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PAPER 2

FOR LANS SAKE: SUGGESTIONS FOR THE USE OF NETWORKED COMPUTERS IN CHEMICAL EDUCATION

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I. ABSTRACT

The use of networked computers has been proposed as a solution to increased computer implementation costs. There are other factors that should be considered when designing and implementing Local Area Networks (LANs). There are two types of LAN configurations: Peer-to-Peer (PtP) and Client-Server (CS) networks. PtP networks allow each computer in the LAN to serve as storage and peripheral connecting devices. CS systems have a dedicated computer that is only used to control access to the software and hardware. Three types of hardware standards exist: proprietary (for example, Lantastic, AppleTalk, Token-Ring), EtherNet (10base5, 10base2, 10baseT), and FDDI (optical). The networks are physically designed into three types of topologies; daisy-chain (each computer connected with a cable in and a cable out), stars (one cable into the cable), and backbones (one major line with individual computers attached to it). When cost, performance and maintenance factors are considered, PtP configurations that run EtherNet in a hybrid active star/background topology are best suited for use in the chemistry classroom and or lab.

II. Introduction

The increased computer use in chemical education has often been accompanied with financial concerns associated with hardware and software. One answer to the implementation cost is the use of networked computers, the notion being that several computers (which have been connected in a network) will be able to share software and peripheral hardware. This paper contains presents some of the author's observations (from working with networked computers for the past 6 years) that have implications for the chemistry class. I will first discuss some principles associated with networked computers, then present some of the implementation issues that I have had to deal with.

III. Networked computers: Some Principles

Personal computing developments have been driven by large corporation computing needs, and the ability to share information easily has been a major business concern. This need has been met through connecting individual computers together with specialized hardware. Once the computers have been connected, they are described as a network. There are two types of computer networks that are important for chemical educators. Local Area Networks (LANs) have computers that are connected by cables (copper or glass) and that are usually confined to a single physical location (building or room). WANs (Wide Area Networks) are large groups of computers and/or LANs that extend over large distances (examples of WANs are computer services such as Compuserve, America Online, or the INTERNET). Note that some companies, such as United Parcel Service, also have a WAN that connects individual delivery trucks with UPS offices. This paper will focus on LANs, as these networks are currently the most important in chemical education.

III.A Networked computers: Configurations

There are two configurations for LANs: Peer-to-Peer and Client-Server. Peer-to-Peer (PtP) LANs allow each machine in the network to access information on each of the other computers in the network. Client-Server (CS) networks (the most commonly encountered network configuration) have one or more "dedicated" machines that act as data depots (servers) for individual computers (often called "workstations"). The workstations can only access data from the server. CS LANs are the oldest network form and there are three operating systems (software) that are most commonly encountered. TCP/IP was one of the earliest CS system software packages and is primarily used with machines that use the UNIX or VMS operating systems. Novell produced one of the earliest CS systems for DOS machines (personal computers that are based on the Intel cpu and its clones), but is an operating system itself. AppleShare is the CS system software for Apple Corporation computers. Note that versions of each of these software systems have been written for each of the "other" machines (i.e., there are versions of Novell that run on Apple Macintosh and UNIX-based machines). The central characteristic of the CS LAN is that there is at least one computer that cannot be used for purposes other than controlling access to the software stored on and hardware attached to it.

PtP LANs are relatively new and allow distributed server functions. In other words, each of the computers in the LAN can provide access to the software stored in and the hardware attached to it. The individual computer has the server software running in the "background" (simultaneously) as other software (such as word processors) are used. The most popular types of PtP software are Windows for Workgroups, LanTastic, Novel Lite (these three are used on Intel-based machines) and Apple System 7.x. I should note that TCP/IP does have some of the characteristics of PtP software, but this is due to the fact that the large mainframes for which TCP/IP was designed were always designed to allow multitasking. As you can imagine, the distinctions between these LAN system software have become indistinct, as the performance demands for networked computers have increased. I have discussed the different types of LANs and the software associated with each, so let's examine the types of hardware associated with LANs.

III.B Networked computers: Hardware Standards

There are three types of LAN hardware standards that are currently used. Proprietary hardware systems are produced by specific companies such as Apple (AppleTalk), Artisoft (LanTastic) and IBM (Token Ring). The computer cards and cables must conform to standards and specifications that these companies license to other hardware manufacturers and have data transmission speeds that are less than 2 Megabits per second. EtherNet LAN hardware confirms to specific IEEE standards for copper-based networking cables. There are three types of EtherNet: 10base5 (so-called "thick", 25-wire cable), 10base2 ("thin" coax cable) and 10baseT ("twisted-pair" cable). The "10" in each of these designations refers to the transmission speed (10 Megabits per second) and the last number or letter refers to the maximum distance that the data can be transmitted (500 or 200 meters) or the type of cable ("T" refers to twisted-pair telephone cable). While each type of EtherNet hardware requires a transmitter to send the data, 10base2 hardware usually has the transmitter built into the interface card and the others require external transmitters. Finally, there is an emerging IEEE standard that uses fiber-optic cable. FDDI uses pulses of light that are transmitted on fine glass fibers to transmit data. Currently, this is the most expensive type of network and is not used extensively for LANs.

III.C. Networked computers: Topologies

Now that the basic LAN software and hardware have been presented, a discussion of LAN physical layouts (topologies) is appropriate. Backbone topologies have a central cable that has individual computers connected to it (see figure #1). So-called "star" topologies have a central computer connection that has several individual computers connected to it. Passive star connections have a simple wiring connector that combines the signals from each of the computers in the star.

Active stars have a computer or dedicated transmitter (often called a "hub") that electronically combines and processes the signals from each computer in the star. Figure #2 presents diagrams of the two types of star topology. Finally, the daisy-chain topology has each computer directly connected to each other. The difference between a backbone and a daisy-chain is the type of electronic connection (see figure #3). The backbone connection is a parallel connection and the daisy-chain is a serial connection. The network connection fails if a single computer connection is broken in the daisy-chain, but will remain active when such a situation arises in a backbone topology (see figure #4).

I have described the different types of software, hardware and topologies that are associated with LANs. Each of the various combinations of hardware, software and topology effect the performance of the LAN in the classroom/laboratory and thus, implementation decisions. In order to simplify these choices, letUs categorize the implementation factors as cost factors, performance factors, and maintenance factors. Cost factors will be limited to initial implementation expenditures for this discussion; performance factors will include access and processing speed, hardware access control, and cross-platform functionality; and maintenance factors will include network administration/supervision and hardware/software maintenance.

IV. Implementation Factors

IV.A. Implementation Factors: Costs

Because costs are often the primary motivation for consideration of networking computers in the chemistry classroom, I will discuss them first. The associated costs vary greatly, depending on the configuration selected. It would appear that the CS configuration would be the most expensive, because the dedication of one or more computers whose sole use is to provide data control adds cost while not increasing students per computer ratios. However, dedication of one high-speed computer with large storage capacity may save some money, if the alternative is to upgrade multiple computers to faster processing speeds (replacing cpu chips and/or computer motherboards) and larger storage devices.

PtP configurations have a low initial investment, because the PtP LAN can often be implemented by the simple addition of a board and cables and the appropriate software. This is probably the main reason that PtP LANs have had such a great growth recently. Most PtP software is less expensive per computer than CS LAN software. In the case of Apple's System 7.x and Microsoft's Windows for Workgroups, the networking ability is built into the operating system, so no additional software is needed.

When we consider the various hardware standards, the least expensive investments are proprietary and EtherNet systems. In the case of AppleTalk, the hardware is built into all of Apple's computer (since the Apple][c), so the major expense is for cables and connectors (approximately $15 per computer). The next least expensive would be EtherNet for the Intel and Apple machines (approximately $120 for 10base2 to $250 for 10baseT per computer) though these require an additional interface card and/or specialized software drivers for each machine. The proprietary systems for the Intel machines are generally more expensive that either AppleTalk or EtherNet, but are much less expensive than FDDI systems. FDDI systems currently cost approximately $400 per machine for just the interface adaptor (the glass fiber costs about $8 per foot for installation vs. an average $2 per foot for copper-based cable).

The major cost factor associated with the LAN topology is whether an active star is used. This topology requires a hub, which is a dedicated computer that reprocesses and routes network packets. Star hubs usually can be obtained for approximately $500. The daisy-chain topologies usually require approximately twice as much cable as a backbone design. Fortunately, cable costs tend to be relatively inexpensive ($2 per foot).

When all of the cost factors are considered, a PtP EtherNet in a daisy-chain or backbone topology is the least expensive LAN and a FDDI CS in active star topology is the most expensive. But it is very important to consider the performance associated with LANs before making a decision.

IV.B. Implementation Factors: Performance

The LAN configuration has a great impact on the performance of the computer network. PtP networks tend to have poorer performance, because the background operation of the networking software tends to slow down computer processing speeds. Another problem associated with PtP systems becomes apparent when more than one type (Apple, Intel-based, or UNIX) of computers need to communicate with each other. On the other hand, most PtP systems allow transparent access to hardware peripherals such as CDROM players and laser printers. Because each computer in a PtP network can act as a server, the number of peripherals that can theoretically be accessed is greater than for the CD systems.

CS networks tend to have the performance edge, because of the dedicated computer server. In most software packages, when a program is run, the code for the software is loaded into the memory of the individual computer. When the individual computer needs additional portions of the program code, it must go back to the place where the software was originally accessed. As you can imagine, this constant accessing of the original hard drive is processor intensive. The server in a CS system is able to more quickly process data requests from the client computers because it only uses its cpu while "managing" the network (controlling access to the storage devices and processing data requests from the clients).

Most of the LAN hardware standards have comparable performance. Typically, the proprietary systems communicate at slower speeds than EtherNet (less than 2 Mbs vs 10 Mbs). FDDI systems are generally the fastest networks, though the advertised speeds can be deceptive. While the optical "cabling" supports extremely high transfer rates, the cpu in the individual computer can rarely process the data as fast as the FDDI system can transfer it. Proprietary systems tend to be fully compatible with only one type of machine (Apple, Intel-based, or UNIX), with limited functionality on the other platforms. EtherNet systems tend to be the most uniform across platforms and this is why they are the most prevalent networks today.

Topology has a great impact on the performance of a network. Because data packets must travel over the cables, daisy-chains tend to have slower performance than star or backbone topologies. Active star and backbone networks tend to have approximately the same performance. Accessing and cross-platform performance tends to be the same no matter which topology is selected.

Cost and performance factors tend to be the only considerations that the chemical educator think about when they attempt to implement LANs. But LAN maintenance is a factor that will greatly determine whether the LAN becomes a useful educational tool, or whether it becomes a technological nightmare.

IV.C. Implementation Factors: Maintainance

The primary maintenance factors associated with LANs tend to be associated controlling access to items on the network and keeping the software and hardware on the network updated and functional.

The CS configuration is the easiest to administrate and update, because there are fewer machines that serve as reservoirs for the software and hardware. When things go wrong with the network, it is easier to determine the source of the problem (which may be hardware or software) related. The main concern associated with this type of network, however, becomes important when there is hardware failure at the server. To use a common metaphor, when all of your eggs are in one basket, if the basket gets crushed, you lose all your eggs. If you only have one server and it has a hardware failure, then the network fails. This can be avoided, however, if the server is periodically backed up. PtP networks provide the easiest route to multiple backup copies of software, but can be difficult to update frequently. When multiple machines are acting as servers, access control can be difficult.

Each topology produces different maintenance issues. The backbone system is the most fault tolerant (allows constant network performance in the event of individual computer software or hardware failure). Star topologies are more complicated and it can be harder to trace network failures in these systems. The major disadvantage to a daisy-chain systems is that if one machine quits functioning, the entire network fails until the problem is corrected.

As you can tell from this paper, there are a lot of factors that must be balanced when the LAN implementation decision is made. Modern LAN hardware and software allow flexibility and the best decision is a function of individual factors that vary from school to school and grade-level to grade-level. Keeping this in mind, let's try to sort out the information and make some suggestions.

V. So which LAN do I implement?

While my practical experience has been in implementing university/college level networks, I am familiar with some of the issues surrounding pre-college network requirements. In each case (pre-college and post-secondary education), eliminating and/or reducing those aspects of educational computing that are peripheral to chemistry is essential. There is a balance between cost, performance and maintenance that must be established. I have found that just because a particular technological "solution" was the less expensive does not mean that it works the best in the classroom, nor that the latest and most expensive is better. If we consider time spent in installing and maintaining the network and the ease of student use as a cost factor, then the choice between systems becomes a little more distinct.

The decision between PtP and CS configurations is difficult to make. My recommendations are that if there are existing machines that are going to be connected to a network, then the PtP system may be the best answer. This is true because though these systems usually have multiple servers, eventually a CS system can be setup with the same software. In the case of a new investment in hardware and software, the CS network is the best design. It allows greater control over software and hardware upgrading and maintenance and better access control. I can't stress too strongly that it is imperative that a server backup system of some sort be maintained if a CS configuration is selected. Another reason that I recommend that a CS network be selected is that it is clear that the future of computer networking is moving toward client-server systems, so the cost and efficiency of these networks will continue to improve.

While proprietary systems may appear to be less expensive at the beginning of a network implementation project, they rarely turn out to be the less costly in terms of performance and maintenance. These latter effects are reduced only if one type of machine is used and there are no plans to consistently upgrade the software and hardware in the system. The one exception to this "rule" is in the case of AppleTalk, and the exception is very narrowly supported. If only Apple hardware is intended to be used, then AppleTalk is the best choice. This situation, however, is very rare and the chemical educator should be careful to closely examine the rational for investing solely in one platform. Each of the other platforms require the installation of special hardware cards and thus, the cost advantages of the proprietary systems is quickly lost.

It is clear that at this time, EtherNet is the best choice because it is available for all computer platforms. The data accessing speeds available over EtherNet are sufficient that the medium to small network (less than 100 machines) perform quite well. As prices for FDDI equipment drops through greater use, this technology will become very important. I strongly recommend that 10base2 (thin coax) cabling systems should be used. Though the twisted-pair cables are very popular at this time, there are already developments that will allow thin EtherNet systems to approach FDDI speeds. The most common reason given for using twisted pair is that phone line is "cheap". What is often not mentioned is that 10baseT connections require a transceiver and a hub, which can add an additional $150 per computer. 10baseT also requires that there be two unused lines in the existing cables, which older phone systems do not have.

Finally, my recommendation for the best topology would be a hybrid backbone/active star system. This system has a central backbone that the central servers are directly connected to, with active star "mini-LANs" attached to it. Each classroom or office area is set up as an active star. This allows greater access control and the use of "intelligent" hubs or routers in the active star will cut down on the packet traffic over the backbone. Daisy-chain and passive star topologies are material and maintenance intensive.

VI. Conclusions

The best generic LAN system for chemical educators would seem to be a Peer-to-Peer, EtherNet, hybrid active star-backbone network. These types of systems have the best cost-performance-maintenance ratios. They offer greater reliability in laboratory/classroom situations and are more adaptable through the addition of data acquisition instrumentation to individual peers. The primary software for this type of system should, however, be stored on machine in the network. Of course, this recommendation would be modified slightly given the types of existing equipment. In the future, FDDI hardware running ISDN software in a backbone topology will be the most popular LANs. This type of system will be required as we move into the areas of distributed learning and interactive multimedia learning systems such as virtual reality and hypermedia. These new technologies hold a great promise for chemistry education and today's chemical educator can be prepared for the future with careful LAN planning.

Questions for Readers

1. I want to connect the computers in my chem lab so that they can be used to collect data. What are the constraints on each type of LAN in this situation?
2. About the time that I commit myself to buy a particular brand/type of computer technology, it seems to be obsolete immediately after I get it. How can I plan for this at the beginning of the LAN implementation?
3. Which types of LANs are most suitable for multimedia educational programs and what factors should I consider when I make my selection?
4. How can I protect the software and hardware when I am trying to use them in the chemistry lab?

Figure Description

There are four figures which are 300 x 300 pixel, 1 bit graphics. The first figure (fig1.gif) shows a backbone LAN topology, the second (fig2.gif) presents a star topology, the third (fig3.gif) is picture of a daisy-chain topology and the fourth (fig4.gif) figure is a comparison of the effect of breaks in a backbone and daisy-chain networks.