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 4051, 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

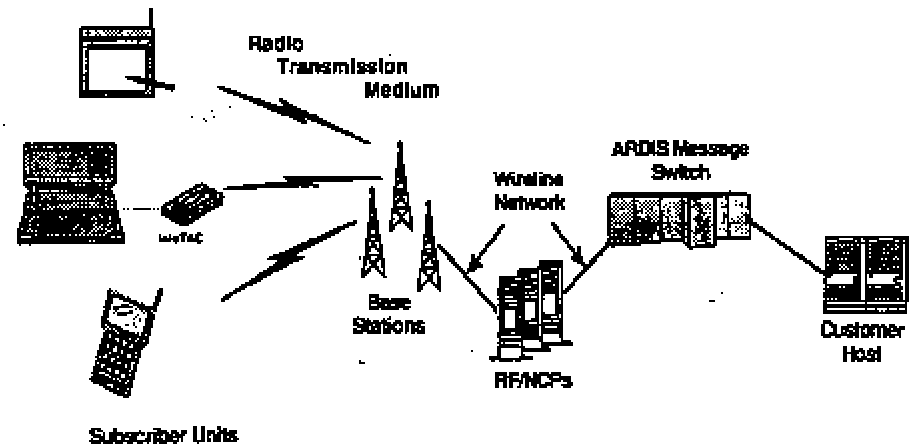

Figure 2 ARDIS network components.

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.