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 nighttime 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.

How does mobile data communication come into the picture? Firstly, wireless communication between remote sites could be used to educate people outside of major learning centers. Secondly, if mobility is an issue, this facilitates distance learning even more: the instructor, or the student, does not have to be in the classroom to meet for a class. Classes could be conducted from a research laboratory, from a manufacturing plant, from an operating table, or even from the office. Of course, this is not meant to replace traditional personal interaction. With this approach, teachers and students will have much greater access to each other and to resources such as national and university library collections of books, artwork, photos, records and films. People who travel between campuses can also benefit from this arrangement.

B. 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.

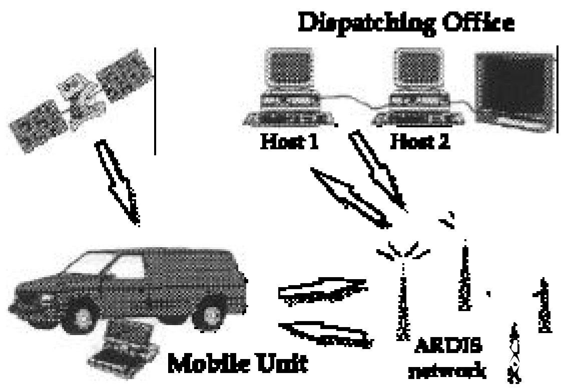

Figure 1 SOLIS system diagram (from Juliano & Sheel, 1995a)

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 (Peace, 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).

III. Other Applications for Educational Institutions

The use of wireless technology extends outside of the classroom. Scientific research that is conducted in remote areas that are not accessible by modern transportation would benefit from both wireless and satellite communications. With communications capabilities improving steadily, movable or "mobile" communications could provide a transportable link back to laboratories or universities. This is also one of the major research initiatives of the NASA ACTS Program (NASA, 1995b). Combining wireless networks with satellite communications could greatly improve access to remote databases that contain much needed information. Researchers would also have the ability to communicate in realtime with other scientists in the field to obtain results from experiments or to consult on problems.

On the administrative side, one possible application is in school bus management (Juliano & Sheel, 1995b). This is an adaptation of the original vehicle tracking prototype system developed by the authors. The proposed application has the following features:

- Buses equipped with GPS receivers can collect data from GPS satellites regarding their current location, speed, heading, etc. This information is received every second and so the most recent positional data is always available locally.
- Furthermore, buses also equipped with wireless radio packet modems will have the capability to transmit GPS data and/or messages through the ARDIS radio network.
- GPS data and messages transmitted through the ARDIS network can be received by destination sites equipped with wireless radio packet modems. Any pertinent positional information can be displayed on a digitized map for precise location of vehicles in a fleet.
- Two-way wireless communication can be achieved between any remote vehicle and the dispatching office.

This was originally proposed as an added safety feature to monitor bus driver job performance and school bus routes. This could also be useful when the school buses are used for field trips and other functions.

IV. Summary, Conclusions, and Recommendations

There is no doubt that educational technology is directly affecting the way we learn and the way we teach. With so much information available around us and technology maturing at an increasing rate, we expect to find the latest hi-tech equipment coming into the classroom. Incorporating wireless networks and satellite communications technologies with existing information systems within educational institutions will clearly increase efficiency and productivity as well as increase the educational opportunities for tomorrow's citizens.

The capacity, quality, and cost of these modes of communication are expected to improve in the next few years. Relative to the prototype vehicle tracking system developed by the authors, recent developments and the growing interest in CDPD technology (Moeller, 1995g) is another possible area to look into. This may be a feasible alternative to the use of the ARDIS network.

We have access to a mere tip of the iceberg as far as wireless data communications and mobile satellite communications goes. And still, with wireless data networks and mobile satellite communications entering the office and business environments – soon, the evolving classroom – it is sure to affect many aspects of our lives.

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International Conference on Computers in Education 1995

edited by
David Jonassen
Gordon McCalla

Proceedings of *ICCE 95*
Organized by the Asia-Pacific Chapter of AACE
Singapore; December 5-8, 1995

AACE Association for the Advancement of Computing in Education

Comments on the ICCE 95 Program

These are the Proceedings of the International Conference on Computers in Education, held in Singapore, December 5-8, 1995. This is the fourth ICCE to be held, the first outside of Taiwan, and the largest to date in terms of contributed papers. The ICCE conferences are biennial conferences organized by the Asia-Pacific Chapter of the Association for the Advancement of Computers in Education (AACE). It is an explicit aim of the ICCE conferences to be a showcase for computers in education research in the Asia-Pacific region, to act as a stimulus to further research in this region, and to provide an opportunity for researchers from all over the world to share ideas and research results with researchers in the Asia-Pacific region. It is also a goal of the ICCE conferences to encourage researchers from diverse areas of advanced educational technology to come together and to take a broad view, whatever their particular narrower research objectives. Finally, it is hoped that the conferences will both demonstrate the quality of computers in education research in the Asia-Pacific region and elsewhere in the world as well as encourage this quality to be enhanced over the years. As program co-chairs, we feel that the ICCE 95 conference contributes to these goals.

First, consider the goal of geographic diversity. There were 154 papers submitted overall. Based on the location of the first author of each paper, the papers hailed from 6 of the 7 continents of the world (excepting only Antarctica!). The breakdown by continent is: Africa (2), Asia (81), Australia/New Zealand (16), Europe (30), North America (21), South America (4).

These papers represent 26 different countries. The top 6 countries in terms of submissions are the People's Republic of China (32), Japan (19), United Kingdom (17), United States (14), Australia (12), and the host country Singapore (11). No other country has more than 7 submissions, although, of course, many papers have multiple authors, sometimes from different countries. It seems clear that the ICCE 95 conference has succeeded in achieving a desired widespread geographic balance, as well as acting as a focal point for Asia-Pacific research on computers in education.

The papers are also balanced as to their research focus. Submissions split right down the middle between papers that could be categorized as being in an "AI" stream and those in a "multimedia" stream, although many of them defy easy categorization. In any event, there is clearly a broad research spectrum represented in the papers submitted, and many of them describe research that is itself broadly based.

Finally, the papers are generally of a fairly high standard. Of the 154 submitted papers, 84 were accepted for full paper presentation and another 29, usually representing more preliminary work, were recommended for poster presentation. Only 41 were outright rejected. Of the rejected papers, many seemed to describe interesting projects, but these were either not in the scope of the conference or the papers were written too poorly to be understood. It is hoped that in future ICCE conferences the communication problem will diminish as researchers gain experience in how to communicate their research in clear, concise terms and in solid English. Overall, however, we can say that the goal of having papers of high quality has been met by ICCE 95.

No conference program can be put together by the program chairs alone. In fact, many people contributed in a major way to the final program of ICCE 95. First, we would like to thank all of our referees for their diligent efforts in reviewing many papers under extremely tight deadlines. We would like to particularly acknowledge the members of our program committee for coordinating the reviewing process and for, in many cases, reviewing by themselves all the papers they were sent. Without the efforts of these dedicated souls, it would simply have been impossible to put together the conference program. The names of the program committee members and of the referees appear elsewhere in the Proceedings. Thank you all! Finally, we would like to thank our "editorial assistant," Mauri Collins for her diligent efforts in managing the immense tide of paper and e-mail that surrounds the submission, reviewing, and decision processes in any conference of this size. Our extreme gratitude, Mauri, for all your hard work.

ICCE 95 Program Chairs:
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FOREWARD

As organizing chair of ICCE 95, I would like to highlight the various activities in the conference, and to thank the many people who helped in its organization.

ICCE 95 focuses on a broad spectrum of inter-disciplinary research topics concerned with theories, technologies and practices of applying computers in education. It aims to provide a forum for scientific interchange among educators, cognitive scientists, computer scientists, and practitioners throughout the world, and especially from the Asia-Pacific region. The main paper track of the conference is handled by the international programme co-chairs with the international programme committee. The other paper track is the Applications Track, a unique feature of ICCE 95, which offers papers from Singapore and other Asia-Pacific countries. These papers present practices in the use of information technology for education. A separate Applications Track committee was formed to run this track as well as review the papers submitted.

We received a total of about 50 papers from countries including Australia, Brunei, Canada, China, France, Guam, Hong Kong, India, Israel, Italy, Malaysia, Singapore, South Africa, and Taiwan. Of these, we accepted 26 for paper presentations. These papers, together with the papers of speakers invited by the Applications Track committee, appear in a separate proceedings. The Applications Track committee has also organized a software demonstration track. This is intended to allow researchers and non-commercial developers to demonstrate and discuss recent results and work in progress and to establish contact with similar projects.

ICCE 95 is held in Singapore at a time when there is a concerted effort by the Ministry of Education and the National Computer Board to introduce computers into schools to enhance learning and teaching. ICCE 95 thus provides an excellent opportunity for policy makers, practitioners, researchers, teachers and principals especially from Singapore to learn from the knowledge and experiences of others in the research, development and deployment of educational technology. It also allows them to share Singapore's work in this area with the rest of the world.

The invited speakers of this conference cover diverse aspects of the use of computers in education. Jan Hawkins, John Gardner, Carmee Lim, Ginny Leong, and Zoraini Wati Abas, will all share the experiences of their efforts in integrating computers into the school curriculum from different perspectives. Louis Gomez, John Anderson and David Dwyer will focus on work which they have pioneered: CoVis, cognitive tutors in Pittsburgh schools, and the Apple Classroom of Tomorrow, respectively. Hermann Maurer's talk will deal with digital libraries for teaching and learning support. John Self will review the role of student modelling in computer-based learning systems. We have also James Rossiter to talk about a Canadian initiative with several industry collaborators to promote distance learning.

I would like to thank all the local organizing and supporting organizations which contributed in many ways to making this conference possible. Many thanks are owed to all those individuals who contributed to the success of this conference. Firstly, thanks go to several colleagues in my institute: Hing Yan Lee who helped to bid for the conference in 1993; Christopher Chia, Joo Hong Lim, and Francis Yeoh who supported me in the hosting of the conference; and Kwee Pah Low and Hwee Suan Ong, who played major roles in the planning and organization of ICCE 95.

Next, my gratitude goes to David Jonassen and Gordon McCalla, the international programme chairs who have undertaken the onerous task of running the programme and doing it extremely well despite their hectic schedules. My appreciation is also due to Yeow Chin Yong for chairing and running the Applications and software demonstration tracks. I thank the invited speakers, authors of presented papers and posters, developers who demonstrated their software, sponsors and exhibitors. Finally, the members of the international programme committee and the Applications Track committee who have undertaken the task of reviewing the papers submitted for the conference, as well as members of the Steering Committee, and the Organizing Committee.

Finally, special thanks go to Gary Marks and Terry Davis of AACE, and AACE Asia-Pacific Chapter President Tak-Wai Chan for their tremendous help and support.

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