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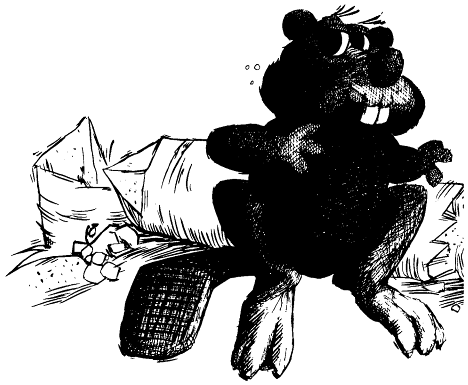

Diversity, Accessibility and Adaptability Data Communication Needs For Higher Education The University of Waterloo Experience

D.D. Cowan
S.L. Fenton
T.M. Stepien
A. Pittman

Research Report
CS-88-03

February, 1988

Diversity, Accessibility and Adaptability

DATA COMMUNICATION NEEDS FOR HIGHER EDUCATION

THE UNIVERSITY OF WATERLOO EXPERIENCE

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ABSTRACT

Diversity, Accessibility and Adaptability are three key-words which help to characterize computing requirements in higher education. Diversity in the number and type of computers needed both now and in the future, in the audience to be served, and in the breadth of computing services required. Accessibility in that computing services should be available to the user community for whom they were intended, wherever and whenever needs arise. Adaptability since the computing and communications system in a university should be able to cope with the changing and diverse computing needs and equipment of the user community.

This paper will explore the implications of these key-words for data communications from the perspective and experience of both users and network managers in one university. The paper concludes by suggesting that university computing facilities will develop as an Extended LAN which will consist of several LANs interconnected by multiple paths via gateways. These gateways contain facilities which will provide the user with a high degree of transparency and the network manager with tools for measurement and control.

INTRODUCTION

Universities typically have a diverse population of computer users who at various times want convenient access to a broad range of computing services. Quite often these services are available on a number of different computers and peripherals. Users want access to these services without having to change location or system interface. In other words to obtain a wide variety of service users wish to use a single device (computer or terminal) and software with which they are familiar.

These introductory remarks imply that a university should develop an integrated computer and communications system which can be tailored to individual user requirements. Such a system is an ideal goal which may be realizable as we learn more about such complex systems.

A description of the University of Waterloo and its current computing and communications configuration is given. This presentation is followed by a brief discussion of the type of computing services that are being requested by the campus community and the issues that are being faced by the developers and managers of the current university computing network. Because of the length restrictions on this paper many of these important issues are only discussed in a cursory manner. Of course, the demands for computing services indicate a direction for the development of the campus data communications network.

The paper concludes by proposing that university computing facilities will develop as an Extended LAN which will consist of several LANs interconnected by multiple paths using gateways. These gateways will contain facilities which will provide the user with a high degree of transparency, and the network manager with tools for measurement and control which should allow for a planned evolution of the campus network. By embedding this processing capability in an Extended LAN campus networks should be able to provide accessibility and adapt to meet diverse user demands.

THE UNIVERSITY OF WATERLOO

The University of Waterloo was founded in 1957 in Waterloo Ontario Canada and currently the University has a population of over 20,000 students spread among the six faculties of Engineering, Environmental Studies, Humanities and Social Sciences, Human Kinetics and Leisure Studies, Mathematical Sciences, and Science. There are also 20,000 part-time students who are enrolled across the entire University.

The University of Waterloo as a public university receives most of its operating budget of $120,000,000 from the government. The University also has a $35,000,000 research budget involving grants and contracts with both government and industry.

The University of Waterloo is a highly computer-literate campus. Because of the era in which it was established and the foresight of the founders, a serious and long-term commitment was made to the use of computers in education, research and administration. Almost all the students graduating from the University of Waterloo have completed several courses where the computer is used as a practical tool, and most of the faculty and staff members are knowledgeable about computers and use them in their teaching, research and administrative activities.

THE CURRENT COMPUTING AND NETWORK ENVIRONMENT

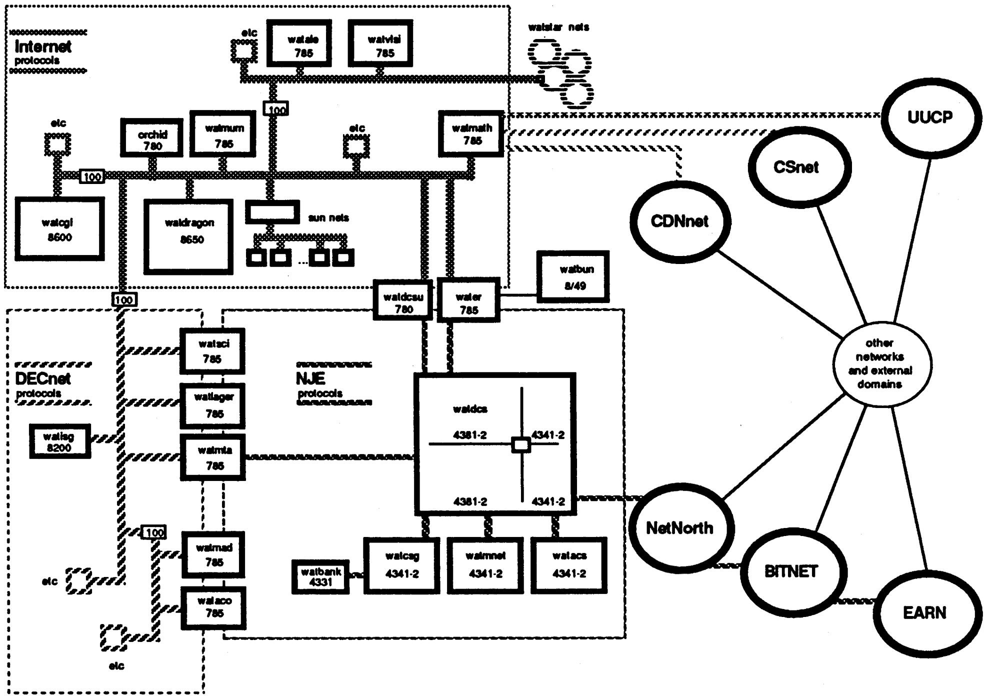

Figure 1. The University of Waterloo Network

A large number of mainframe, mini- and microcomputers and terminals are used throughout the University of Waterloo to support the research, teaching and administrative activities. The diagram in Figure 1 represents the central core of this computer and network configuration. There are 8 IBM mainframes, 15 large-scale DEC VAXes and a Honeywell mainframe all interconnected by various data networks. The boxes marked "etc" on Figure 1 represent collections of 50 or more workstations such as MicroVAXes, VAXstations or SUN/3-180s. The entire configuration is also connected to several wide-area data networks including CSnet, BITNET, UUCP, EARN, CDNnet and NetNorth. The tendency during the past two or three years has been to decrease the number of multi-user systems and increase the number of workstations in the network, thus presenting the network management with a diverse set of computers and user demands.

The IBM mainframes are interconnected by the RSCS store-and-forward network and the VAXes are interconnected by several different Ethernets running either the DECnet or Internet (TCP/IP) file-transfer protocols. There are also collections of SUN workstations which are connected to the Ethernet using Internet protocols.

The IBM complex is connected to four of the VAXes using an RSCS network running NJE protocols, while the Honeywell computer is connected to a VAX using a synchronous HDLC link. The various Ethernet networks are joined together by LAN Bridge 100s, a network level bridge which can control the movement of traffic between networks.

There are also thousands of terminals and microcomputers on campus which are connected to these various computer systems. A large number of microcomputers are grouped together and connected to isolated local area networks (LANs) [1], [2], and [3]. There are over 30 such LANs throughout the university and each LAN connects together a number of workstations, file-servers and print-servers. Recently many of these LANs have been interconnected using an extended LAN, thus permitting more sharing of facilities than in the past, since students are now allowed access to their files from any workstation on the campus. The LANs are being connected to the main networks on campus using intelligent gateways. The majority of the terminals and most of the remaining microcomputers are connected to a Sytek Localnet 2000 system which allows access to all the main computers and many of the microcomputers on campus. A small number of the terminals and microcomputers are connected to the Ethernet.

The Localnet 2000 system is a broadband communications system which normally presents a 9600 baud terminal interface to the attached devices. The current system runs 14 separate channels which group the attached devices into user classes based on their primary service requirements. Users on a given channel have free access to services on any other channel through bridges which interconnect the channels at the data-link layer.

The current computing and network environment at the University of Waterloo consists of a number of interconnected dissimilar local area networks each supporting a variety of computers and terminals. This network environment evolved over nearly two decades from a simple terminal-mainframe network to the Sytek system and eventually to the system shown in Figure 1 on page 3. Both the users and managers of the network have substantial experience in working in and operating a network environment. In the remainder of this paper we discuss their views of networks and then draw some conclusions about the types of facilities which should be available in future university-based LANs.

THE USER'S PERSPECTIVE

The population at most universities usually divides into three major groups: students, administrative staff, and teaching and research staff; and at Waterloo all members of these groups want access to computers to perform their respective tasks.

In this paper we concentrate on the teaching and research staff, as this group is the one whose needs are likely to cause significant changes and growth in the computing and network structure of the university. Not only do many diverse demands arise directly from their regular teaching and research activities, but they often motivate many of the computing needs of the students and administration. Teaching and research staff members also perform administrative duties which require access to the academic and financial information of the university.

The diverse demands of this group of users have implications for the type of service required and the manner in which those services are presented. These needs which affect the form of the university's computing and data communications system are summarized in the remainder of this section.

Since research and teaching are creative activities their computing requirements can be quite unpredictable and may require access to any computing resource on campus. Currently access to a variety of resources often necessitates the acquisition of new operational skills and modifications to existing hardware and software. Although the teaching and research staff at Waterloo are highly computer literate most of them are not interested in being computer and network experts. Users want to minimize the addition of new skills when using networks and computer systems; they want to concentrate on the work to be completed not on the tools. They want to use hardware and software with which they are familiar and to operate in surroundings such as their office or research laboratory.

Each user wants to maximize compatibility and transparency between data, hardware and software. Application programs should see a uniform file system even though the files may reside on different computers. Such a file system would also support uniform mail and file transfer applications as byproducts. Uniform terminal interfaces are also a necessary goal. Users also want the ability to share devices, but have control over access.

If new computing hardware is needed to support the teaching or research function then this equipment should integrate into the existing network. One simple connection to one of the campus LANs should be all that is required to obtain all computing services. These LANs should also be able to interface networks and computers from different vendors.

In many cases staff members access confidential materials such as budget and payroll information or student records. These needs create a requirement for secure and reliable data communications. Not only must access to files and computers be restricted but networks themselves may only be accessible to a select group of users.

In summary each user wants an all-pervasive easy-to-use network. Specific user requirements include uniformity of file access, uniform terminal interfaces, access control, simple multi-vendor connections for both computers and network configurations and reliability and security. The practical implications of this statement being that the network should contain enough computing power to support these specific user requirements.

THE NETWORK MANAGEMENT PERSPECTIVE

Networks in universities cater to a large number of users with varying needs. The users' objectives are innovative research and teaching, and administrative tasks. The network and computer systems are tools to achieve those goals.

Capital budgets in universities are often distributed over the administrative units and so there may be minimal central control of many major computing purchases. Such purchases often depend on current research contracts rather than apparent overall institutional goals. Hence there will always be an impetus to find and install the best networks and computer systems to achieve the current set of local research, teaching and administrative objectives. Such decentralized operation makes an overall campus plan for a network a very challenging design problem.

From the previous remarks it should be apparent that the managers of a computer network in an academic institution must cope with a network which is evolving based on a number of demands which may be contradictory. In fact, a university network is likely to evolve into something never imagined when it was first designed. From our own experience at Waterloo, campus networks will not be configured as a single LAN but will be a collection of several diverse LANs each one offering different service characteristics. These individual LANs will then be interconnected into an Extended LAN to provide the required level of accessibility and service.

From the management perspective the network must provide certain operational functions which permit adaptation to a dynamic and diverse environment. The types of activities which determine these functions are summarized in the remainder of this section.

The network should contain a mechanism to allow minimization of traffic on the interconnected LANs. For example, many LANs currently use a broadcast mechanism which sends messages over the interconnected LAN to request a service from a service provider and allow a user to connect to that service. This method for service identification also often includes hunt-groups to scan all possible paths to the service provider. These two techniques can significantly impact the volume of traffic on a LAN especially at peak periods. Since users' most frequent service requests are usually on their own LAN (the 80/20 rule)[1], the service-request message could be restricted to that network. Network management could use a model similar to the one for long-distance calls and force the users to make a specific request for services outside their own LAN. Hopefully only access would be more inconvenient, transparency of service should remain.

There should be facilities in the network to measure traffic on the interconnected LANs and identify both users and the source and destination of traffic. Measurement at this level will allow the determination of system bottlenecks and the services which need to be augmented. Since users, and traffic sources and destinations can be identified it should be possible to implement charging algorithms to pay for network growth. Also measurements of this type should allow the network to be reconfigured to make traffic conform more closely to the 80/20 rule. Measurements give the operator the information necessary to provide expanded services in a controlled manner where the needs can be attributed to specific user groups and sources of traffic.

Traffic control is another important operation on interconnected LANs. The amount of traffic between LANs should be controlled so that reasonable levels of service can be maintained even during times of peak traffic. Access controls to specific LANs can also be implemented if the users can be identified.

All these requirements imply a need to control passage of traffic based on user identification, and origin and destination of messages. Hence a need for control at the user, message or packet level and not at the data-link level where the identity of the user and the origin and destination of the traffic are no longer available.

There are a number of practical implications to this statement. The network should contain enough computing power to support this level of control and measurement, and cope with a network which is evolving based on a number of diverse demands.

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[1] The 80/20 rule is an observation in computing about many different phenomena. In this case the rule is applied to computer users and notes that users request resources on their own LAN most of the time (80%) and require access to more remote resources infrequently (20%).

MORE INTELLIGENT NETWORKS - THE ANSWER?

Users' computing requirements appear contradictory, there is a demand for simplicity and transparency while requiring total campus connectivity. It would appear that simplicity and transparency may have to be sacrificed if connectivity is to be achieved, because as local area networks grow they tend to become more complex in order to satisfy diverse user demands.

Perhaps the situation can be managed by observing that locality of reference applies to computing needs, that is users tend to access resources on their own LAN most of the time and require access to more remote resources less frequently. Hence a campus network should be a number of LANs based on user groups which should be interconnected into an Extended LAN to provide access to scarce resources such as mainframes and special peripherals.

The Extended LAN should allow multiple connections and paths among LANs via gateways to provide flexible traffic patterns. A single backbone will not suffice since traffic in a campus network is unpredictable and a single path will eventually saturate. The model of a LAN for a post-secondary institution with diverse computing facilities would be an Extended LAN, that is a number of LANs interconnected by gateways. These gateways in the Extended LAN would interface at the OSI Network Layer [4] and [5], and operate application programs which would perform a number of functions including:

i) controlling access to specific LANs based on source and destination addresses of messages or packets,

ii) controlling access to specific LANs based on current capacity constraints,

iii) controlling access to specific LANs based on user identification,

iv) logging capabilities to provide various types of real-time and average traffic measurements,

v) various file and protocol conversion capabilities to provide a degree of transparency to the user,

vi) and the provision of uniform interfaces for network access.

Installing this type of programmable gateway should provide the flexibility to allow a network to evolve as the demands of the user groups diverge.

Providing this flexibility will result in increased complexity in protocol design and implementation. Currently many LANs are interconnected with Level-2 bridges at the OSI Data-link Layer, whereas in this paper we are proposing Level-3 bridges or gateways which operate at the Network Layer. Gateways will introduce new problems, protocol design and implementation are far more difficult because the traffic is structured and hence more information must be interpreted.

Any developments in this area should attempt to adhere to standards where applicable in order to bring some uniformity to networks. Although standards may not be perfect they force us a clarity of thought in the design process which is most valuable. In particular the OSI model has forced us to be more careful in our design and to create more modular structures.

CONCLUSIONS

This paper has discussed some of the data communications needs of the University of Waterloo as presented by both the users and the management of the University network. The LAN system or Extended LAN on a university campus should be designed more in the spirit of the telephone system, whereby a number of disjoint LANs are interconnected with multiple connections by intelligent gateways which operate at least at the OSI Network level. These gateways could run application programs which provide functions for measurement, routing, user interfaces, and protocol and file conversion. By embedding this processing capability in an Extended LAN, campus networks should be able to adapt to meet future diverse user demands.

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