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A LOW-COST WIRELESS NETWORK* FOR TENNESSEE SCHOOLS AND COLLEGES

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ABSTRACT

The exchange of electronic mail and computer files using telephone lines is widespread—and often expensive. Packet radio is a recent innovation in communications technology which permits the exchange to take place over the airwaves and includes automatic correction of errors incurred in transmission. In such a communications system, the telephone and modem are replaced by a specialized radio modem known as a terminal node controller (TNC) and a radio transceiver. A network of these wireless computer stations would provide a valuable, reliable, cost-effective link between Tennessee schools and colleges. The system could also function as an emergency communications network in case of disaster and has considerable educational potential in its own right.

INTRODUCTION

The ability to communicate effectively with others is a valuable asset to a researcher, a teacher, or a student. Whether the message is a query, an answer, a routine announcement, or an emergency bulletin, the act of exchanging information often brings the participants together and usually is mutually beneficial; i.e., it is synergistic. The value of intra- and inter-university communications is demonstrated by the level of participation in various digital data networks that have been established to link separate institutions. These networks have been established to cover several scales. Wide-area networks include the Defense Advanced Research Projects Agency network ARPANET (McQuillan and Walden, 1977) which serves 70 sites; the Computer Science Research Network CSNET (Crocker, Szurkowski, and Farber, 1979) which serves 130 sites (electronic mail only); BITNET (Fuchs, 1983) which was first established in 1981 between the City College of New York and Yale University and now routes files and messages and runs jobs between 100 universities; MFENET (Jennings, et al., 1986) which links fusion-energy researchers at universities and government laboratories; and USENET (Jennings, et al., 1986) which is a volunteer-supported network that uses the UNIX command structure and links several thousand users on a worldwide scale.

Several of these networks are either formally or informally connected at "gateways" through which electronic mail may be forwarded. Furthermore, plans are being made under the auspices of the National Science Foundation to link some of the above wide-area networks, forming a "super network" called NSFnet. Networks linking users within a single state have also been implemented (Jennings et al., 1986). The Merit Computer Network in Michigan links the University of Michigan with computers at Oakland, Michigan State, Wayne State, and Western Michigan. A New York State education and research network (NYSERNet) has been proposed, and is expected to link academic research institutions with high technology industrial research laboratories within the state.

THE ELECTRONIC PAGES (Nogueira, 1987) provides computer networking services for many educational groups in Texas and elsewhere. MICRONET (Micronet, 1987) at Western Carolina University offers on-line courses for credit, electronic mail and many other services to 75 high school science and mathematics teachers throughout the state of North Carolina via a toll-free telephone number. (This article was worked on independently by the authors, with frequent exchange of files through MICRONET.) Services, such as MICRONET, with users who are hundreds of miles apart, often have prohibitive telephone expenses. To reduce costs they may limit usage or charge a fee. Wireless links are a viable alternative. One example of a wireless link is the telemetry system and inter-network link between

* Editor's Note: This paper is not a scientific research paper, nor is it an expository paper on a branch of science or engineering; it is, rather, a discussion of an idea of the authors for establishing a low-cost computer communications network that would link Tennessee schools and colleges. Because of its special nature, the editor feels that it merits publication in the *Journal*.

the US seismic network operated by the Institute of Physics of the Earth, and the Soviet network operated by the Institute for Automated Systems (Berger et al., 1987).

Indeed, some networks are entirely wireless, although they are often one-way. Examples are public and private radio and television networks, and remote data transponders.

One wide-area digital wireless network exists, and it is run entirely by voluntary participants. This net is composed of amateur radio operators, who have recently begun to experiment with Packet Radio. The standard telephone modem is replaced by a specialized radio modem known as a terminal node controller or TNC. The TNC is connected between the computer and a transceiver, a radio that receives and transmits. Because the airways are noisier than the telephone lines, the TNC at each end of the link does its own error-checking to insure that the information it receives is 100% error-free.

The packet radio network established by the amateur radio operators has grown rapidly and continues to evolve and mature (Mayo, 1986). It is a viable system that has the potential to provide an affordable network linking institutions of higher education, research facilities, and high schools. The purpose of this article is to explore the possiblilty of such a network. Our thesis is that an inexpensive, wireless, digital communications network could be established in Tennessee to link such institutions.

The equipment, the expertise, and the network protocols have been developed by the amateur radio community. Complete network nodes, capable of initiating and receiving messages and data, and of storing and relaying these messages and data under computer control can be mplemented for under $600 per station. In many cases, such a system would pay for itself in the first year in telephone costs alone.

Such a system might be called SOCRATES, an acronym for "Synergistic Organization of Computers and Radios for Access by Tennessee Educators and Scientists."

FUNCTIONAL DESCRIPTION

A digital data network handles numerical data or text equally well. A network such as SOCRATES would have many applications, depending on the needs of the user. An example of the application of SOCRATES may be beneficial.

Imagine, if you will, that you are a high-school teacher in rural Tennessee. A student asks you a difficult question about lasers. Fortunately, your school is a part of SOCRATES, so the student sits down at the computer and types in the question. It is relayed automatically to other computers throughout the state. Later that day, a physics professor sees the question on the university's SOCRATES computer and responds. The next morning, the student is delighted to see that the question has been answered.

How was this done, asks the student. Is it expensive? How easy is it for anyone to use? What else can I do with such a system? The student learns that SOCRATES is a network that utilizes a new technology known as "packet radio". No telephone lines are necessary. Each user has a network node, consisting of a wireless radio transceiver, a computer, and a small box (about the same size as a telephone modem) known as a Terminal Node Controller. Instead of the telephone line, an antenna broadcasts the signal. And instead of talking, the user types and the message is coded and transmitted. The coded message (or "packet") is routed to a destination node or nodes, similar systems located at points throughout the state, by being relayed, automatically, by unused network nodes. Each node, under the control of its TNC, receives, stores, and retransmits packets of information. The system is easy to use and one can exchange any information that can be sent in digital form.

How expensive is such a system? Packet radio is used by many businesses to relay information without using the telephone lines. These people are spending many thousands of dollars but the initial costs are offset by the saving of long-distance charges. Although all this high-tech equipment can be expensive, it is possible to set up this network for well under $600 per school. Packet radio is a hobby for thousands of amateur radio-operators ("hams") throughout the United States and throughout the world. Hams, by their very nature, are extremely cost-conscious and they have developed very low-cost equipment which is adequate for their needs—and for the needs of schools.

A new TNC can be purchased for $100–$125 and a single-channel transceiver for $200–$250. A considerable quantity of used equipment is also readily available.

How easily can the packet system be used? The system will be as easy to use as a telephone. Computers have evolved considerably in recent years and telling a computer what to do is no longer the time-consuming activity it used to be. Also the TNC connects the computer exactly like a telephone modem, so any terminal program will work.

In a typical situation, one "tells" the computer that the user is ready to type in a message, types the message, and then types the recipient(s), who could

be either a specific person, a group selected according to particular specifications, or the general user population. "Telling" a computer what to do means choosing from a "menu" or "pointing and clicking" with a mouse. The computer does the work of sending all the proper codes.

What else can be done with such a system? Aside from the fact that SOCRATES is a wireless system, it is identical in many ways to existing computer networks that use the telephone lines. The amateur radio community operates Bulletin Board Systems (BBS's) that handle electronic mail, conferencing, and file transfers—services that are identical to those offered to telephone network users. Consequently, the SOCRATES network permits all of these and more. Why more? Because the telephone line is a preexisting network—the links are in place and rigid. With a wireless network, the links can be changed at any time. For example, instead of having a centralized source, several schools could be set up as nodes. Each node would serve the schools in its region, providing local services. Yet, at any time, it would be a simple matter to change node assignments. This is a reconfigurable system with many benefits.

CONDITIONS FOR THE IMPLEMENTATION OF SOCRATES

Implementation of SOCRATES would require several steps. If licensed operators are not to be present at each node, then permission must be obtained from the Federal Communications Commission to use a selected frequency for transmitting the packets and to use low-cost amateur radio equipment. Second, the assistance of amateur radio operators might be enlisted to set up and maintain each station. Amateur radio operators have a long tradition of public service and they are often highly-motivated inidviduals. Many hams would be delighted to assist on a volunteer basis. These are essential conditions if the cost is to be kept as low as possible. Fiscal and administrative support must be gained from the school districts.

SUMMARY

As has been discussed, recent innovations in communications technology have made it feasible for a large number of individuals to exchange messages and computer files over long distances with automatic correction of errors incurred in transmission. Such a comunications system, consisting of a computer terminal, a terminal node controller, and a radio transceiver, can be assembled from inexpensive modules and would provide a valuable link between Tennessee schools and colleges.

Benefits to the educational community would be several. The system could also function as an emergency communications network in case of disaster. Other benefits include exposing our children and our teachers to higher technologies; acquainting students with aspects of engineering, ham radio, and telecommunications; and creating a model network that can be "exported" and eventually linked with other state networks.

SYNTHESIS

The authors are configuring a three- or four-node packet network for demonstration at the annual meeting of the Tennessee Academy of Science in November, 1987. Readers who might be interested in taking part in such a demonstration are invited to correspond with one of the authors.

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