A Look at the Evolving Classroom: Wireless Data Communication and Mobile Satellite Communication

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In this paper, the authors describe potential applications of wireless data communications and mobile satellite communications technology aimed at improving education. The motivation behind this work is that the technology now exists for providing today's students with not only better access to educational facilities, but also instantaneous communications with distant sites and mobile units. Incorporating these communications technologies with existing information systems for education will increase efficiency and productivity as well as the educational opportunities for tomorrow's citizens.

I. Introduction

The technology now exists for providing today's students and employees with not only better access to educational and training facilities, but also instantaneous communication with distant sites and mobile units. Recent advances in wireless communications systems - of which cordless phones, pagers, and cellular telephones are some of the most familiar examples - and its integration with mobile satellite communications have made this possible.

A. Wireless Data Communication

There is an emerging shift from a world where telephone subscribers are constrained to communicate over fixed telephone lines to a world where the tetherless and mobile communications environment has become a reality (Pahlavan & Levesque, 1994). Today's smaller and more powerful personal digital assistants (PDAs) are coming out with the capability to support wireless data transmission with modems implemented on a Personal Computer Memory Card International Association, or PCMCIA, card (Moeller & Siegal, 1994; Moeller, 1995h). Despite the progress within the past several years, there continues to be a growing demand for better, clearer, and cheaper wireless voice and message paging services.

Wireless data networks fall in two forms: mobile data networks and wireless local area networks (WLANs). The chief characteristics of three of the five or so currently available mobile data networks that provide packet data services are summarized in Table 1.

ARDIS, formed by IBM and Motorola, is a two-way radio service first implemented in 1983. The service is suitable for two-way transfers of data files of size less than 10Kb (256 byte transmission packets), and much of its use is in support of computer-aided dispatching, such as is used by field service personnel, often while they are on customers' premise. ARDIS supports portable communications from inside buildings as well as on the street. These are achieved by overlapping coverage areas, combined with designed power levels and error-correction coding in the transmission format. Transmission rate is at 9.6K bps, to be upgraded to 19.2K bps by the end of 1995. Current coverage is over 90% of the U.S. population.

RAM Mobile Data Network uses Ericsson MOBITEX data technology. RAM is a nationwide, interconnected, trunked radio network developed by Ericsson and Swedish Telecomm. While the MOBITEX system was designed to carry both voice and data services, the U.S. and Canadian networks are used to provide data service only. The transmission rate is 8K bps and the service is suitable for file transfers up to 20 Kb (512 byte transmission packets). Both MOBITEX and ARDIS use packet-switching techniques to allow multiple users to access the same channel at the same time. Also, both provide in-building and mobile communications coverage.

Table 1. Chief characteristics of three mobile data services (adapted from Pahlavan & Levesque, 1994).

System:	*ARDIS*	*MOBITEX*	*CDPD*
Channel Bit Rate (kbits/sec)	19.2	8	19.2
Packet Length	Up to 256 bytes	Up to 512 bytes	24 to 928 bits
Open Architecture	No	Yes	Yes
Carrier	Private	Private	Public
Service Coverage	Major Metro. Areas in U.S.	Major Metro. Areas in U.S.	30 Major Cities in U.S.*
Type of Coverage	In-Building & Mobile	In-Building & Mobile	Mobile

* Automatic switching to analog cellular, if available and required.

The Cellular Digital Packet Data, or CDPD, system is being designed to provide packet data services in an overlay to the existing analog cellular telephone network. CDPD is being developed by IBM in collaboration with nine cellular carriers: McCaw, GTE, Contel Cellular, AmeriTech, Bell Atlantic, NYNEX, Pacific Telesis, Southwestern Bell, and US West. CDPD's compatibility with the existing cellular telephone system allows it to be installed in any analog cellular system in North America, thus providing data services that are not dependent upon support of a digital cellular standard in the service area. Transmission rate is up to 19.2K bps. Intended applications for CDPD service include: electronic mail, delivery tracking, inventory control, credit card verification, security reporting, vehicle theft recovery, traffic and weather advisory services, and a potentially wide range of information retrieval services. As of this writing, CDPD provides mobile communications coverage: in-building is not guaranteed, but systems usually switch automatically to analog cellular in these cases.

On the other hand, WLANs use either licensed cellular, unlicensed spread-spectrum, or diffused and direct-beam infrared technologies. The technology used at a site depends on the required data transmission rate, transmission range, mobility, and other factors. Spread-spectrum systems provide the largest coverage and are suitable for applications where penetration through building walls and floors is desired. Transmission range is between 100 to 800 feet. The evolving next generation of WLANs is designed to be incorporated into laptop, notebook, and pen-pad computers, where significant reductions in size and power consumption are needed (Santamaria & Lopez-Hernandez, 1994).

B. Mobile Satellite Communication

Satellite communications for mobile applications has only recently flourished (Wu, Miller, Pritchard & Pickholtz, 1994). There are a number of global satellite systems for mobile communications. One of them is the Global Positioning System, or GPS. GPS is a constellation of satellites that orbit the earth twice a day, transmitting precise timing information. The primary purpose of this system, which differs from the communications purpose of other satellite systems, is for mobile location or position identification. There are 21 active and three spare satellites, each 10,500 miles above the earth. Transmissions may be collected by any GPS receiver at no charge at any hour. Receivers transform these signals into latitude-longitude-altitude information, or any other format that suits the user's application.

GPS receivers listen to 3-4 satellites at a time. Each satellite transmits two signals: a C/A-code signal for worldwide civilian use, and a P-code signal for U.S. military use only. C/A-code is a spread-spectrum signal broadcast at 1575.42 MHZ. It is not affected by weather and electrical noise, and it is resistant to multipath and night-time interference. GPS receivers use these captured signals to determine the position of the receiver based on the computed distance from the satellites. Position and velocity information are quite accurate at C/A-code errors of less than 25 meters for the former and 5 meters/second for the latter.

Commercial and potential applications of GPS continue to grow at a rapid pace. In addition to communications, navigation, and location identifications for aircraft, ships, and land mobiles, GPS applications have been spruced up for oil and gas rigs, utility installations, tracking for law-enforcement agencies, urban and regional planning, data collection, worldwide search and rescue, accurate survey and mapping, as well as hurricane identification and relief. This interest is primarily due to the location accuracy on the earth surface, and the decreasing costs of GPS receivers (Wu, Miller, Pritchard & Pickholtz, 1994).

C. Information Systems in Education

Educational institutions rely heavily on campus-wide information systems. These systems tend to be classified as either academic or administrative, and in most cases, both. Some examples of these systems include payroll management systems, student registration and/or information systems, library information systems, and others. There are also educational institutions that disseminate information through student-run radio or television stations, electronic bulletin board systems (or BBSs), and even remote host dial-up access.

It is this information explosion, coupled with advances in communications technology, that spawned a growing interest in *distance learning*. Using two-way, interactive audio-video equipment, classes can be held remotely, possibly even via satellite. This is highly supported by the increasing availability and affordability of fully integrated two-way data, voice and video services on the same communications channel. The same technology is being used in the medical field. In this scenario, doctors at remote locations from each other can share and/or demonstrate new surgical techniques, request for advice based on patient information, and more.

Another important issue is the growing demand to have access to the Internet. In some states, this is now being provided at the middle school level. Students are being exposed to electronic searches and the World Wide Web at a steadily growing earlier stage in their academic life. Similarly, graduate students, researchers, and faculty also demand such access to facilitate their research and even conduct collaborative work *remotely*. The use of such extended information systems are becoming commonplace in the curriculum as Internet resources continue to improve and become more accessible to everyone.

Despite all this available technology, there is still an apparent need to improve existing information systems in education. As existing technology matures and new discoveries surface, we will continue to witness changes in the evolving classroom.

II. Communications Technology and Information Systems in Education

Within the last few years, educators and employers have been excited about the potential of Computer-Based Education and Training or CBET (Reinhardt, 1995). Three new technologies, quickly making their way into our classrooms, are making this possible: networking, multimedia, and mobility. Networking consists of local area networks (LANs), wide-area networks (WANs), and on-line services. On-line services also include access to the Internet and searching through the World-Wide Web. Multimedia combines analog and digital video, 2D and/or 3D animation, audio, hyperlinks, and others. In institutions where this is available, mobility involves on-line communication between remote notebook computers and in-campus computers.

In addition to the organization and layout of connecting cables, existing wired LANs often require extra space for wiring. Since WLAN technology allows data transmission through walls and floors, there would be no need to setup cable connections and waste office/classroom space to accommodate networked computing equipment. Wireless optical networks could also be used if communications privacy within the office area is desired. Infrared signals have limited range and do not penetrate walls. This transmission technology is more popularly used for low-speed remote-control and short distance wireless connections between the keyboard or mouse and the terminal. It is also used for in-office data transfer between PDAs and host computers. Clearly, WLAN technology facilitates transient networks. Such networks that are easy to set-up and dismantle, fairly flexible and extendible, and hence simple to maintain.

PC Week magazine's section on Mobile Computing is up-to-date on the latest in wireless communications. These include significant advances and their effects, say, to the office (Decarlo, 1995) and business (Moeller, 1995a) environments. One of the most interesting moves is that towards the "virtual workplace". AT&T Global Information Solutions envisions this as an integration of notebooks (including mobile PCS and peripherals, LAN and PCMCIA cards), communications products, network services, application software, and support services (Decarlo, 1995). American Airlines is using wireless technology for customer service that provides real-time database access (Moeller, 1995a). Soon to be available are "smart phones" (Moeller, 1995e), phones with PDA-like features (*e.g.* LCD screen and note-taking capability) that combine voice, organizer, and other capabilities. Networking companies are also recognizing an increasing demand for wireless service and are constantly trying to improve the service and support they provide (Moeller & Siegal, 1994; Moeller 1995b; Moeller 1995c; Moeller 1995d; Moeller 1995f).

A. The "Virtual Classroom"

The American Council on Education has released the results of its Campus Trends 1995 survey (Roberge, 1995). The top four trends seen for the next five years were reported as follows:

Table 2. Percentage of institutions reporting these changes as "very likely" (adapted from Roberge, 1995).

More courses using electronic materials	68%
More courses through distance learning	47%
Class assignments submitted electronically	36%
Registration by telephone/computer	35%

This clearly indicates a growing awareness of technological advances and their potential for improved, new ways of learning and teaching. It also supports the incorporation of networking capability, multimedia systems, and mobility with existing information systems in education.

Similar technological changes in the corporate office should be expected in the classroom as well. The classroom is evolving into a "virtual classroom". We have witnessed students moving from the traditional paper notebook, to the laptop or electronic notebook. Soon, we will see "smart" subnotebooks with wireless data communication capabilities in the classroom. These will be similar to the "smart" phones by Nokia and IBM (Moeller, 1995e), in that they will also feature:

- Note-taking capabilities
- Organizer/Scheduler
- Rolodex
- Internet access
- E-mail capabilities
- Faxing

The same piece of equipment could be used for taking down notes, for solving problems and assignments, for accessing in-campus information systems (be it searching for library materials or registering for a class in the coming semester), for sending e-mail to instructors (possibly for turning in assignments), and for many other functions.

II. Lessons Learned from Designing a Vehicle Tracking System

Working as consultants for Signal Oriented Location and Information Systems (SOLIS), Inc. of Myrtle Beach, South Carolina, the authors developed a prototype wireless communications system for vehicle tracking (Juliano & Sheel, 1995a). Constrained by a limited budget and a tight schedule, the successfully implemented prototype is capable of transmitting messages and vehicle locations from a mobile unit for real-time communication and digital map display at a central dispatching office.

The system uses Motorola RPM 405i radio packet modems to send and receive messages on the ARDIS network and Magellan AIV-10 GPS receivers for mobile vehicle location. Perhaps one of the most interesting characteristics of this system is that it was developed from off-the-shelf components. The system is cost-effective, and still flexible enough to deliver high-quality service (Juliano & Sheel, 1995a; Juliano & Sheel, 1995c). It is the experience the authors had in developing this system that prompted them to look at possible applications in education, based on the issues presented in the previous paragraphs. Figure 1 below illustrates the different components of the SOLIS system and how they relate to one another.

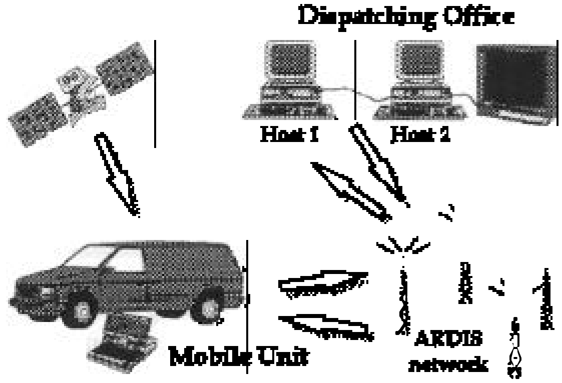

Figure 1 SOLIS system diagram (from Juliano & Sheel, 1995a)

One important item to note, though, is that some companies providing goods or services in the wireless arena are charging ridiculously high prices. This will most likely change as competition becomes tougher. On the meantime, the authors realize that off-the-shelf components could be used to develop such systems. For example, a system similar to the prototype system developed by the authors was purchased by the city of Minnesota from a company called Guidestar (Pesce, 1994). The system tracks 80 of their 1000 city buses. There are also a few kiosks integrated with the system that commuters can use to determine more precise bus arrival and availability times The city paid $6.5M for the whole system. In comparison, the prototype developed by the authors has similar features at a fraction of the cost!

Although the tracking ability using mobile satellite communications does not really fit in the classroom scenario, satellite communication will increase the range at which two-way wireless communication can be achieved. Integrating this with the "virtual classroom" will provide better communication between teachers and students. This is one of primary goals of NASA's Advanced Communications Technology Satellite, or ACTS, program (NASA, 1995a).