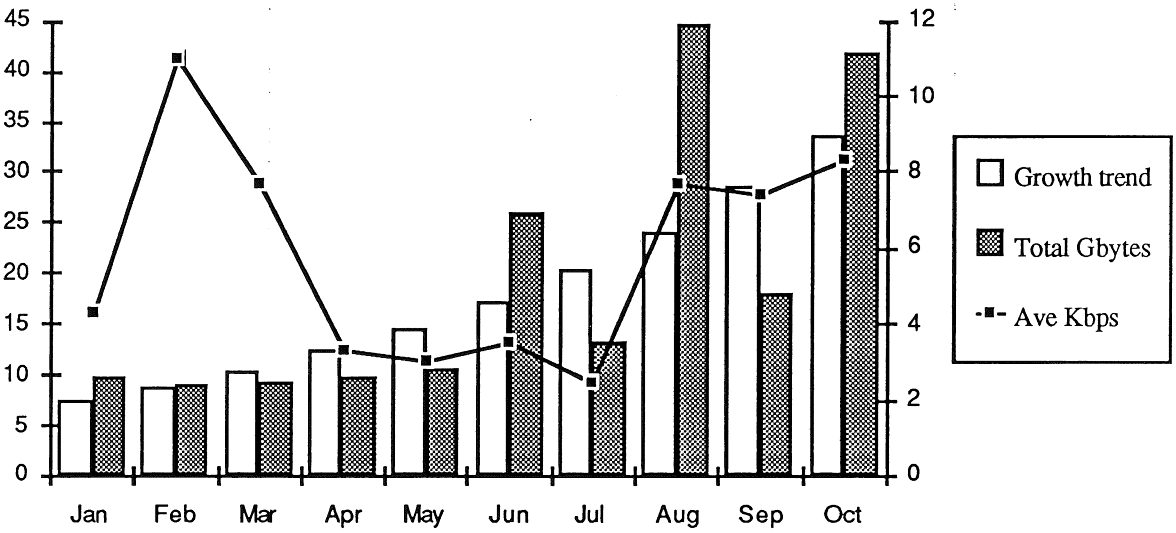

Figure 9
DECnet Growth in 1990

Conclusions

The growth experienced in 1990 is expected to continue into 1991. Therefore more DECnet upgrades will be necessary to keep up with the traffic load. The central VAX/VMS systems (UQVAX and UQADM) will soon be upgraded to higher performance hardware so that should carry the load for the immediate future. However, in the longer term improvements to the physical network will also probably be required.

The TCP/IP Network

Used predominantly for communications between computers using the Unix operating system.

Management of the TCP/IP network during 1990 has focused mainly on configuration issues. Effort was concentrated on two major areas. One was the reconfiguring of the network so departments were connected to the Wellfleet bridge/router installed in May. The other was concerned with the domain name server (DNS). This is a distributed database that holds information about configuration parameters for the network. A lot of work was done on training staff to use the DNS and on entering new information.

Reconfiguration work had to take priority over the development of tools to collect TCP/IP statistics and due to limited resources this work is still not complete. Two projects are currently in progress to develop software to be used to gather statistical information. These projects expected to be completed early in 1991. One uses software running on an IBM RT computer dedicated to the task of logging information. The second project is to develop software to use a special protocol to interrogate network devices for statistical information. The protocol called Simple Network Management Protocol (SNMP) is an international standard.

Some data has been gathered during testing of the new statistical software and statistics have been collected by the AARNet management in Canberra. This data is presented in the following section.

Data

Because statistical information available for the TCP/IP network is still fairly sparse, there is no information on the growth of the network during 1990. What is available is a comparison of the traffic levels for some departments.

Figures are now being recorded for the campus departmental subnets. Using information gathered from the Wellfleet bridge/router a comparison can be made of the volume of traffic on a number of subnets. Figure 10 shows such a comparison for the departmental subnets connected to the campus backbone network by the Wellfleet. The figures indicate that the Mining and Metallurgy transferred the most data during the week shown. In the future this sort of information (recorded over the year) will show which departmental networks need to be upgraded first.

Comparison of some IP subnet traffic for one week ending 6th November 1990

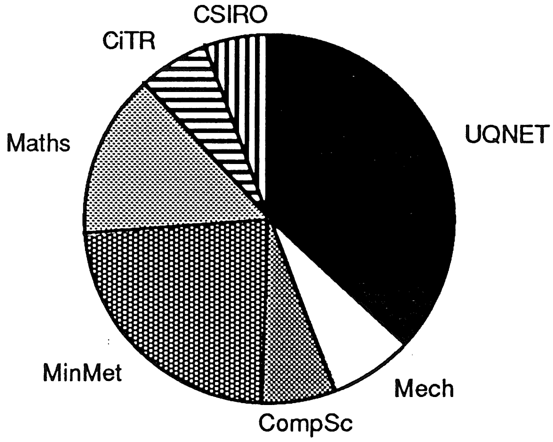

Figure 10
IP Subnet Traffic

Statistics for AARNet are collected by the AARNet management personnel in Canberra. Figure 11 shows typical data transfer rates for the satellite link to Hawaii and the links from Melbourne to some of the regional hubs. The information is for the week ending 4th November 1990.

The first graph shows that the 56Kb/s satellite link is saturating frequently. This link has since been upgraded to 128Kbps to resolve the problem. As far as Queensland is concerned the graph indicates that the 48Kbps line has sufficient bandwidth for the present level of traffic.

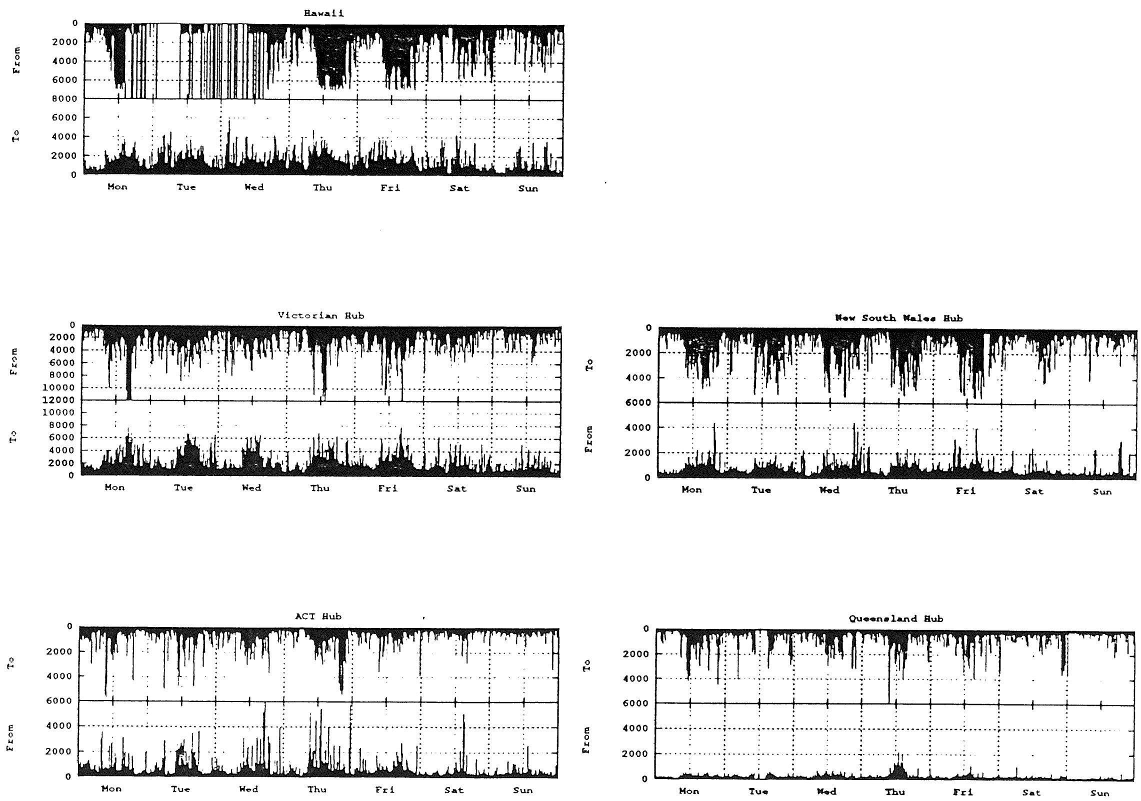

Figure 11
AARNet Hub Traffic (Courtesy of AARNet)

The AARNet management collects figures on the traffic over the regional tail links. Shown below are graphs of the traffic rates on the QUESTnet tail links for the week ended 14th October 1990. The graphs indicate that the links currently have sufficient bandwidth for current traffic levels.

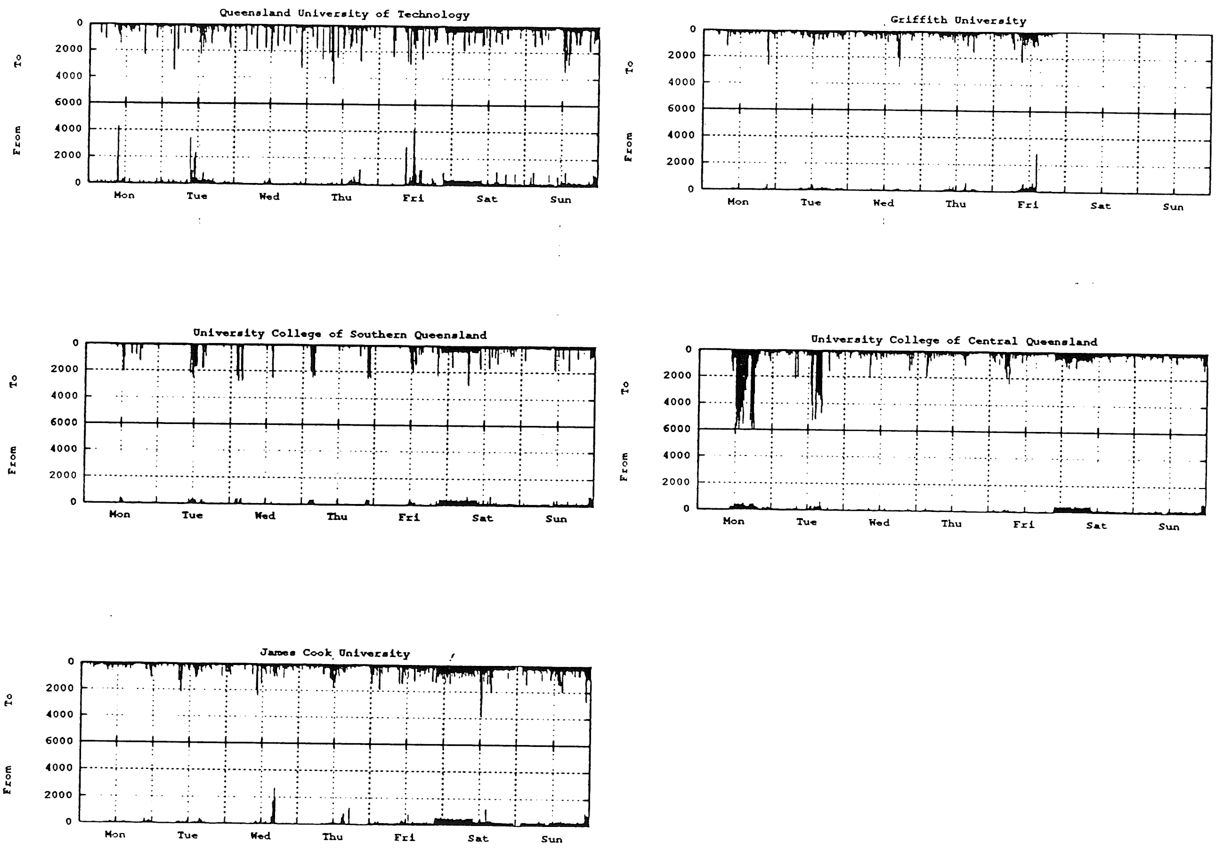

Figure 12
ARRNet Traffic on Qld Tail Links (Courtesy of AARNet)

Conclusions

There are no figures to determine the long term trends in the TCP/IP network. This situation is being addressed and figures will be available in 1991. For the QUESTnet and AARNet traffic the current levels are within the capacity of the lines. However, the lines will be monitored throughout 1991 to ensure that any rapid growth in traffic is detected before saturation problems occur.

The X.25 Packet Switch network

Used to access packet switched networks in Australia and overseas. Much of the traffic goes to AUSTPAC, the public network provided by Telecom Australia.

The Queensland network linking tertiary institutions (QUESTnet) consists of X.25 links in addition to the TCP/IP links installed by AARNet. Statistics have been collected for the X.25 links since August 1988 so there is a large volume of data available for analysis.

Data

The diagram in figure 13 shows monthly totals of traffic transferred over the X.25 QUESTnet links. It can be seen that there was an exponential rise in the monthly traffic volume until the AARNet was commissioned. Since AARNet started, the volume of traffic has been steadily reducing because some users have started to use TCP/IP protocols instead of X.25.

Total Segments Transferred over QUESTnet (in Millions)

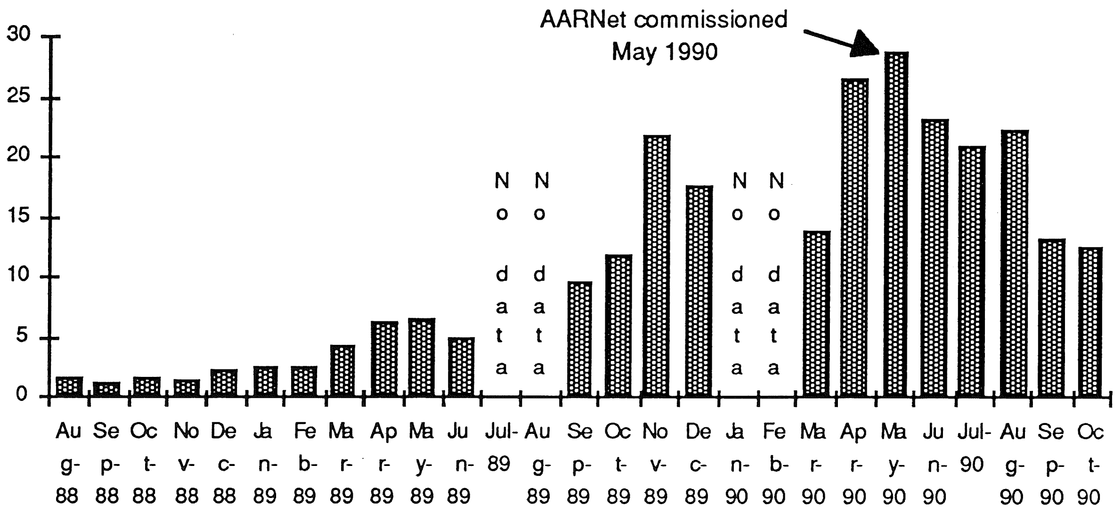

Figure 13
QUESTnet X.25 Traffic

Conclusions

The volume of X.25 traffic is reducing but there is still a lot of software using this protocol. So X.25 support will continue to be needed in the future. Currently the QUESTnet X.25 traffic is routed over serial lines which are separate to the AARNet serial lines. In the longer term, it is planned to route the X.25 traffic over the 48Kb lines used by AARNet. When that work is finished the existing dedicated X.25 lines can be decommissioned.

The AppleTalk Network

Used for primarily for communication between Apple Macintosh computers.

The campus-wide AppleTalk network now includes twenty departmental networks. These AppleTalk networks are interconnected using AppleTalk-to-Ethernet gateways connected to the campus Ethernet network.

Data

The Network Management Group has recently developed a method of extracting traffic statistics from the AppleTalk-to-Ethernet gateways on a weekly basis. The diagram in figure 14 is a graph of the figures collected so far.

Mbytes Transferred over the Campus AppleTalk Network

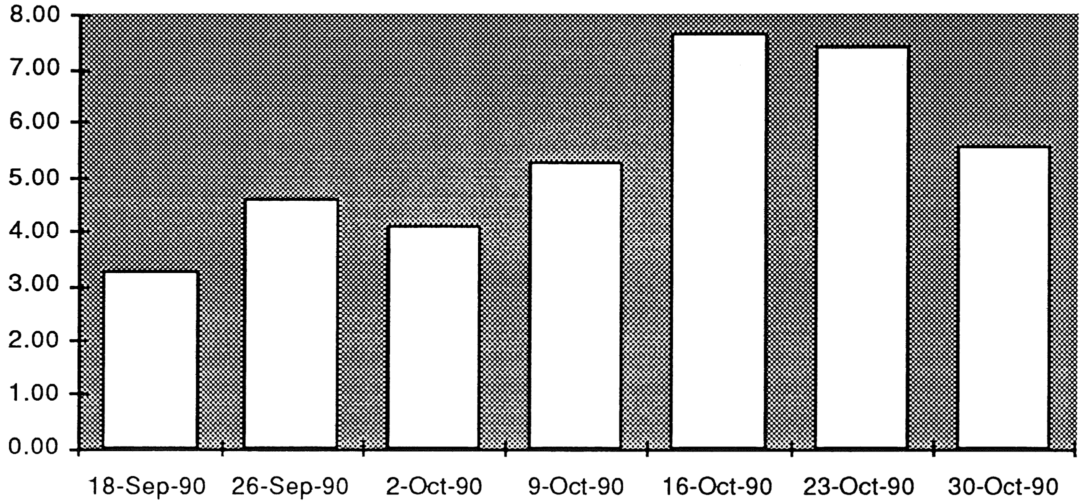

Figure 14
AppleTalk Traffic

Conclusions

There is really not enough statistical information at this stage to draw any conclusions, but the traffic level has increased in the short time that the gateways have been monitored. The number of AppleTalk-to-Ethernet gateways has increased each year so this does indicate that the use of AppleTalk on campus is growing.

The Campus Ethernet Network

The 10Mbps physical network which is the preferred method of connection to UQNET.

The campus ethernet network has grown rapidly this year. As explained in the *overall growth* section of this report, 1990 saw a considerable increase in the amount of spending on physical network installations. A major part of that spending was on ethernet facilities. As the ethernet network has grown it has been necessary to divide it into smaller segments to keep the ethernet traffic confined to those local segments as much as possible. This configuration philosophy maximizes the amount of bandwidth available for each departmental Ethernet.

Data

Because the configuration of the campus Ethernet has been changing so rapidly, it has been extremely difficult to gather long term statistics on the network. However, it has been possible to take "snapshots" of the utilization of Ethernet bandwidth throughout the year. The figures that follow show some of these snapshots. When examining these figures it should be noted that the performance of Ethernet drops off rapidly once the utilization exceeds 30 percent. Therefore if a safety margin is to be maintained, further segmentation of a network should be considered when the utilization starts to exceed 20 percent.

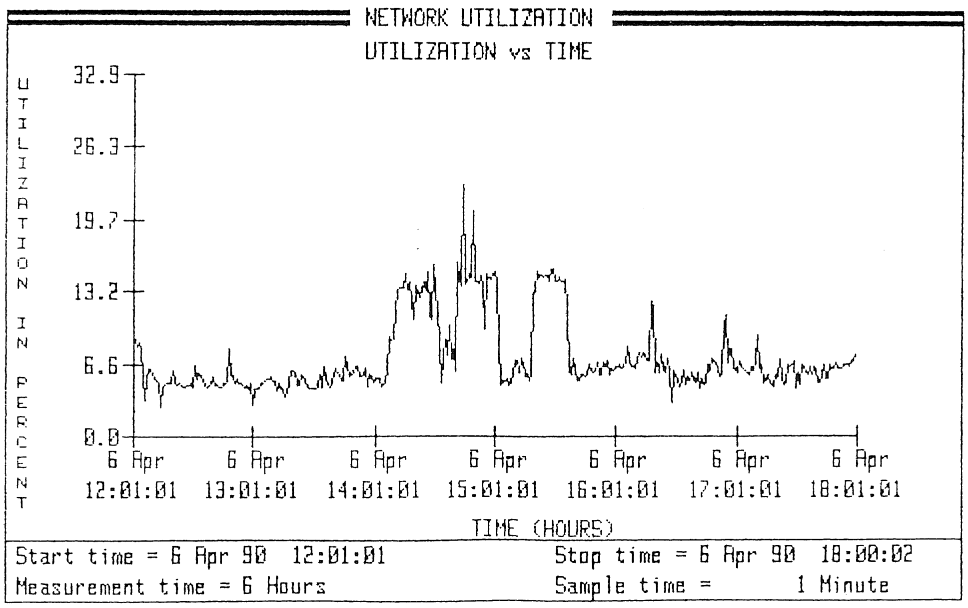

Figure 15
Ethernet Utilization on Campus Backbone - April 1990

Figure 15 shows that the campus Ethernet backbone was reaching peaks of 32.9 percent utilization in April. This was considered to be too high to guarantee acceptable levels of performance. It was decided to segment the network by installing ethernet bridges. These were ordered and eventually installed in late July. The resulting configuration put Administration and Prentice Computer Centre computer systems on separate segments to reduce the bandwidth utilization.

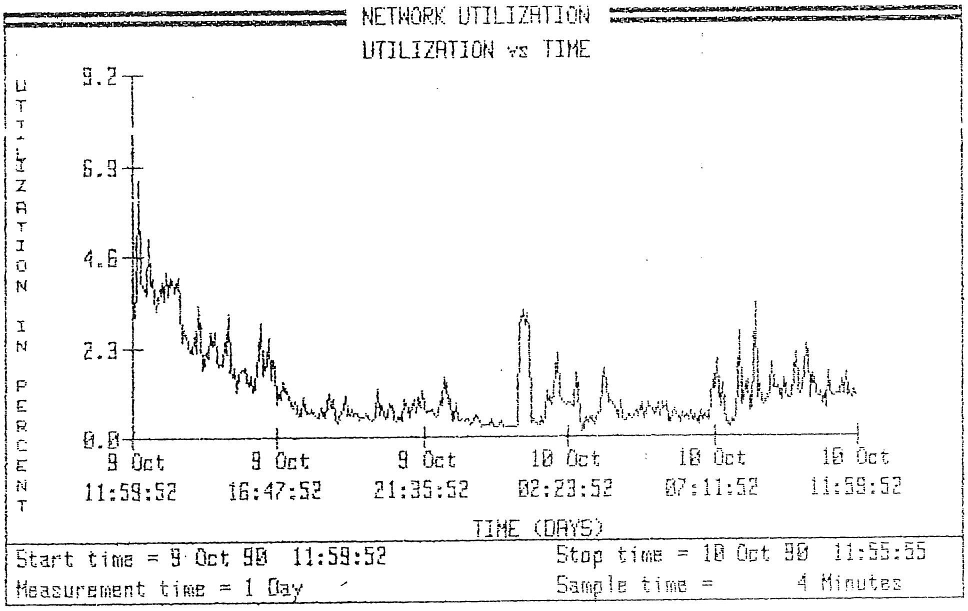

Figure 16
Ethernet Utilization on Campus Backbone - October1990

The figure above shows a typical utilization graph for the campus backbone in its current configuration. The utilization is now usually below 10 percent. The campus backbone ethernet segment now carries only the interdepartmental traffic and the off-campus traffic.

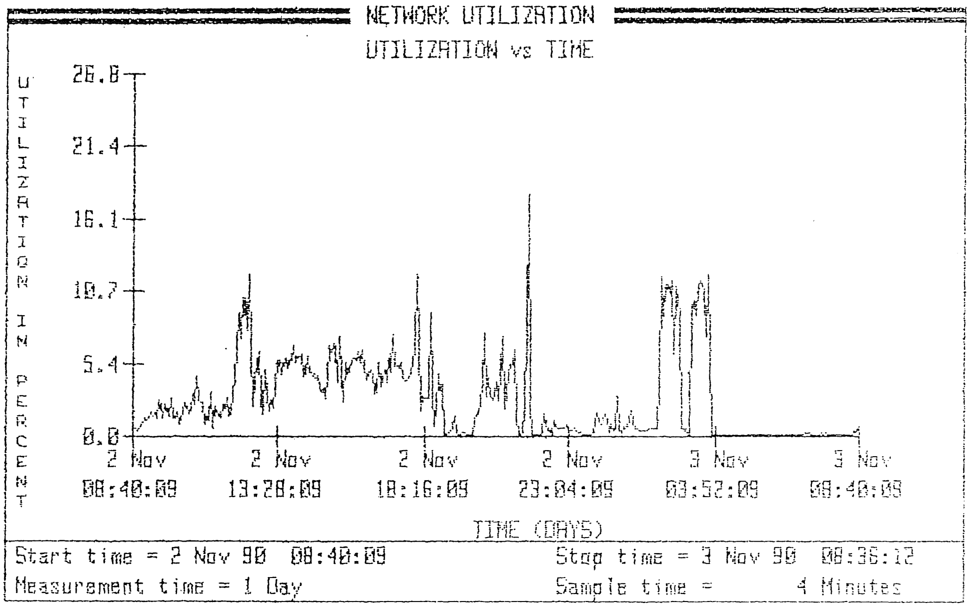

Figure 17
Ethernet Utilization for Administration Machines - November1990

The ethernet segment for Administration computers now averages less than 10 percent utilization. Figure 17 displays a typical profile taken over twenty four hours.

Statistics are now being collected on the amount of traffic seen by bridges on the network. This information gives an indication of the total volume of ethernet traffic on campus. The collection of data was started in September. Figure 18 below shows the results to date. It appears as though the amount of traffic is reducing but this could be associated with the end of the teaching year.

Weekly Totals of Frames on the UQNET Ethernet Backbone (in Millions)

(Data collected from ethernet bridges.)

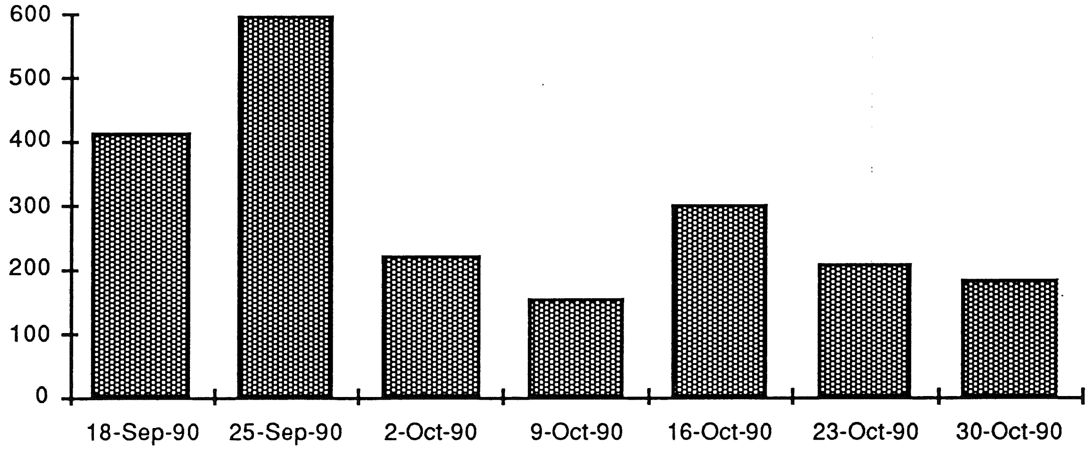

Figure 18
Ethernet Traffic

Conclusions

During 1990 performance levels for ethernet were maintained by segmenting the network as traffic loads increased. This approach cannot be continued indefinitely because there is a limit to how much a network can be segmented.

As more devices such as X-window terminals and diskless workstations are connected to the network the demand for high performance physical networks will rise. Ethernet will not be capable of meeting that demand for much longer. Therefore it is quite likely that 100Mbps FDDI networks will be required in the near future.

The Circuit Switched Network

The physical network that interconnects most serial lines on campus. It is designed around a Micom circuit switch, a device that switches user's lines to any of a number of host computers.

Statistics are being collected for lines on the circuit switched network. The Micom circuit switch reports the status of all connections it makes. That information is logged by a process on UQVAX and later analyzed using software developed at Prentice Computer Centre. The software allows any group of Micom lines to be monitored.

Data

Using the statistical information collected, a number of bottlenecks were identified in the circuit switched network this year. The first one concerned the dial-in modem bank. A graph of usage against time showed that that particular group of lines was frequently saturated. The diagram in figure 19 displays the situation being experienced. It shows how many of the seven lines available on X2922 are in use at any time. As you can see, all seven are usually in use. There are currently thirty new modems being installed to relieve this unsatisfactory situation.

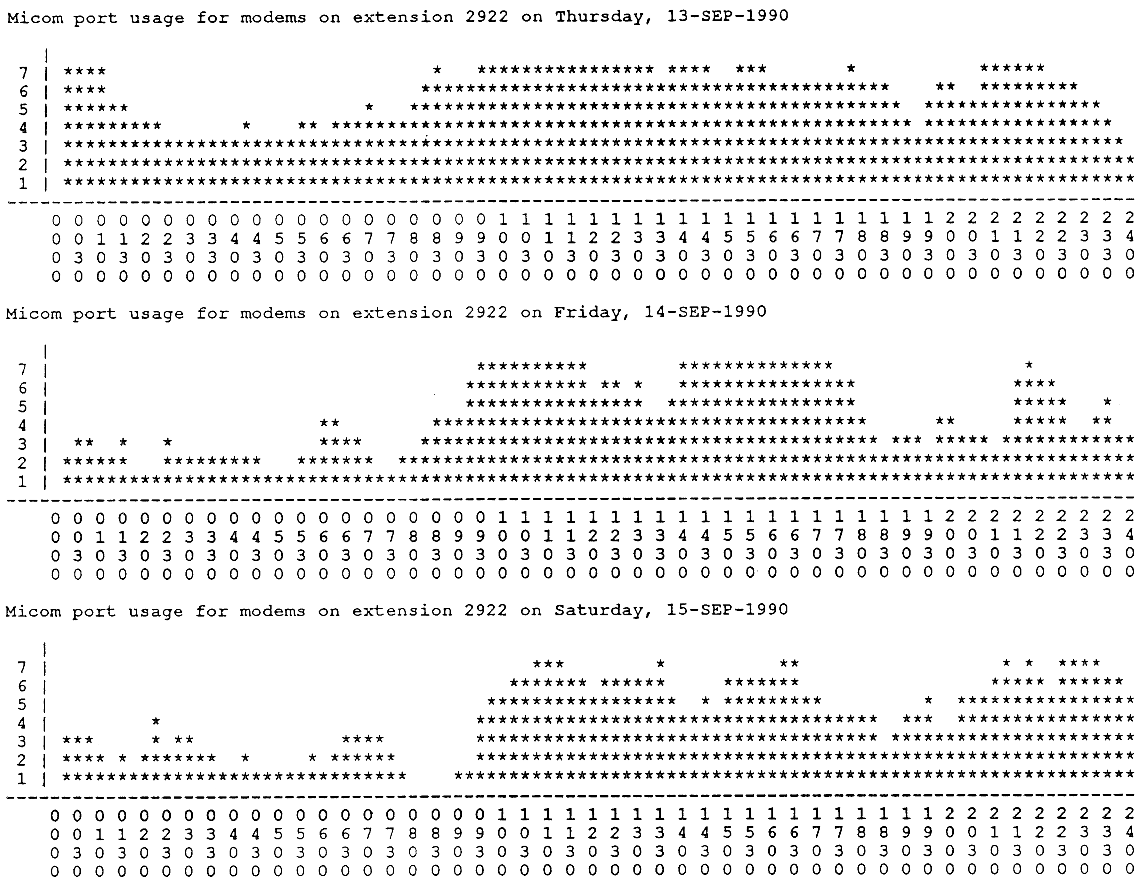

Figure 19
Availability of Modem Lines on 2922 - September 1990

The second problem area identified this year concerned lines connected to the DS500 terminal server. It was discovered that the lines would remain connected even if users had no active sessions logged in. This limited the availability of lines and all 16 were therefore often in use. (See figure 20 below.) To improve the situation a timer was enabled to disconnect the line after half an hour if no sessions were logged in. Figure 21 shows the effect of the change. You can see that it is still reaching saturation, but for much shorter periods. More terminal server lines are now being installed to eliminate this problem.

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Micom port usage for Micom lines to the DS500 on Friday, 31-AUG-1990

   |
16 |
15 |
14 | ***                      ********** *********** **  ********************           ***  **
13 | ****    *********       ************************************************        * **************
12 | ************************************************************************************************
11 | ************************************************************************************************
10 | ************************************************************************************************
 9 | ************************************************************************************************
 8 | ************************************************************************************************
 7 | ************************************************************************************************
 6 | ************************************************************************************************
 5 | ************************************************************************************************
 4 | ************************************************************************************************
 3 | ************************************************************************************************
 2 | ************************************************************************************************
 1 | ************************************************************************************************
-----------------------------------------------------------------------------------------------------
     0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2
     0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 0 0 1 1 2 2 3 3 4
     0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0
     0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

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Micom port usage for Micom lines to the DS500 on Saturday, 01-SEP-1990

   |
16 |
15 |
14 |                                **   ******  **   *  **  **********
13 |                         ********** ************ **  *** ***********
12 | ******  ******  **     *********************************************                      *
11 | **********************************************************************  **  **  ******* ********
10 | ************************************************************************************************
 9 | ************************************************************************************************
 8 | ************************************************************************************************
 7 | ************************************************************************************************
 6 | ************************************************************************************************
 5 | ************************************************************************************************
 4 | ************************************************************************************************
 3 | ************************************************************************************************
 2 | ************************************************************************************************
 1 | ************************************************************************************************
-----------------------------------------------------------------------------------------------------
     0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2
     0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 0 0 1 1 2 2 3 3 4
     0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0 3 0
     0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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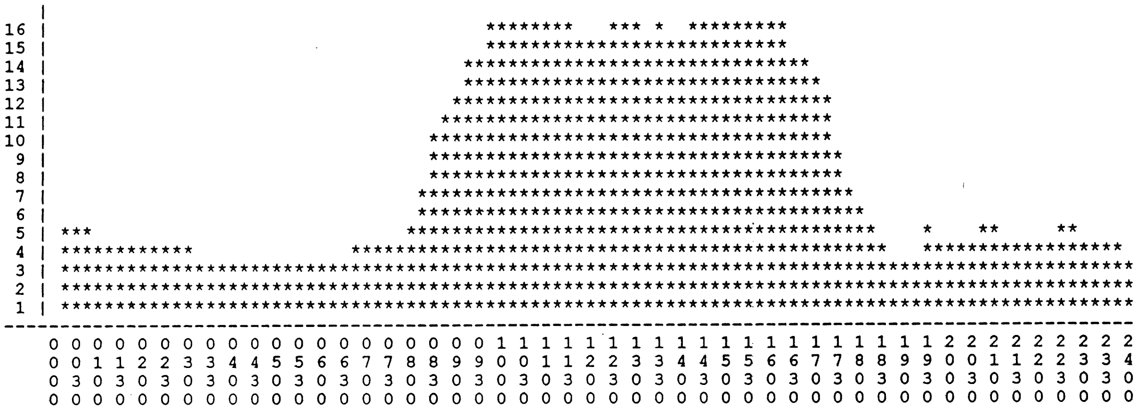
Figure 14
Availability of DS500 lines - August 1990

Micom port usage for Micom lines to the DS500 on Wednesday, 19-SEP-1990



Micom port usage for Micom lines to the DS500 on Thursday, 20-SEP-1990

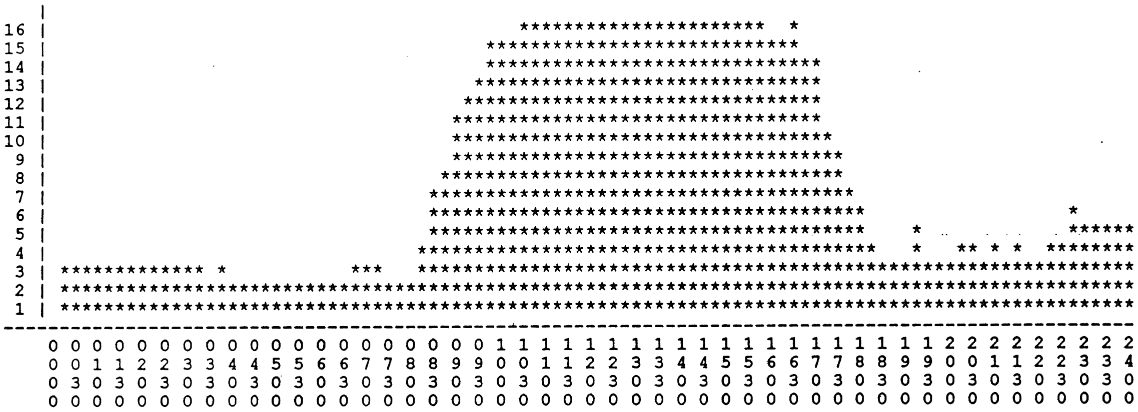


Figure 15
Availability of DS500 lines - September 1990

Conclusions

Statistics collected on the circuit switched network this year have identified a number of lines experiencing congestion. Those problems are being resolved by the installation of new hardware, so 1991 should see an improvement in the performance of the network.

Conclusion

The figures presented in this report indicate that during 1990 UQNET experienced an overall growth in the amount of traffic on the network. As the network loads grew the network was expanded to accommodate those loads and maintain performance levels. In all parts of the network (except one) where long term trends have been examined, indications are that the growth will continue in 1991. To cater for the growth experienced this year, the Network Management Group has put most effort into network expansion and establishing new tools to monitor network activity.

The installation of the Wellfleet bridge/router has proved to be an ideal way of providing University departments with robust high speed network facilities. The Wellfleet will continue to be central to network expansion in the foreseeable future. However, it may soon be necessary to introduce FDDI networking on campus and this could change the emphasis on what equipment is installed for network upgrading.

To effectively monitor the traffic on the network a number of new programs were introduced during the year to collect statistics. More work is required in this area and effort is now focused on using the SNMP protocol to collect statistics for the TCP/IP network. This work should lead to much better statistical information being available in 1991.

Despite the overall growth of traffic on the network this year, performance levels were maintained. By installing new equipment and reconfiguring the network when statistical information indicates it is necessary, UQNET will continue to be a robust high performance network in 1991.