DOCUMENT RESUME

ED 387 099 IR 017 316

AUTHOR Juliano, Benjoe A.; Sheel, Stephen J.
TITLE Wireless Data Communications Prototyping: A Flexible, High-Quality, and Cost-Effective Information System for Education.
PUB DATE 95
NOTE 12p.; In: Association of Small Computer Users in Education (ASCUE) Summer Conference. Proceedings (28th, North Myrtle Beach, South Carolina, June 18-22, 1995); see IR 017 305.
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Communications Satellites; Computer Mediated Communication; Computer Uses in Education; Information Systems; Information Technology; Networks; *Radio; *Telecommunications

ABSTRACT

In this paper, potential applications of wireless data communications and mobile satellite technology are described which aim at improving education. The motivation behind this work is that the technology now exists for providing today's teachers and students with not only better access to educational facilities, but also instantaneous communications with distant sites and mobile units. Wireless data communications systems integrated with mobile satellite technology use wireless radio packet modems for message transmission between a fixed dispatching center and mobile units. Messages are relayed over a wireless data network, and mobile units are equipped with satellite receivers which read signals from Global Positioning System (GPS) satellites. A discussion of mobile satellite communications includes an examination of GPS, the Magellan AIV-10 OEM GPS Module, and Blue Marble Graphics MAIL Map, Geo View, and GeoCalc. Topics addressed in the wireless data communications discussion include the ARDIS Radio Network and the Motorola RPM 405i Radio Packet Modem. Mobile unit design, dispatching office design, and development issues and interface requirements are addressed in the section on system design. Wireless data networks, Internet access and distance learning, and administrative computing are offered as examples of applications in education. The last section of the paper addresses other applications and future directions. (Contains 19 references.) (MAS)

Wireless Data Communications Prototyping: A Flexible, High-Quality, and Cost-Effective Information System for Education

Benjoe A. Juliano, Ph.D.
Assistant Professor of Computer Science
Coastal Carolina University
P. O. Box 1954, Conway, South Carolina 29526 Tel. (803) 349-2144

Stephen J. Sheel, Ph.D.
Associate Professor and Chair of Computer Science
Coastal Carolina University
P. O. Box 1954, Conway, South Carolina 29526 Tel. (803) 349-2081

Abstract

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 teachers and students with not only better access to educational facilities, but also instantaneous communications with distant sites and mobile units.

The proposed solution uses cutting-edge technology while maintaining cost-effectiveness. The authors experiences in developing a prototype vehicle tracking system based on wireless data communications and mobile satellite communications furnished some ideas for using the same technology in education. In particular, this may facilitate access to the Internet and distance learning, possibly via mobile units. Remote areas not accessible by modern transportation, much less fiber-optic cable for communications, will benefit from such links back to major learning centers. Teachers and students will have much greater access to each other and possibly to other resources as well. Furthermore, wireless technologies can be used to implement local area, metropolitan area, and wide area communication networks. Administrators will have the ability to track and to communicate with mobile units such as school busses, maintenance vehicles, etc. Incorporating these communications technologies with existing information systems will increase efficiency and productivity as well as educational opportunities for tomorrow's citizens.

I. Introduction

A. Overview of the System

Recent advances in wireless data 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 provided better access to remote resources as well as instantaneous communications with distant sites and mobile units. This same technology was used by the authors to develop a flexible, high-quality, and cost-effective vehicle tracking system. This system uses wireless radio packet modems for message transmission between a fixed dispatching center and mobile units.

These messages are relayed over a wireless data network. Mobile units are equipped with satellite receivers that read signals from Global Positioning System, or GPS, satellites. Much of the same technology can be incorporated into the educational environment.

In the next two subsections, the authors take a brief look at mobile satellite communications and wireless data communications. The authors elaborate on the prototype system developed they developed in Section II. Applications of this technology in education are discussed in Section III and future directions are projected in Section IV.

B. Mobile Satellite Communications

Satellite communications for mobile applications has only recently flourished. There are a number of global satellite systems for mobile communications. Among these are (i) the International Maritime Satellite Organization (INMARSAT), headquartered in London, which has been providing voice, data, telex, and facsimile services to ships through its satellites since 1982; (ii) American Mobile Satellite Corporation (AMSC) and Telesat Mobile Incorporated's (TMI) MSAT geostationary satellites; and (iii) the National Aeronautics and Space Administration's (NASA) Advanced Communications Technology Satellite (ACTS), designed to access the telecommunications tools of the 21st century [14,15,19].

1. What is GPS?

The Global Positioning System, or GPS, is a constellation of satellites that orbit the earth twice a day, transmitting precise timing information. 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.

2. The Magellan AIV-10 OEM GPS Module

Magellan Systems Corporation of San Dimas, California manufactures a variety of GPS receivers and modules. The Magellan AIV-10 OEM GPS Module [9] is one that comes with a Developer's Kit.

Communication between an external application software and the Magellan AIV-10 OEM board takes place via serial data transmitted between UARTs operating at CMOS levels. All data is transmitted as 8-bit bytes. Communication is asynchronous so that both input and output can be occurring in parallel. Input to and output from the board is at 9600 baud. There are two UARTs on the OEM board. The first, UART 1, is used by the OEM board to receive commands and to transmit information back to the external application software. The second port, UART 2, is dedicated for receiving RTCM-104 differential GPS corrections. The actual use of this port is optional and depends on the corresponding application.

There are eight UART 1 input messages and six UART 1 output messages that can be used to manage communication between an external application software and the Magellan AIV- 10 OEM board. These messages are outlined in Figure 1.

Input messages	Output messages
(1) Setup;	(1) Position/Velocity
(2) Message Request;	(2) Time;
(3) Initial Position;	(3) Receiver/Satellite Status;
(4) Initial Time;	(4) General Status;
(5) Altitude;	(5) Setup; and
(6) Restart;	(6) Almanac.
(7) Change Baud Rate of Port #2; and	
(8) Set Almanac.	

FIGURE 1. Magellan AIV-10 OEM Module UART 1 messages.

Status information include satellite healths, number of satellites being tracked, receiver mode, and others. This accommodates a wide range of uses for external application programs.

The AIV-10 is also capable of specifying position information in Geodetic (lat/long/alt), in Earth-Centered-Earth-Fixed or ECEF (XYZ in meters), or in Universal Transverse Mercator or UTM (northing/easting/alt) formats. Position datum can be in the World Geodetic System (WGS-84), North American Datum (NAD-27, NAD-83), Australia, Europe, Great Britain, Alaskan, Tokyo, and others.

3. Blue Marble Graphics MAIL Map, GeoView, and GeoCalc

A digital map displayer is needed for graphical displays of vehicular positions. Blue Marble Graphics (BMG) of Gardiner, Maine developed a Windows application called The Geographic View version 1.05, or GeoView [3]. It is a visual interface for digital maps. It supports a variety of graphics file formats, including Aldus's tag image file format (TIFF), Truevision's Targa (TGA), Compuserve's graphics interface format (GIF), encapsulated postscript, and Windows bitmaps (BMP). The package allows the user to navigate around a digital map using mouse clicks. A more recent version of GeoView is MAIL Map prerelease version 2.00. It shares most of the features of GeoView, but its support for dynamic data exchange (DDE) is cleaner and more improved. The digitized maps are accurate U.S. Geographical Survey renditions in TIF format.

Another application BMG developed is the Geographic Calculator version 3.0, or GeoCalc. This tool allows users to convert positional information from one format (see the previous section on the Motorola AIV-10 for more details) to another.

C. Wireless Data Communication

1. The ARDIS Radio Network

The ARDIS corporation operates the largest radio packet network in the world [1]. This company was formed in 1990 as a result of a joint venture between Motorola and IBM. Currently, ARDIS provides coverage to 90% of the population of the United States, Puerto Rico and the U.S. Virgin Islands. ARDIS provides service to over 10,700 cites and over 70 companies with approximately 35000 users. This service is provided 24 hours-a-day, seven- days-a-week. The system generates 45,000,000 messages per month [18]. In contrast to cellular wireless transmission, radio packet transmission provides both mobile coverage and in-building coverage at a fixed site. The performance and cost of a transmission on the ARDIS network are independent of location and distance between locations.

The ARDIS network (see Figure 2) consists of a subscriber unit, typically a personal computer attached to a radio packet modem, such as the Motorola 405i, which broadcast over a radio transmission medium to one of 1,300 base stations (RF towers) throughout the United States. Multiple base stations are positioned in major metropolitan areas to provide overlapping

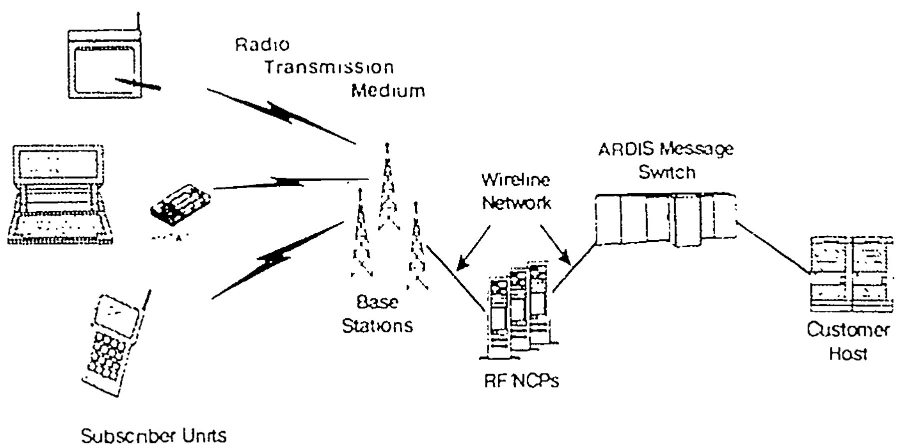

Figure 2 ARDIS network components.

coverage, which enables in-building transmission. The subscriber units and the base stations transmit and receive on a narrow-band FM signal operating at a frequency of 800 MHz. Separate frequencies are used for transmitting and receiving thus providing a full duplex channel that operates currently at 4800 bps in both directions. The base stations are connected by high speed digital lines to one of six intermediate level processors known as Radio Frequency / Network Control Processor (RF/NCP). The RF/NCPs are high speed specialized computers that interconnect multiple base stations with one of two ARDIS messages switches. The message switches are located in Chicago, IL and Lexington, KY. The message switch is a general purpose computer that coordinates the ARDIS RF data network. The network is managed from one of these two sites. In case of a disaster either site is capable of supporting the network.

Inbound wireless messages transmitted over the network are heard by the base station and transmitted to the by high speed phone to the intermediate RF/NCP processor, which transmits the message by high speed phone line to the ARDIS message switch for processing. Radio packet wireless transmission does not require a dedicated line for the duration of the transmission and there is no delay in establishing connections. Consequently, the ARDIS network provides real-time two way data transfer not dependent upon location. In contrast to cellular wireless transmission, the ARDIS network provides data encryption for security and Cyclic Redundancy Checking -16 (CRC-16) for error checking. Security is further enhanced by assigning a tamper proof unique ID to each subscriber unit (Radio Packet Modem) at the time of manufacturing [1].

2. The Motorola RPM 405i Radio Packet Modem

The wireless portable 405i, InfoTAC, radio packet modem (RPM) is manufactured by the Motorola Corporation. This device is the heart of the messaging system, allowing any mobile or fixed position microcomputer to be connected quickly to the ARDIS radio packet network. The RPM interfaces with all mobile and base units through a standard RS-232 9-pin connector. The unit weighs 95 grams and requires a power source of 7.2 volts [13].

There are two modes of data transmission supported by the InfoTAC, transparent presentation and native presentation. In transparent presentation, the unit supports asynchronous communication using 8-bit words, no parity, and one stop bit. In this mode the InfoTAC can be programmed using both standard and extended Hayes AT commands. The unit receives data from the UART chip on the microcomputer and transmits data to the ARDIS radio network at 4800 bps on a frequency of 806 to 866 MHz. Messages are limited to 255 bytes in the transparent presentation. In the native presentation mode, the InfoTAC can send messages of up to 2500 bytes in length. This mode is also capable of a more detailed analysis of possible error conditions, such as "low battery", "host down", etc. The advantages of the transparent mode are that modem is easy to program and that it can utilize terminal emulation software such as ProComm, etc., while programming of interfaces in the native mode are more complex [2].

II. System Design

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. 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. Perhaps one of the most interesting characteristics of this system is that it was developed from off-the- shelf components. As described in [6], the system is cost-effective, and still flexible enough to deliver high-quality service.

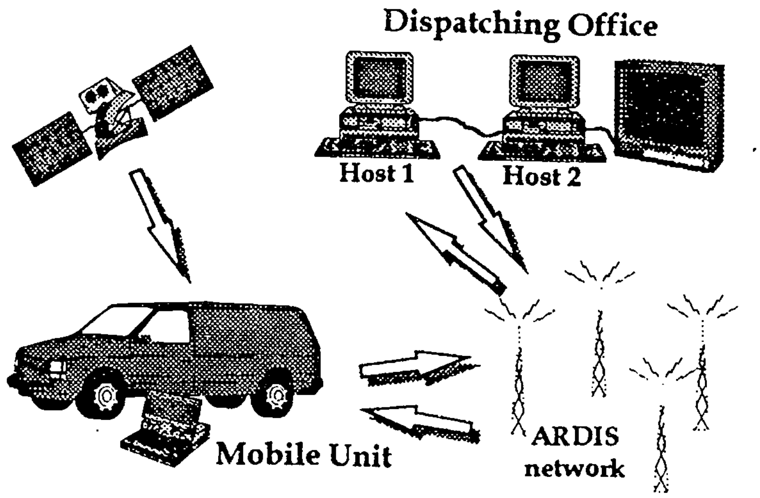

Figure 3 Overall system design.

The overall system design of the prototype developed by the authors is given in Figure 3. The main components include (at least) one Mobile Unit and a Dispatching Office. Details of each component will be discussed next

A. Mobile Unit Design

The mapping feature was taken off the prototype Mobile Unit developed (see the subsection on Development Issues for an explanation). Hence, only wireless data communication capabilities were provided for this component. In other words, this unit would require (i) a GPS receiver, to identify the vehicle location on the surface of the earth; and (ii) a radio packet modem, to send and receive messages to/from the Dispatching Office.

A simple split-screen design was used for the communications software. Messages from the Dispatching Office are received and displayed on the remote terminal. These are also saved to a file for future reference. GPS coordinates are automatically read and sent to the Dispatching Office at regular time intervals or these were sent upon request of the mobile operator. Of course, messages could also be sent back to the Dispatching Office.

B. Dispatching Office Design

The Dispatching Office consists of two hosts: Host 1 for messaging and Host 2 for tracking. The sole purpose of Host 1 is to manage both incoming messages from, and outgoing messages to, all Mobile Units. This includes managing databases that organize driver/vehicle information with radio packet modem numbers, databases that contain the current coordinates of all vehicles in the fleet, vehicle tracking information, and others. Hardware requirements for Host 1, aside from the network connection, is just a radio packet modem for messaging.

Host 2 will be running the digital map displayer to indicate vehicular positions. In the prototype developed by the authors, they used the Blue Marble Graphics application package. Host 2 may also be connected to a large screen monitor for better viewing. Both Hosts are connected to each other via a small network so they can share information between them (e.g. GPS coordinates).

C. Development Issues and Interface Requirements

The Magellan AIV-10 OEM GPS Module Developer's Kit comes with all the hardware required to receive GPS signals for use with an external application program. As far as the developer is concerned, the main task in correctly interfacing with this GPS receiver is to implement an asynchronous communications program that will read from (or write to) the serial port of the computer to which the AIV-10 is connected.

An asynchronous communications program was developed by the authors using Borland International's Turbo C++ for Windows version 3.1 compiler. The authors decided to dedicate the COM2 serial port for GPS functions (COM1 was used for the radio packet modem). The modules developed by the authors consist of routines to clear the registers of the serial port, set UART parameters, abstractions of various control messages to the AIV-10, and others.

After several trials and tests on how to initialize and startup the GPS receiver from an external application program, the authors used the following sequence: (i) set the initial time, (ii) set the initial position, and then (iii) restart. Position/Velocity information, for this application, was set to UTM (northing and easting values), with the altitude in feet and the velocity in miles per hour. The decision to use this format was for compatibility with the Blue Marble Graphics MAIL Map program.

In the authors prototype, the radio packet modem is brought on-line and transmits messages in the following sequence using the presentation mode:

(1) Read Source RPM ID
(2) Execute Modem AT Script
(3) Open Inbound Message File (PC to RPM)
(4) Create Inbound Message (User Generated or Automated Tracking Coordinates)
(5) Read Destination RPM ID
(6) Format Inbound Message
(7) Write Inbound Message to RPM for Transmission over ARDIS network

Outbound messages from the ARDIS network are received by the radio packet modem and processed as follows:

(1) Outbound message is received by the RPM (2) Transfer Outmessage from RPM's buffer to Microcomputer (3) Read Source RPM ID, Date & Time of Transmission (4) Classify Inbound Message (User Message or GPS Coordinates) (5) Process Inbound Message (Display, Write to Disk, Printer, etc.)

The authors decided to use FoxPro 2.6 for Windows as the interfacing language for the project. The original application was for vehicle tracking in the transportation industry (delivery, pick-up, parcel/package, etc.), which required some database handling. Microsoft s Access and Borland's Paradox were also considered. Budgetary constraints played a vital role in the decision to go to FoxPro.

FoxPro's support for dynamic data exchange (DDEs) allowed the authors to integrate the database component with the BMG MAIL Map program. BMG's GeoView did not support DDEs too well, and that for MAIL Map is more improved. Unfortunately, during initial runs at early stages of the system, the author's deemed it necessary to switch to a DOS-based application for most of the communications, primarily because FoxPro's user-generated screens and BMG's MAIL Map were using too much memory and were both taking too much time to redisplay in Windows. The next step was to develop the communications aspect as a DOS-based application written in Borland International's C++ for DOS version 3.0.

The same reasons were used in deciding to take out the mapping component from the Mobile Unit of the prototype. After initial runs with a FoxPro graphical interface and the BMG MAIL Map package, the authors decided to stick to a DOS-based communications program for the Mobile Unit. Similarly, the GPS receiver program was recompiled with Borland International's C++ compiler for DOS.

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 [17]. 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!

III. Applications In Education

A. Wireless Data Networks

Advances in wireless technologies have made wireless networks both practical and cost effective for the end user. Particularly in education, wireless networks can be beneficial. The geographic scope of radio packet networks can instantly set up a local area network at a remote school or add that school to a wide area network of virtually any geographical size. Wireless data networks can provide communication services to fixed sites where existing wiring within the building does not support networking. It also can be used to support building to building networking where the cost of wiring the different sites would be prohibitive. Radio packet modems allow wireless data networks to provide 2-way communication with mobile units independent of geographical location. In addition to fixed and mobile services provided by wireless radio packet networks, the technology can be used to quickly implement transient or portable data communication networks on a temporary basis. Consequently, wireless data communication networks using radio packet modem transmission can be used to both implement and supplement in-building and mobile connectivity over local and wide area networks.

B. Internet Access and Distance Learning

The ability to instantly add a school to a communication network facilitates distance learning. Information can be shared and distributed between all the nodes on the network. Thus, teachers and students have greater access to each other and to costly resources that can be accessed across the network. In addition to libraries, photos, records, digital images, and other collections that can be accessed by schools on the network, the wireless data communication networks allow students at distant schools to connect to and interact with students on field trips and at remote sites such as an archeological dig, etc. The wireless networks also will provide students and faculty at distant sites access to the Internet, which effectively allows the sharing of information and e-mail communication throughout the industrialized world. Estimates put the numbers of users of the Internet at currently more than 1 million and increasing almost exponentially [18].

C. Administrative Computing

The ability to set up transient data communication networks and to communicate with mobile units offer school admistractors at all levels access to instant real-time information. Transient data communication networks could be set up to provide communication and network access at conferences and special events at any site through the school system. School administrators would be able to both communicate with a moving school bus and to track its location, direction, and speed. In case of an accident or any emergency situation, the driver of a local school bus or the driver on a field trip of a vehicle located a thousand miles away could communicate with school administrators instantly. The ability to track a moving vehicle such as a school bus would also provide parents and students the ability from their homes to locate the proximity of the vehicle at any time.

IV. Other Applications And Future Directions

There have been quite a number of significant advances in wireless data and voice communications over the past few years. These have a direct impact on the office [5] and business [10] environments. One of the most interesting moves in the business environment is that towards the "virtual workplace". AT&T Global Information Solutions envisions this as an integration of notebooks (including mobile PCs and peripherals, PCMCIA and LAN cards), communications products, network services, application software, and support services. American Airlines is using wireless technology for customer service that provides real-time database access [10]. Soon to be available are "smart phones" [12], phones with PDA-like features (e.g. LCD screen and note-taking capability) that combine voice, organizer, and other capabilities.

Similar changes should be expected in the classroom as well. The classroom is evolving into a virtual classroom . We have witnessed students moving from the traditional 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 [12], in that they will feature

* note-taking capabilities
* organizer/scheduler
* rolodex
* (wireless) Internet access
* (wireless) e-mail capabilities
* (wireless) 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.

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, as well as greater access to resources such as national and university library collections of books, art work, photos, records and films. In fact, this is one of primary goals of NASA's Advanced Communications Technology Satellite (ACTS) program [14,15].

V. Summary And Conclusions

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. And with wireless networks and satellite communications entering the office and business environments - soon, the evolving classroom - it is sure to affect many aspects of our lives.

VI. References

[1] ARDIS Corporation. 1994. ARDIS Network Overview. ARDIS Corporation, Lincolnshire, Illinois.

[2] ARDIS Corporation. 1994. ARDIS Network Application Programmer's Guide. ARDIS Corporation, Lincolnshire, Illinois.

[3] Blue Marble Graphics. 1994. The Geographic Viewer: Getting Started Guide. Blue Marble Graphics, Gardiner, Maine.

[4] Blue Marble Graphics. 1994. The Geographic Calculator: Getting Started Guide. Blue Marble Graphics, Gardiner, Maine.

[5] Lisa Decarlo. 1995. AT&T maps virtual office environment. PC Week, 12 (8), 1&101.

[6] Benjoe A. Juliano and Stephen J. Sheel. 1995. "The design, analysis, and implementation of system interfaces that integrate the Magellan AIV-10 global positioning system module and the Motorola RPM 405i radio packet modem." Presented at the South Carolina Academy of Science 1995 Annual Meeting, April 7, Greenville, South Carolina, with abstract appearing in the Bulletin of the SCAS, Vol. LVII, p. 118.

[7] Benjoe A. Juliano and Stephen J. Sheel. 1995. "A Look at the Evolving Classroom: Wireless Data Communication and Mobile Satellite Communication." Submitted for presentation at the International Conference of Computers in Education, Association for the Advancement of Computing in Education, December 5-8, Singapore.

[8] Benjoe A. Juliano and Stephen J. Sheel. 1995. "Managing school buses on the information superhighway." To appear in Coastal Business Review, Coastal Carolina University, Conway, South Carolina.

[9] Magellan Systems Corporation. 1994. User Guide for the Magellan AIV-10 OEM GPS Modules. Magellan Systems Corporation, San Dimas, California.

[10] Michael Moeller. 1995. "Airline to give its agents wireless access to databases." PC Week, 12 (3), 41-42.

[11] Michael Moeller. 1995. "McCaw digital cellular networks to support e-mail, voice." PC Week, 12 (8), 8.

[12] Michael Moeller. 1995. "Smart phones seen as smart choice." PC Week, 12 (8), 33&40.

[13] Motorola Wireless Data Group. 1994. RPM4X5i Radio Packet Modem Technical Manual. Motorola Corporation, Bothell, Washington.

[14] National Aeronautics and Space Administration. "Advanced Communication Technology Satellite (ACTS) and Education." (Downloaded from the NASA Spacelink Internet

Repository, Spacelink.msfc.nasa.gov)

[15] National Aeronautics and Space Administration. "Advanced Communication Technology Satellite (ACTS) and Science." (Downloaded from the NASA Spacelink Internet Repository, Spacelink.msfc.nasa.gov)

[16] K. Pahlavan and A. Levesque. 1994. Wireless Data Communications. Proceedings of the IEEE, Vol. 82, No. 9, pp. 1398-1430.

[17] Carolyn Pesce. 1994. "In Minnesota, 'smart' buses getting a whirl." USA Today, November 28, page 14A.

[18] J. Quarterman. 1990. The Matrix: Computer Networks and Conferencing Systems Worldwide. Digital Press, Bedford, Massachusetts.

[19] W. W. Wu, E. F. Miller, W. L. Pritchard, and R. L. Pickholtz. 1994. Mobile Satellite Communications. Proceedings of the IEEE, Vol. 82, No. 9, pp. 1431-1448.