Implementation Brief ■

Arizona Telemedicine Program:

Implementing a Statewide Health Care Network

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Abstract The Arizona Telemedicine Program was established in July 1996 by the Arizona state legislature. The organizational center for the program is the Arizona Health Sciences Center in Tucson. Key goals for the program include increased access to specialty services for rural, underserved populations; development of cost-effective telemedicine services; and expansion of opportunities for education of health professionals in rural areas. The program provides several levels of services based on both store-and-forward and real-time interactive applications. The telecommunication infrastructure is provided by two methods: The first is a private asynchronous transfer mode network established and operated by program personnel. The second is dial-up access via the public switched telephone network. After an extensive period of organization and vendor evaluations, most of the private network was implemented between June and December 1997. This paper describes experiences establishing the asynchronous transfer mode network.

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Existing trends in health care, coupled with advances in technology and related economics, have led to widespread interest in telemedicine services.[1,2] These services typically include transmission of multimedia information in support of interactive video consultation, both radiologic and nonradiologic imaging, and text and physiologic monitoring. The diversity of applications for which telemedicine is applied is certain to grow dramatically.[3,4] In July 1996, work was initiated on a program to establish integrated telemedicine services supporting several rural sites in the state of Arizona. This paper describes the requirements that guided the selection of the wide area networking and application technology used to support the program. It also describes some of the complexities that may be encountered in implementing a statewide telemedicine network in collaboration with multiple organizations and provides a status report of the information technology aspects of the program.

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Background

The Arizona Telemedicine Program is funded by the state legislature and the federal government. The original state funding was approximately $1.2 million a year for four years beginning in July 1996. Federal grant opportunities are evaluated each year and typically are one- or two-year projects that build on the growing infrastructure initiated by the state funding. This funding is, in part, a response to the increased recognition of the needs of underserved populations in the state. Arizona has an area of 113,909 square miles and is the sixth largest state in the United States. Slightly more than one quarter (26.7 percent) of the state is set aside for Indian reservations. There are other federal reservations throughout the state, and only 17.6 percent of the land is privately owned. In spite of this, the population growth rate over the last several years has been tremendous. According to the 1990 census, 18.8 percent of the state's population is

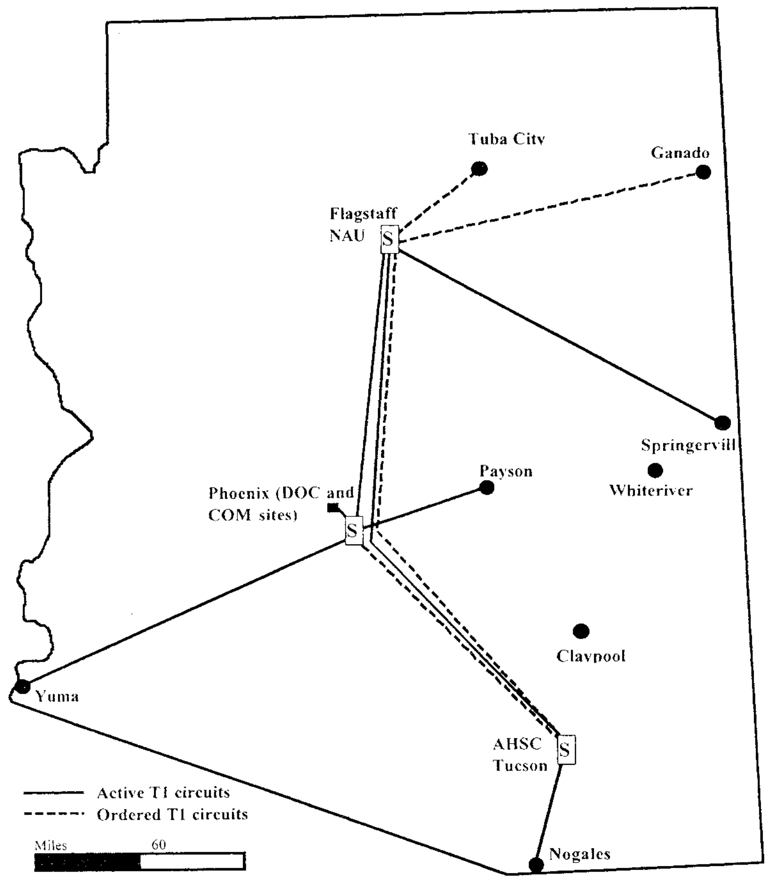

Figure 1 Map of the Arizona asynchronous transfer mode (ATM) network. A boxed S indicates an ATM switch; NAU, Northern Arizona University; DOC, Department of Corrections; COM, College of Medicine; AHSC, Arizona Health Sciences Center.

of Hispanic origin, and 5.5 percent is Native American. Although it has a large area, Arizona is divided into only 15 counties. Thirteen of these are designated rural. Only Maricopa and Pima counties, in which Phoenix and Tucson respectively are situated, may be considered high-density, metropolitan areas. About one quarter of the state's population lives in rural areas covering 95,000 square miles. The Rural Health Office at the University of Arizona has identified an uneven distribution of health care resources, with most rural areas significantly underserved. The large size of the state imposes difficult geographic constraints that can be best met through the use of networking and computing technologies to support health care delivery, education, and research.

Design Objectives

Key network requirements originally specified (in order of priority) included the following:

- Development of a flexible, scalable, and enduring network infrastructure;
- Support for point-to-point real-time interactive video consultation (initially only a single consulting station was planned for the central site);
- Local area network–like support for store-and-forward data applications;
- Dynamic allocation of bandwidth;
- Support for voice and other real-time applications (e.g., digital stethoscopes);
- Support for access to Internet-based resources at the Arizona Health Sciences Center library and other sites (e.g., the National Library of Medicine);
- Multicasting of "grand rounds" continuing medical education programming; and
- Support for multipoint conferencing.

System Description

Communication Infrastructure

The combination of requirements and constraints and an offer of collaboration by Northern Arizona University led to the selection of a private asynchronous transfer mode (ATM) network based on T1 carriers.

This choice was also based on a review of other telemedicine projects[5,6] and the limitations of services that affect many telemedicine efforts.[7] The network would have a core of three ATM switches located in the northern, central, and southern regions of the state. The choice of three switches allows for extensive savings on monthly communications charges, since each T1 circuit to a rural site can be routed to the nearest switch. Based on the requirements and budget constraints, the switches were to be initially connected by single T1s. This would not be an immediate problem and would present a bottleneck only for multipoint conferencing or when an additional real-time unit was acquired for the Arizona Health Sciences Center site. A map of the network (Figure 1) shows each ATM switch as an S enclosed in a box. The northern switch is located on the campus of Northern Arizona University in Flagstaff. The central switch is located at the Phoenix Programs office of the University of Arizona College of Medicine. The southern switch is located at the Arizona Health Sciences Center on the campus of The University of Arizona. A nonrural site in Phoenix is the Department of Corrections Inmate Health Services Office.

With the choice of network architecture determined, the selection of equipment vendors followed. Two important criteria that influenced this decision were the availability of ATM access concentrators that were suitable for the T1 network and capable of dynamic bandwidth allocation, and attractive pricing. Fore Systems, Inc. (Warrendale, Pennsylvania) met these requirements and was simultaneously selected under a state request-for-proposal (RFP) process. A decision was made to utilize switches capable of accepting additional switching fabric in order to accommodate future growth of the network and to facilitate collaboration with other organizations within the state. "Switching fabric" refers to the processing electronics within the switch that makes decisions about switching ATM cells from an input line to an output line. In ATM all data, whether they represent voice, video, or computer information, are packaged into small, fixed-length cells that are moved through the network from a source to one or more destinations. The first ATM switch was ordered at the beginning of 1997.

Selection of telecommunication service vendors followed a formal RFP process. Initial purchase orders were issued at the end of May 1997, and the first circuit was delivered in mid-June 1997. By design of the network, the services ordered under this process were all intra-LATA (local access transport area). The first switch at the Arizona Health Sciences Center was brought up in early June and the first rural site, Mariposa Health Clinic (Nogales), was brought online in mid-June. Subsequent sites have been brought online as equipment and communications circuits have been delivered.

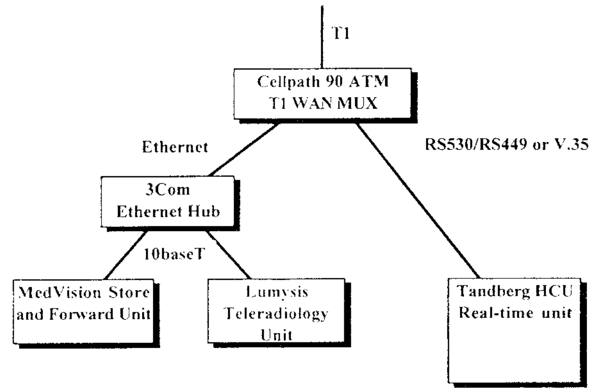

Figure 2 Application and networking equipment at a typical rural site. ATM, asynchronous transfer mode; WAN MUX, wide-area-network multiplexer; HCU, Health Care Unit.

Concurrently, personnel concerned with medical and video applications selected the Tandberg (Herndon, Virginia) CANVAS Health Care Unit for interactive telemedicine equipment. Previously, MedVision (Minneapolis, Minnesota) had been selected for general purpose store-and-forward applications, and CompuRAD (Tucson, Arizona) was selected as teleradiology vendor. CompuRAD was recently purchased by Lumisys (Sunnyvale, California). The network and application equipment at a typical rural site are shown in Figure 2.

Implementation

Significant complexity arises from the use of multicarrier services in a large rural state. At the beginning of June, after completion of the RFP process, bids were accepted and orders placed with carriers. Such complexity will arise for any project leasing telecommunication infrastructure that crosses LATA boundaries or spans areas served by different local exchange carriers. When planning for a widely distributed telecommunication infrastructure, programs lacking inhouse technology expertise may outsource to a systems integrator to coordinate this work. Outsourcing will push the details of dealing with carriers to the integrator but will not necessarily speed up the process, since the circuits ultimately depend on the carriers. For most of the communication circuits used by the ATP, four or five separate organizations were involved in the implementation process. In the case of some vendors, the contacts dealt with by ATP personnel were in another state and were not familiar with the geography of Arizona.

For the Arizona program, most circuits linking rural sites to the core network were awarded to U.S. West, and in general these were delivered within about 30 days. Facilities were found to be limited for the Yuma prison and Payson Regional Medical Center circuits. For the former, a lack of facilities between Yuma and Phoenix imposed a small delay on delivery of the circuit until the last week of September. Extension of the circuit across the prison to the telemedicine unit was then accomplished by Department of Corrections personnel with assistance from U.S. West. Additional electronics were obtained to allow extension of the circuit over existing fiber-optic cables.

For Payson, U.S. West determined that they could not deliver the required coding and framing (B8ZS, ESF) required for use with our ATM equipment but could provide only an older format on the T1 (AMI, SF). They have committed to upgrading their facilities by April 1998. A temporary solution was developed to delay extension of the ATM network to Payson. Currently, the T1 is used to route video-only data back to the core network point-of-presence in Phoenix. This limits the Payson site's usage of the network to real-time video only. Store-and-forward cases are sent via dial-up over the public switched telephone network until the facilities changes can be made.

The core network T1s linking the three ATM switches are leased from Northern Arizona University and are provided by AT&T. These circuits, requested in April, were not part of the RFP process and were delivered within 90 days.

The two sites remaining from the current set of rural sites are Sage Memorial Hospital (Ganado) and Tuba City Indian Medical Center (Tuba City), both on the Navajo reservation in northeastern Arizona. Delivery of T1 circuits by Electric Lightwave, Inc. (Vancouver, Washington), an interexchange carrier, was completed on January 12, 1998. Integration into the ATM network and installation of communication and application equipment should be complete by mid-February, when application equipment is delivered.

Figure 3 shows the complete physical path from the Springerville site to the nearest ATM switch, located in Flagstaff. The figure shows the segments of the path for which different organizations have primary implementation responsibility. Notice that there are two different local exchange carriers.

Telemedicine service support for the Arizona Health Sciences Center is distributed among three locations. A training and consultation room provides systems for both interactive and store-and-forward applications. The room has two interactive telemedicine units ("send" and "receive") and several store-and-forward units. These systems are used for both training and clinical services. Teleradiology is supported by a new dedicated facility in the Department of Radiology, which is linked to the training room by fiber-optic cables. This facility provides both a dedicated teleradiology viewing station (Lumysis) and a general-purpose store-and-forward system (MedVision). The primary difference is that the dedicated teleradiology software is DICOM compliant and provides specialized functions for image display and manipulation that are not available on the general-purpose system. DICOM is the Digital Communications in Medicine standard, which is widely used in radiology. The teleradiology-specific software provides more sophisticated image-viewing tools, which are required for radiology but not for general telemedicine. Con-

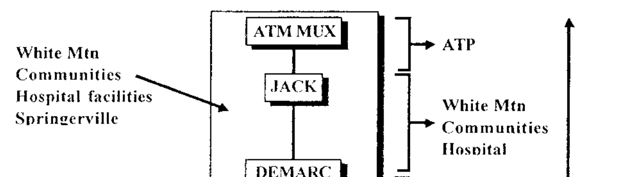

Figure 3 Organizations involved in the Springerville T1 circuit. ATM MUX indicates asynchronous-transfer-mode multiplexer; DEMARC, demarcation point; CO, central office; ATP, Arizona Telemedicine Program; NAU, Northern Arizona University.

versely, the general-purpose system provides multimedia features that allow rural sites to send voice and video clips as well as text and scanned documents. The MedVision software is not currently DICOM compliant, but it supports a very easy-to-use e-mail facility for sending cases. Support for DICOM-formated images is planned by the vendor.

Servers for both store-and-forward systems are located at the Radiology Research Lab in an adjacent building that is also linked by fiber-optic cables. Data applications are broken out to a LAN by a multiprotocol bridging router that provides a gateway between ATM and 10baseT/100baseT networking. Since the ATM access concentrator equipment at the rural sites also includes an Ethernet port, the data applications at the remote sites and at the Arizona Health Sciences Center all appear to be attached to a contiguous LAN. An ATM access concentrator is considered an "edge device," because it is at the "edge" of the ATM network and provides the interface for non-ATM equipment. Access concentrators typically provide conversion from a variety of external data formats to ATM cells and a possibility of multiplexing those cells into the ATM output stream. The reverse is done for cells arriving on the ATM input stream.

Status

The following four rural sites are utilizing telemedicine service over the ATM network:

- Mariposa Community Clinic, Nogales (on line July 1997)
- White Mountain Communities Hospital, Springerville (on line October 1997)
- Arizona State Prison complex, Yuma (on line November 1997)
- Payson Regional Medical Center, Payson (on line November 1997)

Currently, three of the sites use the network for both real-time interactive consultation and store-and-forward applications. In addition to these sites, the Department of Corrections Inmate Health Services Office in Phoenix is connected to the network for both interactive and store-and-forward applications.

By mid-May 1998, a total of 928 telemedicine sessions had been completed, including teleradiology. Store-and-forward technology was used for 748 cases, while real-time video was used for 65 cases and 115 administrative meetings. Specialty consultations included teleradiology, dermatology, surgery, endocrinology, cardiology, oncology, rheumatology, and neurology. Other specialties with at least one consultation included gastroenterology, toxicology, genetics, pulmonology, and urology. Specialists in most of these areas are not available at the rural sites, and the alternative is usually to refer patients or transport them in emergency situations. Physician support for telemedicine services at the Arizona Health Sciences Center has been very strong.

For real-time interactive video cases the interaction times have ranged between about 15 minutes (for a single consult) and two hours (for virtual clinics). For store-and-forward cases the turnaround time may vary between 30 minutes and 48 hours, depending on the case and the availability of appropriate specialists.

The clinic at Nogales has the longest term of experience using telemedicine and has provided 177 cases. Springerville has rapidly gained confidence in the use of telemedicine, with 136 cases sent, and has been the most active in using more sophisticated techniques such as sending real-time ultrasound consultations (e.g., in echocardiology). Tuba City has utilized dial-up access to send 41 cases while waiting for delivery of their high-speed communication line. Other sites have moved more slowly as they develop their internal protocols for promoting the use of telemedicine. The Department of Corrections facility initially used the communication infrastructure significantly to send test cases to their central Inmate Health Services Office while they developed official protocols for conducting telemedicine consultations involving inmates. Since completion of the protocols in February 1998, they have sent 48 cases.

In addition to the sites connected via the ATM network, four sites are using dial-up access for teleradiology services. These include the Veterans Administration Medical Center and Kino Hospital in Tucson, the Indian Health Services Hospital in Whiteriver (located on the White Mountain Apache Indian Reservation), and Cobre Valley Community Hospital in Claypool. Teleradiology consultations from these sites have totaled 490 cases. The provision of teleradiology service is well integrated into the routine operation of the Department of Radiology, and planning is in progress to allow radiologists to view teleradiology images at their desktops.

Discussion

The ATP initially sought a "turnkey" communication solution from a vendor, which would place the responsibility for the network in the hands of the vendor and allow the ATP to focus on clinical usage. Although this was not feasible in Arizona, it should be the first choice for those telemedicine organizations that do not have technical or engineering personnel. In exploring this option we found that vendors were often concerned more with fitting our requirements into a standard solution than with finding a solution that satisfied our requirements.

The choice of the ATM configuration reduces the amount of equipment that must be purchased and installed at the end-user site, at a savings of approximately $1,000 per site. Furthermore, it reduces the complexity of the configuration by reducing the number of devices required. This simplifies management and maintenance compared with the alternative of static multiplexing over T1 circuits. From another cost standpoint, a key advantage of the ATM network architecture is that it allows us to reduce the costs associated with the rural T1 circuits, since we can route each circuit to the nearest ATP network point-of-presence and thereby shorten the distance. This is beneficial because T1 circuit costs have a distance component. All rural sites share the backbone of the network to get to the hub site. This architecture ensures that the backbone is fully utilized and reduces the cost of connections to the rural sites. It also allows us to connect most rural sites without the need to cross LATA boundaries. Crossing LATA boundaries would limit the program to using long-distance carriers to obtain communication services, since local exchange carriers cannot haul traffic across those boundaries. By providing points-of-presence in three regions of the state, competition among providers for the individual rural T1s is made possible, allowing us to select the lowest possible price. The backbone lines do cross LATA boundaries and are subleased by the ATP from Northern Arizona University at very favorable rates, since they have a long-term commitment for the circuits from AT&T.

We have found that ATM technology provides a powerful and flexible mechanism to support our communication requirements with dynamic bandwidth allocation. ATM requires a steep learning curve and significant time investment to ensure its effective use. Our network management personnel spent two weeks reviewing manuals and planning the configuration of the network. Even with planning ahead, it took about two weeks of experimenting to refine the operation of LAN emulation services across the wide area network. LAN emulation allows the store-and-forward application computers at the hub and rural sites to appear to be on a LAN. We benefited significantly from the assistance of the technical advising center at Fore Systems as well as from hands-on help from the in-state support engineer. An important misunderstanding is that ATM is very expensive because it is associated with very-high-speed (622 or 155 Mbps) signaling channels. We have found ATM to be very inexpensive and to work extremely well over T1 circuits to support a mix of video and data applications.

Our costs for ATM switches and access concentrators for the whole network has been about $192,000. Compare that with a typical cost of about $155,000 for the application equipment (real-time video and store-and-forward) for a single rural site. Overall, including sites that are dial-up only, approximately $578,000 has been spent on real-time video conferencing application equipment and $400,000 on store-and-forward application equipment. The capital costs for the network infrastructure have been about 22 percent of the overall capital costs. Costs for the T1 circuits are the key issue for long-term viability of most telemedicine programs that lease dedicated high-speed lines. This is certainly true in Arizona, with current annual telecommunication costs of approximately $300,000 per year. We have applied for Universal Service support for all eligible circuits and expect to reduce this cost by a minimum of $100,000 per year.

There is still a long way to go in the development of application equipment designed to work directly with ATM. Operating a private ATM-based telemedicine network certainly requires a permanent network manager. Organizations without existing technical personnel will typically outsource their infrastructure to a systems integrator and hire a more administratively oriented person to act as "technical" liaison with vendors. Such organizations may want to select an older, more turnkey infrastructure such as ISDN. In our case, we utilize the infrastructure for research purposes in addition to clinical operations and have faculty interested in ATM protocol research and the development of native ATM-capable applications.

Current plans for the telemedicine network include adding components to support additional end-user requirements. A grant has been awarded by the National Library of Medicine to install a firewall that will allow the rural telemedicine sites to gain access to Internet-based resources at the Arizona Health Sciences Library, the National Library of Medicine, and other information sources. A multipoint control unit was installed in April 1998. This unit supports multiparty video conferences with voice-activated video switching and will be an important resource for educational video-conferencing activities over the network.

To facilitate more responsive provision of telemedicine services at the Arizona Health Sciences Center, two additional video units and store-and-forward units will be set up in clinical areas. These will be in the Emergency Department (to support urgent care consultations to rural sites) and at the new Heart Center (to support cardiology interactions with rural sites). These new facilities will allow physicians to provide consultation services without having to leave their normal working environment to go to a special telemedicine suite. Tests have been completed linking the ATM network to existing television facilities used for continuing medical education, and the first educational programming has been delivered to a rural site. Regular educational programming and regular clinics are now being scheduled. Also, the University of Arizona is an Internet 2 (or Next Generation Internet, NGI) site and is connected to the new high-speed national backbone. We will connect the telemedicine ATM network to the university's ATM backbone to allow telemedicine interactions across the NGI. The NGI backbone is also an ATM network.

Elizabeth Krupinski, PhD, has provided regular updates on the case totals. A great deal of valuable assistance has been provided by Becky Tucker of U.S. West (Tucson) in coordinating the provisioning of T1 circuits. Fore Systems provided substantial technical support for the installation of ATM networking equipment. Simon Fraser of Tandberg USA has been an invaluable asset for the installation and fine-tuning of interactive video systems. Doug Vuxon-Von Beek of MedVision provided excellent support for the installation of store-and-forward applications. Finally, Matt McGlamery and Troy Lorents of Northern Arizona University have provided a great deal of help in establishing the core network.

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