Internet: road to heaven or hell for the clinical laboratory?

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The Internet started as a research project by the Department of Defense Advanced Research Projects Agency for networking computers. Ironically, the networking project now predominantly supports human rather than computer communications. The Internet's growth, estimated at 20% per month, has been fueled by commercial and public perception that it will become an important medium for merchandising, marketing, and advertising. For the clinical laboratory, the Internet provides high-speed communications through e-mail and allows the retrieval of important information held in repositories. All this capability comes at a price, including the need to manage a complex technology and the risk of intrusions on patient privacy.

INDEXING TERMS: laboratory management • Internet • World Wide Web • networking • e-mail

The Department of Defense (DOD) Advanced Research Projects Agency (DARPA) started ARPAnet in the 1960s to share expensive computers through networking technology. For the first decade, the ARPAnet was mostly limited to universities and other research groups developing the technology. Because electronic mail (e-mail) was popular on the computers being networked, scientists added it to facilitate their communications. E-mail consumed very little of the expensive 56 kilobits/second line connecting computers and was considered "free." Discussion groups based on e-mail were also developed as a byproduct. One bulletin board system that emerged was the Usenet Netnews. Some corporations allowed outside use of private networks during periods of low utilization. For example, AT&T networks frequently carried Usenet and e-mail traffic at night for universities. This use of extra capacity on private networks also fostered the concept of "free" e-mail. One problem encountered by ARPAnet engineers was that different computers often used different communications protocols, and this prevented exchange of information. TCP-IP (transmission control protocol–internetwork protocol) was developed to overcome this, and it gradually became the dominant protocol on ARPAnet. The name Internet originates from IP, the abbreviation for "internetwork protocol." Until the early 1980s, network users were mostly in government research, universities, and technology companies. ARPAnet was designed to survive a nuclear attack, i.e., it was redundant and lacked a control center. This philosophy was to have significant influence on future growth and control.

Paralleling ARPAnet, technology companies developed private computer networks for transferring data. The ARPAnet backbone, regional networks, and private networks soon became interlinked and inseparable. Because the ARPAnet was taking on activities unrelated to its original mission, DOD dropped funding in the 1980s. The National Science Foundation (NSF) began funding the backbone (renamed NSFnet) with the goal of enhancing research activities. Data on the backbone increased rapidly, requiring upgrades to T-1 lines carrying 1.5 megabits/second (mbs) and later to T-3 lines carrying 45 mbs. Promotion of the network since the 1980s, now called the Internet, has been extremely successful. Growth by 20% per month has been possible only because of the decentralized design. By the end of 1993, the Internet consisted of an estimated 2.4 million host computers world-wide operating on 30 000 networks. Estimates of current users range from 7 million [I] to >25 million [2–4], and this number is expected to grow to 200 million by the year 2000 [I]. Vice-President Al Gore and the National Library of Medicine have promoted the development of a 1 gigabit/second backbone to support future traffic. Government support for the Internet is unlikely to continue, however, and NSF plans to withdraw funding within 3 years.

Under DARPA and NSF sponsorship, commercial use of the Internet was prohibited. As these restrictions were lifted, commercial use of the Internet became the greatest contributor to its growth. With a large and desirable audience profile, the Internet has been perceived as a large untapped resource for marketing services [5] and has received much attention in the press [I, 2, 6, 7]. For example, the Hermes Project at the University of Michigan identified Internet users as 81% college-educated and 59% professionals and managers [8]. Many advertisements

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1Nonstandard abbreviations: DOD, Department of Defense; ARPAnet, Advanced Research Projects Agency; NSF, National Science Foundation; mbs, megabits/second; and WWW, World Wide Web.
include World Wide Web (WWW) or e-mail addresses to support information and to get consumer responses. Charging individual users for Internet use is unlikely, even with loss of government support, because commercial ventures, which generated an estimated $1 billion in 1995 and anticipate up to $23 billion by the year 2000 [1], are expected to support this expansion. Growth of local hospital networks has paralleled the growth of public networks. Most new computers require networking technology, and hospitals have built extensive networks to support growth in information requirements. This and the consolidation of hospitals into vertically integrated healthcare systems have resulted in linking local networks to the Internet.

As with any technology, the benefits of networking are balanced by liabilities. A major strength of the Internet is rapid and easy communication through e-mail and access to electronic information anywhere in the world. Some of these Internet tools have been adapted to support electronic medical records and retrieval of laboratory results. The Internet remains a collection of heterogeneous computers and provides a medium through which computers exchange information. This exchange results in the delivery of services that are otherwise unavailable through individual computers. Some of the services the Internet can provide to clinical laboratories are listed below. This list is not complete, nor are all services available on all Internet-linked computers.

**E-mail.** E-mail, the most common Internet service, requires a post office host computer to receive and send messages. Recipients and senders have addresses in the form of username@computer.extension. The username often includes the name of the individual. The computer is the name of the receiving or sending computer. Extensions used in the US are: *edu* for educational institutions; *com* for commercial companies; *org* for nonprofit organizations; *mil* for military facilities; and *gov* for governmental agencies. Outside the US, the extension is a two-letter abbreviation of the country (e.g., *au* for Australia). For example, my address is chou@po.lab.ccf.org, where po.lab.ccf refers to the post office computer. E-mail today is highly reliable and typically delivers messages to a receiving computer in seconds, provided the user adheres to basic rules and has the recipient's correct e-mail address [9]. CD-ROM collections of e-mail addresses from public sources are available, but their accuracy is poor. Organizations such as AACC are providing e-mail addresses in membership directories. E-mail services are provided by universities, corporations, and many commercial providers. A computer receiving or sending e-mail tries to send it to the computer nearest the destination. In either case, e-mail delivery depends on the good will of intermediate computers, and failure of an intermediate computer can result in a lost message. Undelivered mail may be returned to the sender with a message of nondelivery. A return receipt can be requested upon receipt of the e-mail letter, but there are no guarantees that the recipient is the one intended by the author, nor are there guarantees that the recipient reads the letter. Reading mail can be time consuming when a lot of messages are received. Many mailers permit enclosures to be sent with the message, but variations in the handling of enclosures often causes the enclosed message to be unreadable. Nevertheless, e-mail permits users to exchange information (e.g., grant applications) rapidly, and has replaced the overnight letter in some communities.

**Usenet news groups (Netnews).** An outgrowth of e-mail has been the creation of automated mailing lists for discussion groups. Mail servers became unmanageable if the list was long because the server had to send a copy of the article to every user on the list. To overcome this difficulty, computer science departments at Duke University and the University of North Carolina at Chapel Hill developed the Usenet bulletin board system, or Netnews. The contents of discussion groups are distributed to subscribing computer systems, which are then responsible for redistributing them to other computers, creating a pyramid scheme [10]. Users read the news groups locally on their own computer. There are thousands of news groups, and more are added daily. Because of this, reading news groups can be very time consuming and intimidating. Maintaining a computer supporting Netnews also requires a lot of attention by the computer system manager. Netnews topics cover topics from computer technology and astrophysics to house repair and cars. Some news groups are managed by a moderator, which greatly reduces irrelevancy and repetition. News groups of probable interest to those in pathology and the clinical laboratory are listed in Table 1.

**Remote computer access.** Thousands of repositories exist on the Internet. Typically these repositories are maintained by an individual or small group and include collections of public domain programs, such as the Simtel20 collection being maintained at the University of Oakland (Michigan), or databases such as the LOINC collection of standardized clinical laboratory test names at Duke University. Other sites support commercial products (e.g., the Microsoft Corporation). Universities often maintain technical reports on Internet servers. Usually, these reports contain details too large to publish in the usual manner or topics of limited interest. In the past, use of information repositories required complex tools such as the file transfer protocol (FTP), but recent software such as Gopher, Archie, and Mosaic has made this easier [11, 12].

Mosaic, associated with the WWW, has become one of the most popular tools for Internet information retrieval because it is easy to use and provides color graphics and sound clips in addition to text [12]. Mosaic emerged from the University of Illinois <2 years ago and has been commercialized by several vendors, including Netscape. Mosaic, through the hypertext markup language (HTML), permits the reader to link to documents anywhere on the Internet on demand. For example,

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<th>Table 1. Netnews groups covering topics of interest.</th>
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<tr>
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<tr>
<td>sci.med.laboratory</td>
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<td>sci.med.pathology</td>
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using a Mosaic reader to look up a laboratory test result, one can reference drug interference and normal values with a click of the mouse. WWW servers are frequently called web sites.

Many healthcare institutions, including the Cleveland Clinic and the University of Iowa, maintain web servers to publicize services available at their institutions, including lists of practitioners, their areas of interest, their publications, and how to reach them. It is not known whether these web servers are successful in attracting patients, but the cost of creating such servers is low. Companies who have created web catalogs to sell products have not been particularly successful in soliciting sales, but web pages can provide customers with information and reduce printing and mailing costs [5].

At least three examples of using Mosaic software to access laboratory information at physician workstations have appeared in recent publications [13-15]. For example, the University of Minnesota, Columbia University, and the University of Washington have web servers that provide laboratory results or information on the use of laboratory tests; Columbia University and the University of Iowa display interesting cases; and the web page at the University of Washington can provide laboratory test information, substantially reducing the need for telephone calls and printed laboratory guides.

Major problems associated with the Internet include exposure of computer systems to malicious attack, possible loss of privacy in computerized patient information, complexity in supporting networks and networked computers, and the inaccuracy of some information being distributed. Any computer on the Internet is potentially vulnerable to data destruction. Break-ins by malicious users are probably the biggest problem. Data destruction by viruses and worms acquired through the network is a lower risk event. The most famous worm was written in 1989 by Robert Morris, a student at Cornell University whose father worked as an AT&T Bell Laboratories computer security expert. This worm incapacitated thousands of computers through exploiting a bug in e-mail software, but fortunately it destroyed little data. In most cases, barriers or firewalls can be created to block users outside an institution from breaking in [16]. Firewalls are less effective for break-ins initiated by individuals within the institution. Identifying and capturing individuals breaking into systems is usually difficult [17]. Building secure systems is possible, but high-security computer systems are inconvenient to use and may be impossible to implement in teaching institutions [18].

Balancing patient confidentiality and medical necessity in computerized systems is also difficult. Networked computers do not maintain the natural physical boundaries created for the paper chart. This benefits large multinstitutional and vertically integrated healthcare systems, but raises issues about patient privacy [19, 20]. Even insignificant demographic information such as bed location can reveal that a patient is in an alcohol and drug rehabilitation unit. What information must be withheld from the electronic chart and what is needed to support patient care needs? These and many other issues must be addressed to resolve the problem of patient confidentiality [21-23].

The ease with which users navigate web servers and networks hides the complexity of this technology. The support of such networks, firewalls, and associated computer systems requires substantial technical and administrative skills. In addition, the technology changes rapidly. The transmission of graphic images contained in WWW servers requires high bandwidth not available a few years ago. High-bandwidth real-time sound and motion picture video images require network administrators to implement new technology. Control of how the network is used is often impossible because central control is impossible.

The greatest weakness of the Internet is its ability to provide too much information. The democratic and anarchic nature of the Internet permits all users to provide data equally, whether or not it is accurate or valuable. For example, the Internet "published" the Pons and Fleishman cold fusion paper without peer review. Some newsgroups are cluttered with meaningless responses, and commercial junk e-mail has already appeared in my mailbox. Unless the reader is aware of the expertise of the poster, information should be suspect. Cliff Stoll, a longtime Internet user, has observed: "With its thousands of newsgroups, I have to plow though a vast number of postings before stumbling on one worthwhile notice" [24].

Ironically, the Internet has emerged as a medium for human rather than computer communications. The strengths and weaknesses of this medium bear many similarities to television, which was once viewed as a golden resource. Programs such as Edward R. Murrow Presents and The Hallmark Hall of Fame were examples of what high-quality television could offer. Marshall McLuhan once expressed that the richness of television as a communications medium would change the world, but he later became disillusioned [25]. The richness of the Internet in the past has in part resulted from its use by an elite group. As the use of the Internet spreads and users become more heterogeneous, its distinction as an elite resource will likely disappear. Moreover, the Internet can provide so much information that users are overloaded [26]. Despite these negatives, the Internet remains a valuable resource for communications and for information, and permits the laboratory user to work in a manner more consistent with today's needs.

References

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