Diploma Thesis

Prototype of an Animal Tracking System

The main purpose of this thesis is the prototype development of a police dog tracking system. The area of applications in Location-Based services, e.g. fleet and asset tracking, E-911 and public safety issues, and wildlife management, has been increased during the last few years. The developed tracking device can be used for any of these tasks, but the created device is suitable to be worn by a dog. Police officers are able to attach the small tracking device to the dog's collar or to a canine vest. The field of duties of police dogs comprises tracking, drug searching and searching for people as well as evidence. The challenge of wearing this entity by a dog can clearly be seen, police officers or special task units are able to track their dogs while they are tracking suspicious subjects or searching for people. This system increases the efficiency of a police dog, relieves tracking and enhances safety of the dog.

The tracking system consists of a mobile unit attached to the dog and a Monitoring station, which can either be a police department or any officer with a computer and an Internet connection, to display the position of the dog on a map. The system is based on two approaches, first Global Positioning System (GPS) and second Cellular Digital Packet Data (CDPD). Satellite technology provides the position information and the cellular system transmits the information to a configured computer address. The position can be monitored in real-time and a police officer can follow up his dog with his vehicle. This study shows one possibility of an efficient real-time tracking system, at the same

time size, weight, and shape of the mobile unity are aligned to attach the mobile unit to a dog's collar or to a canine vest.

There are a few other possibilities to perform this task like GPS compared with Short Message Service (SMS), General Packet Radio Service (GPRS), Radio Modems or as an alternative Mobile Phone Location Services. The approach used in this prototype development was tuned to digital data transfer possibilities in the test area.

The most important factors of this system are size, weight and coverage area. The system should fit on a dog's collar or should be mounted on a canine vest, so it has to be very small. The weight of a dog depends on its race. German Shepherds are one of the favorite races and there weight is between 30 – 40 kilograms. The weight of a tracking device, which is mounted on the dog, should be less than 3 percent of the dog's weight, it means a weight around one kilogram or less.

1 USED TECHNOLOGIES

1.1 Cellular Digital Packet Data (CDPD)

1.1.1 Introduction

In 1991 the U.S. cellular operators began a process to offer packet data technology for services such as e-mail and telemetry. The result was Cellular Digital Packet Data (CDPD), which the carriers began to deploy in 1993. Today, regions of CDPD coverage include most of North America's population. CDPD shares radio frequency channels with AMPS cellular voice calls, but it has its own infrastructure that piggybacks upon the AMPS technology. Cellular carriers who choose to support CDPD must install additional equipment to handle data separately from AMPS voice. CDPD also requires its own modems for end users, and operates quite separately from cellular voice handsets—even while sharing channels with them. Cellular carriers derive the vast majority of their revenues from voice, and are expected to continue to do so for some time, although data use is growing. The need to optimize voice revenues therefore drives the development of new technology, so CDPD was developed with the primacy of voice in mind. The overall CDPD network operates as a collection—an internetwork—of CDPD service provider networks, where the CDPD networks of each cellular carrier communicate with one another, routing data from one CDPD network to another, often through the wider Internet (see figure 1). CDPD carriers provide services such as data connection to other networks, application services, network management, network security and accounting and billing. Just as cellular carriers ensure that end users see the AMPS network as a nearly seamless part of the wireline PSTN, they work to ensure that CDPD users are transparently connected to the Internet, and to each other [Sierra Wireless, 2001].

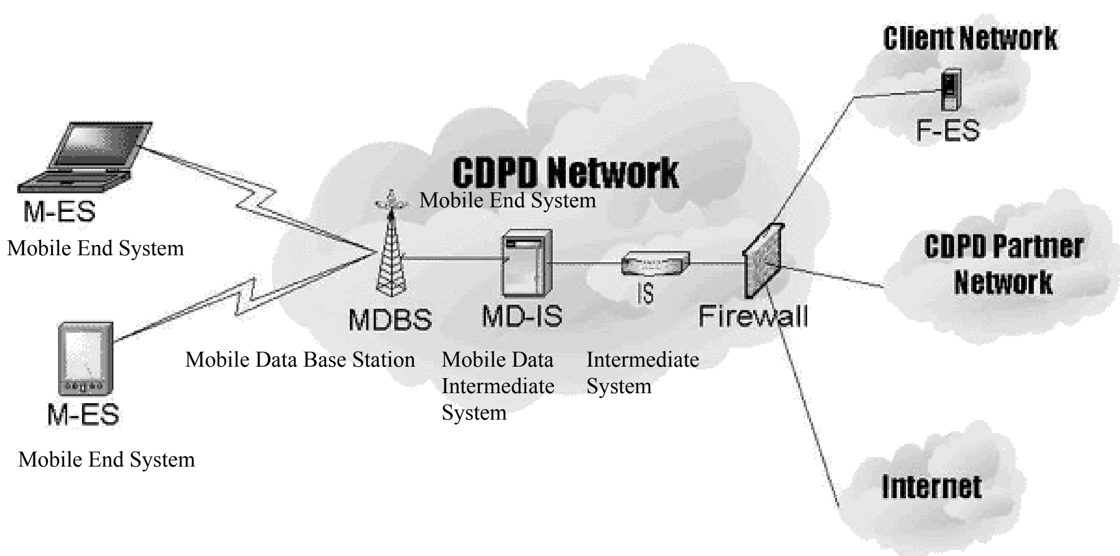

Figure 1: Overview CDPD Network [after Cox, 2001].

1.1.2 Packet-Switched Data Shared With Voice Calls

Although CDPD operates over the AMPS analog cellular telephone network, CDPD itself is fully digital, using Gaussian Minimum Shift Keying (GMSK) modulation to encode data on the same 824-894 MHz radio frequency channels as AMPS voice calls. In fact, CDPD is designed as a way for cellular carriers to capture additional revenue by using the short blank spaces between AMPS voice calls to transfer data. There are long periods during which one or more of the radio channels within an AMPS cell sector are not in use. In other words, there is spare capacity available on the cellular system.

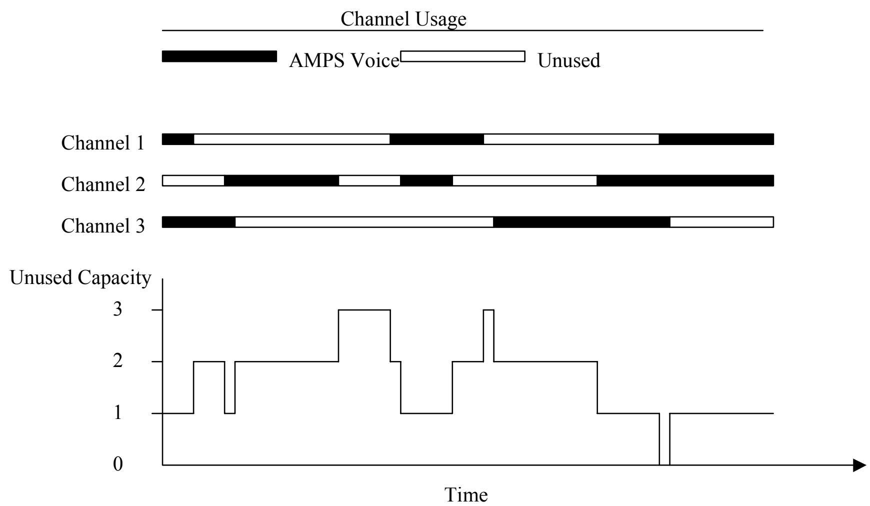

Figure 2: Cellular radio channel usage within a single cell sector.

Figure 2 shows a simplified sample with three channels in a sector allocated for cellular voice use. In this example, the unused channel capacity ranges between 0 and 3 radio channels. The CDPD concept is based on sending packet-switched data on radio channels within a sector when they are not used for cellular voice communications. It reuses these unused voice channels by hopping from one unused voice channel to another whenever that channel is required for cellular voice. In other words, CDPD reuses the unused channel capacity in a voice cellular network for packet switched data.

1.1.3 Channel Hopping

Channel hopping on the airlink - the wireless portion of a CDPD transmission - works well under typical voice usage, but as the network becomes congested, less room is available for data traffic. Many CDPD carriers have therefore agreed to guarantee to have channels dedicated to data transmission only. Otherwise, in an emergency situation like a flood or hurricane, the cellular system could become completely clogged. Even in a dedicated system, there is no guarantee that the modem will stay on an acquired channel very long. If the modem is mobile, it will be forced to frequently change channels as it travels through the carrier's territory from cell to cell. Two types of channel hops can occur in CDPD systems not using dedicated channels: Planned channel hops and Forced channel hops.

In the example figure 3, a single CDPD data link is supported within the three-channel sector. Of the six channel hops shown in the example, four are planned and two are forced. The first forced channel hop is used to avoid the cellular voice activity that occurs on channel 2, and the CDPD data link is maintained by the CDPD base station, forcing the subscriber device to hop to channel 3.

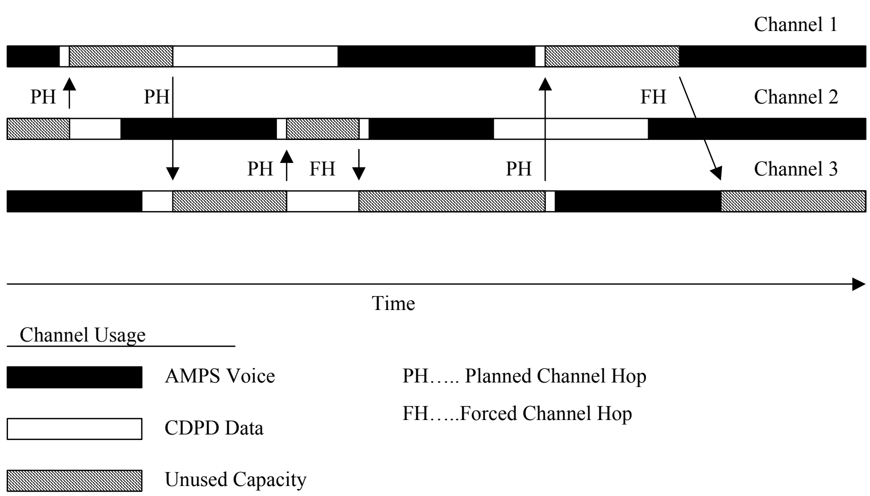

Figure 3: How cellular voice and CDPD coexist in a three-channel sector.

1.1.4 Dedicated CDPD Channel

CDPD data traffic was originally expected to be infrequent short bursts of data typical of telemetry or credit-authorization applications. In the early days, most CDPD systems used shared channels only with voice having priority. It quickly became apparent that during busy periods there were few if any channels available for CDPD to switch to—the CDPD system was "blocked." A number of applications, including public safety and credit card authorization, could not tolerate blockage of the system. The carriers solved the problem by reserving one or more channels on most CDPD cell sites for CDPD traffic only. Although giving up a voice channel for CDPD meant less voice revenue, carriers did not want to hinder the growth of CDPD by forcing it to use only the available extra space on voice channels, although such service can still be found in some rural areas [Sierra Wireless, 2001].

1.2 Global Positioning System (GPS)

1.2.1 Introduction

GPS represents the fruition of several technologies, which matured and came together in the second half of the 20th century. In particular, stable space-born platforms, ultra-stable atomic frequency standards, spread spectrum signaling, and microelectronics are the key developments in the realization and success of GPS. These technologies have been used to implement an ancient idea for positioning: trilateration, or position determination by measuring from known points. The Global Positioning System is an universal positioning system that provides 3-D accuracy up to 5 m horizontal and 7.5m vertical. This information is available anywhere one earth (see figure 4).

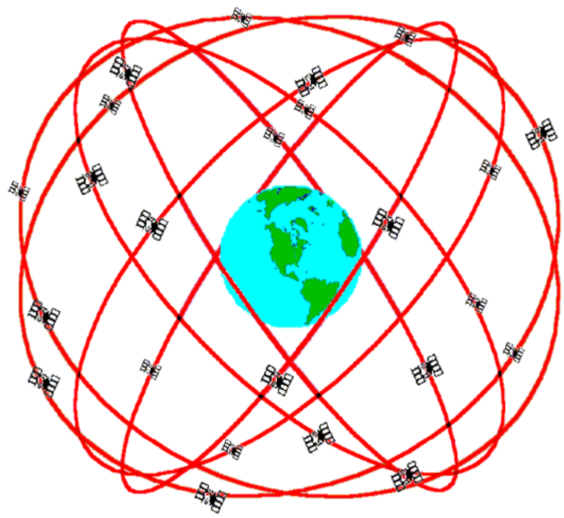

Figure 4: Orbital Plans - GPS nominal constellation - 24 satellites distributed in six orbital plans, 4 satellites in each plane nearly circular orbits with radius of 26.560 km, 55º Inclination relative to equatorial plane [Dana, 1998].

1.2.2 System Architecture

According to Army Space Reference Text [Space Division, 1993], the Global Positioning System consists of three major segments:

- Space Segment
- Control Segment
- User Segment

Space Segment

The space segment has currently 28 satellites in 6 circular orbital planes with an inclination of 55° at 26,560 km [Misra p.32] altitude with a period of about 12 hours. The inclined orbits and altitude result in complete global coverage. The design life of GPS satellites is seven years. Some have continued to function for more than 10 years. After the full constellation of 24 operational GPS satellite is in orbit replacement satellites will be launched, as necessary, to replace ones that begin to develop problems. The GPS signals are transmitted continuously by all the GPS satellites. If fully operational users anywhere in the world are able to receive signals from at least four satellites at all times. Usually, six GPS satellites will be in view. As a result, availability of the system is estimated at more than 99% of the time.

Control Segment

The control segment, operated by the 50th Space Wing of the U.S. Air Force Space Command, consists of the GPS Master Control Station (MCS) and a Monitor Station at Falcon Air Force Station, Colorado Springs, Colorado. Other Monitor Stations are located in Hawaii, Ascension Island, Diego Garcia and Kwajalein Atoll. Monitor stations track all GPS satellites in view and collect ranging data and satellite clock data passed to MCS over Defense Satellite Communications System satellites. Operators in the MCS calculate each satellite's status, ephemeris and clock data which is then sent to transmitting antennas located at the Monitor Stations (except Hawaii) where the data is uploaded to each satellite for inclusion in the navigation message transmitted by the satellites.

User segment

The USER segment consists of antennas and receiver-processors that provide positioning, velocity and precise timing to the user. The user segment of GPS consists of all military and civil users, both U.S. and foreign. There are two basic types of service available, the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS).

1.2.3 Signals

Currently, each GPS satellite transmits continuously using two radio frequencies in the L-band referred to as Link 1 (L1) and Link 2 (L2). The L-band covers frequencies between 1 GHz and 2 GHz , and is a subset of the ultra-high frequency (UHF) band.

The center frequencies of L1 and L2 are as below:

L1: f_{L1} = 1575.42 MHz L2: f_{L2} = 1227.60 MHz

Two signals are transmitted on L1, one for civil users, and the other for DoD-authorized users. The one signal on L2 is intended for the DoD-authorized users only.

2 DIGITAL DATA CAPABILITIES NEW BRUNSWICK

Different data communications require different data transport mechanisms to be used efficiently and economically. E-mail and Web browsing benefits from packet switching protocol, where idle times on a channel can be used for other active data streams. This channel sharing also reduces the cost of communication and tariffs are typically based on the number of packets transferred and not on the connect time. IP-based packet switching capabilities are preferred today because of immediate interoperability with the global internet. On the other side time critical data streaming applications require a reserved channel with guaranteed data rate, such as offered by circuit switched connections.

2.1 Bell Wireless Alliance

The service reseller in New Brunswick is NBTel Mobility. The network standard is IS95a (CDMA) at a range of 1800 MHz. There is no full set of digital data capabilities in the CDMA network, except circuit switched data and one-way SMS (receive only). So Bell made their existing CDPD network available to the public, CDPD was before only used by the government. The CDMA coverage extends to all provinces, but mainly to the larger cities. The CDPD coverage contains Moncton, St. John, Fredericton, Fredericton to Moncton highway area and Bathurst (see figure 5). In other areas the system switches automatically to the analog AMPS system.

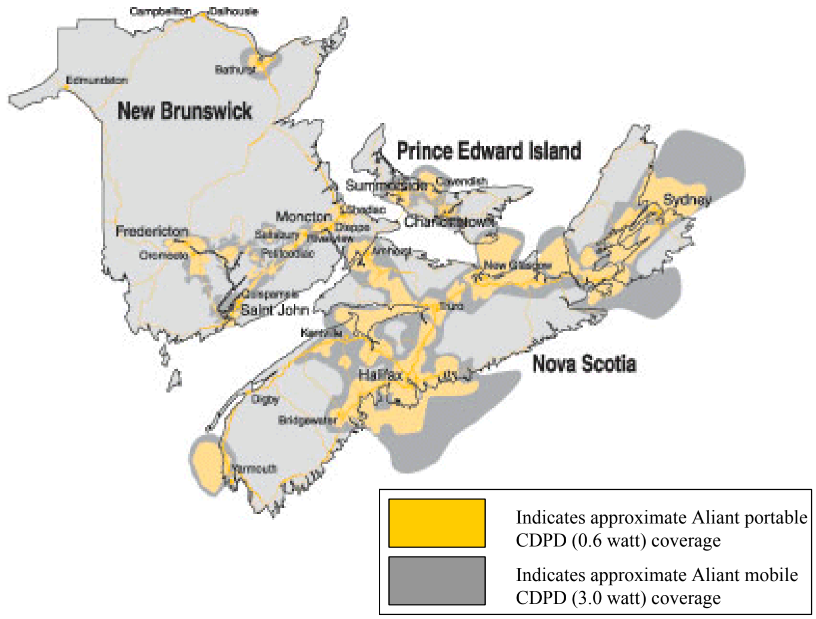

Figure 5: NBTel CDPD coverage New Brunswick and Nova Scotia [after NBTel – An Aliant Company, 2001].

3 THE EXPERIMENT

The main components of this system were the Mobile Unit, mounted on the dog, the Transmission System and the Monitoring Station (Figure 6).

The Mobile Unit consisted of a GPS receiver, which collected continuously data transmitted by satellites and sent them via a serial cable to a cellular modem. This modem transmitted the collected NMEA sequences to the IP address of the Monitoring Station, where the position of the tracked dog could be visualized. A power supply for both units completed the mobile part. The Transmission System was the Radio Frequency Spectrum. Radio signals were carrying the information from the Mobile to the Monitoring Part. The used spectrum of this transmission was based on the chosen system, in this case the CDPD (Cellular Digital Packet Data) network, which worked between

800.00 and 900.00 MHz. The Monitoring Station was a PC or laptop with a particular IP address. The disposition of a Moving Map Software enabled the user to indicate the Real Time Position of the tracked subject.

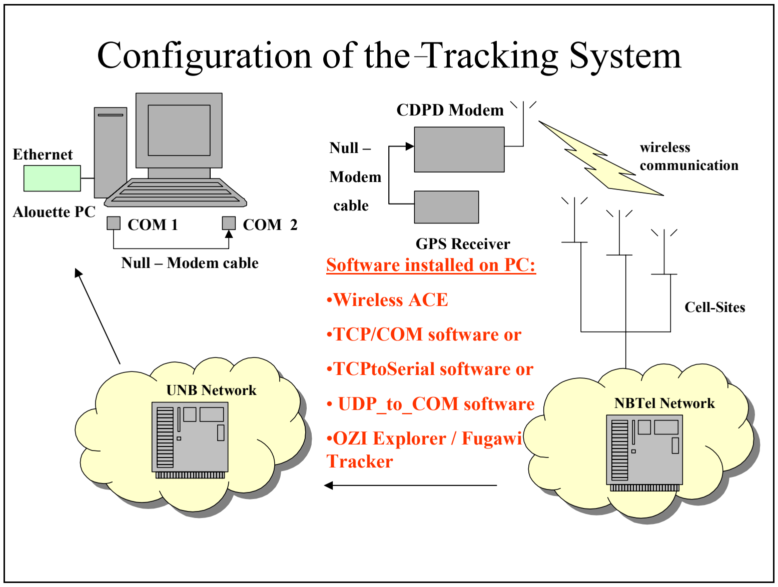

Figure 6: Real Time Tracking system view

3.1 The Mobile Unit

The Mobile Unit was the part of the system, which was mounted on the police dog. As shown if figure 7, it consisted of three main components, the GPS receiver, the CDPD modem and a Power Supply.

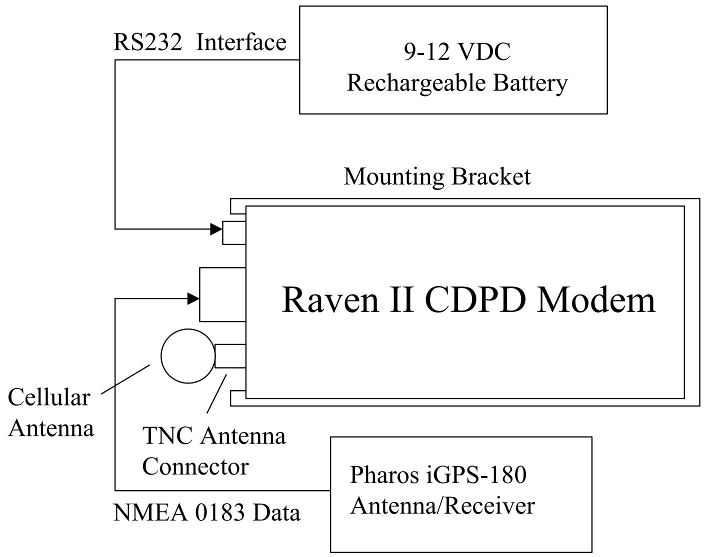

Figure 7: System view Mobile Unit

This device was fixed on the dog's collar, another possibility for mounting this unit was to fix it on a canine vest, which was often in usage to protect the dog from ballistic weapons (see figure 8).

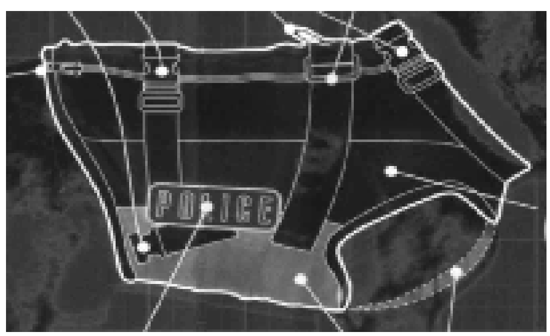

Figure 8: Ballistic Vest for dogs [after K9 Storm Incorporated, 2002].

3.1.1 The GPS Receiver

The Pharos iGPS receiver has been chosen for this prototype because of two properties, the weight and the size of the receiver. The dimension is 57mm x 49mm x 21mm and the weight is 68 grams without the cable. The dimension of this receiver compared to a 1 Cent coin is shown in figure 9.

Figure 9: Pharos Receiver in comparison with 1 Cent coin.

The Pharos iGPS Receiver was an integrated receiver with built-in low-profile antenna. The IGPS receiver consisted if a high-performance GPS-engine based on the SiRFstar architecture. The receiver delivered navigation information at 4800-baud rate in NMEA (GGA, GLL, GSA, GSV, RMC and VTG) protocol. It was a 12 Channel parallel C/A code GPS receiver operating on L1 (1575.42 MHz) frequency. The position update rate was 1 Hz and the accuracy was around 10m 2D-RMS. See Appendices 1 for an accuracy test of this receiver. It worked at 3.5 to 5.5 volts DC and the operating temperature was between minus 20 degree and plus 75 degree. The receiver was enclosed in a water resistant cover.

3.1.2 The CDPD Modem

The AirLink CDPD Raven II was a rugged, full duplex Cellular Digital Packet Data (CDPD) modem that provided wireless transport capabilities for fixed and mobile applications. Built-in encryption maintained the security of the application data over the air. The Raven's embedded TCP/IP stack enabled virtually any type of remote device to access the CDPD network, in this case the GPS receiver. Beside this application was the Raven II modem installed with many different types of Remote Terminal Units that performed remote metering and monitoring functions in the oil, gas, water, and transportation industries.

This modem provided many features, which were useful and necessary for this system. The dimensions of the modem were 7.6cm width x 2.54cm height x 12.9cm and its weight was less than half a kilogram. The modem was enclosed in a rugged aluminum case, the operating temperature range was between minus 30 degree and plus 70 degree. As shown in figure 10, the modem provided LED's (Light Emitting Diodes) of the status of the CDPD operation like power, channel acquired, link status, network registration, RSSI (Received Signal Strength Indicator), transmit/receive and block errors.

Figure 10: Modem – LEDs on the Front Side

Two different application interfaces have been used in this project, the AT command interface applied with the Wireless ACE software and the PPP (point-to-point protocol) interface communicating with the Windows Dial-Up Networking. The modem had a RS-232 DB-9F serial interface to connect with the GPS receiver.

Figure 11: Modem - Serial Port, antenna connector and power plug-in.

This device could work with a raw data transfer rate up to 19.2 kbps, but during the tests this rate had been set-up to 9.6 kbps or 4.8 kbps depending on the used GPS receiver. The modem transmitted at the frequency range 824 MHz to 849 MHz and received at a range 869 MHz to 894 MHz. As shown in figure 11, the modem had a TNC Antenna connector, for this project two different types of antennas have been tested. The power requirements were 9 volt DC to 30 volt DC.

3.2 The Monitoring Station

The meaning of the Monitoring Station in this project was a computer with an Internet connection and few software packets installed on the computer. There have been two different methods of resolutions in this project, the first one was a stationary station and the second was a mobile station.

The stationary station was a PC situated on the campus of the University of New Brunswick, Fredericton. This computer was connected to the network and was able to receive UDP and TCP packets transmitted by the Mobile Unit. If this kind of application comes to operation, a Central Police Department will receive the position information of the Police dog and they will forward the information about the latest habitation via a radio modem to a Police Officer in his car.

The second and easier way to work with this system was a laptop with wireless Internet connection as Monitoring Station. This performance allowed the officer in the car to track the position of the Police dog by himself. Precondition for this system was a second CDPD modem or a similar wireless device to get connected to the Internet.

3.2.1 Map Source

Three different types of maps have been tested, a Satellite Image, an Arial View and a Vector based Street Map. The Satellite Image and the Arial View Images are raster images while the last one is a vector image. They differed much in resolution, image size and covered area. The end-user has to define which one is the best for his purpose. Most of the time during this project the vector map has been used, because this allowed tests outside the city area of Fredericton. The area of the other two images was restricted to the city limits of Fredericton or only parts of the city.

3.2.2 Software

A few software packets have been tested and used during the test phase of this project. This part will describe the Moving Map software, two different kinds of Server-Client TCP/UDP software packets and last the Modem Configuration software.

3.2.2.1 Moving Map Software

A Moving Map Software enables a user to visualize the position of a with a GPS receiver tracked subject. The reason for the name Moving Map is that if the position of a subject changes from one map source to another, the software is as smart to switch between them automatically. It is up to the user to choose map sources. A software like the two mentioned later accepted data via a serial port. In this project the incoming data streams were IP packets, either UDP or TCP. Since there was no way to accept these data files with one of these software packets, there was the necessity of finding a way of remedy. The incoming IP packets were transferred to the first serial port and via a back-loop cable fed to the second serial port. The software had so the possibility to grab serial data as predicted. As far as known there has been a Moving Map Software available on the commercial market, which accepts incoming TCP data streams [Fugawi, 2000]. Before a test had been performed, the General COM settings were checked. It was necessary to set-up the COM-Port, Parity, download baud rate and NMEA baud rate depending on the used GPS receiver. This was guilty for all tested software packets. Nine different software packets have been tested, but only two of them met the demands of this project, the Fugawi Map Software and the Ozi Explorer Software.

3.2.2.2 Server – Client IP Software

A Server – Client Software was essential to perform this project. A computer with an unique IP address needs a software to accept TCP or UDP packets. The following two software packages have been used because they had this feature and additional they transferred the incoming data streams to a serial port.

TCP to Serial Software

In this project the Monitoring Station with the installed TCP to Serial Software worked in Server Mode. A destination TCP port and IP address has to be specified in the modem to send the packets to the right socket [Gottbehued, (n.d.)]. TCP to Serial waited for a TCP connection on a port specified by the user. After connecting to the transmitting part any data from this connection was forwarded to a serial port. If the data could not be sent to the serial port immediately, it was buffered dynamically by this application (see figure 12).

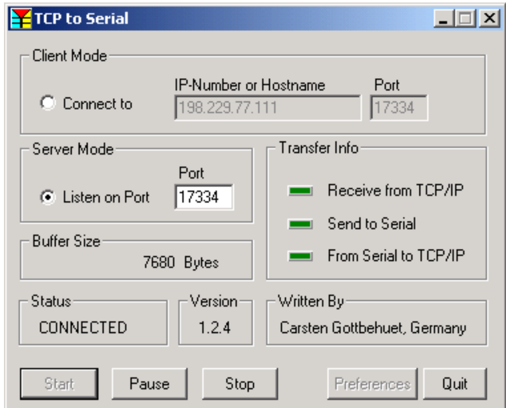

Figure 12: TCP to Serial Server – Client software.

UDP to COM Software

This software worked also in Server Mode and waited for incoming UDP packets. The configuration within the modem had to be changed to send UDP packets. The destination IP address and port were the same, but the Start-up-Mode of the modem had to be changed to UDP and the Destination Connect Mode to P for UDP instead of T for TCP. This software displays the last packets and saves also these packets in a log-file (shown in figure 13). Both software packets needed to be configured in respect the serial port. Com-Port Number, Speed, Connection Preferences and Flow Control had to be specified [Casperson, 2002].

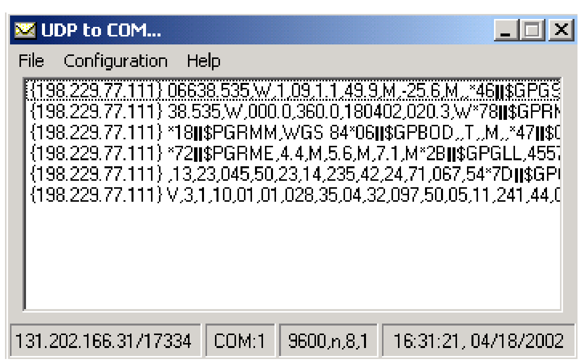

Figure 13: UDP to COM Server – Client software.

3.2.2.3 Wireless ACE – Modem Configuration Software

During this project the Wireless ACE Software has been a useful tool. Provided by the modem's producer company, this software was used to configure the modem and check the modem's status. [Airlink Communications, 2001].

Wireless ACE (AirLink Configuration Executive) is a Microsoft Windows based tool for easily configuring the Raven II modem or checking the modem's status either locally or remotely. AT commands are usual the method for configuring modems through a terminal emulation program (like HyperTerminal). AT commands however only work locally to a modem that is connected via a serial port. The Raven II modem does not only accept AT commands, but with Wireless ACE the AT commands can be set quickly and easily in a graphical, Windows environment. In addition, the modem can be configured over a serial port with ACE or remotely in the field, accessing it over an Internet connection from the computer instead. ACE not only configures the modem but will display statuses from your modem either locally or remotely as well. Wireless ACE can be set-up to either talk to the modem via a serial port, or over an existing Internet connection to remote modems.

3.2 Examples of test results

Example I:

Two tests have been made during this day, the route for both was exactly the same. The solely difference was the data transfer mode, the first test with UDP and the second test with TCP data mode. The results were nearly the same, so only the result with the UDP data transfer mode will be shown here (see figure 14). The light blue color was indicating tracking points, the dark blue color data gaps. It is difficult to see data gaps in this image. The performance was very good with biggest gaps around 10 seconds. The mileage of this trip was 21.038 km, 1922 tracking points have been saved and the track was performed between 9:10 PM and 9:54 PM. The good result of this test belonged to the time the track was made. All tests during the night showed a better result than the tests during the day. This fact was due to data traffic on the CDPD network.

Figure 14: Real Time Tracking Test, 15th March 2002 – Test 3, displayed with Fugawi Tracker software and Ikonos-Multispectral 4.0 m resolution map source.

Example II:

This test was quite different compared to the previous one. This was a post-processing test instead of a real-time test. The route of the test was the way from Fredericton to Moncton, New Brunswick and a part of the return trip. Incoming UDP packets containing the NMEA data structure were saved in a text file. The test was carried out on the 26th of April between 13:53 pm and 20:32 pm, this was the time the 9.6 V battery was able to supply the tracking device. The CDPD modem was configured to send every NMEA format in a different packet caused by the data forwarding character “$”, since every data structure started with this expression. The saved text file was about 5.0 MB for these 6.5 hours. Later on the NMEA data was formatted to the fit for the data structure required by the Fugawi Moving map software. The software was able to read in the latitude and longitude information extracted from the NMEA messages and displayed the track of the car. The purpose of this test was to get NMEA data of the track instead of a real-time application with the displayed track on the screen. The CDPD coverage between Fredericton and Moncton was really excellent, there was only one gap during the route between these two cities. This gap occurred at the intersection of highway Nr.2 and the 880. There have been 18.0 kilometres along the highway with poor network conditions. A few gaps happened in this area, the biggest with a distance of 4.2 kilometres and a few smaller between 0.4 and 1.3 kilometres. This was exactly the result, which was assumed by the dedicated CDPD coverage. Figure 15 shows the track of the car in Moncton. The provided map source did not fit exactly in all areas, the reason for this was first the changed situation of some streets within the city and second a simplification of some streets in this map.

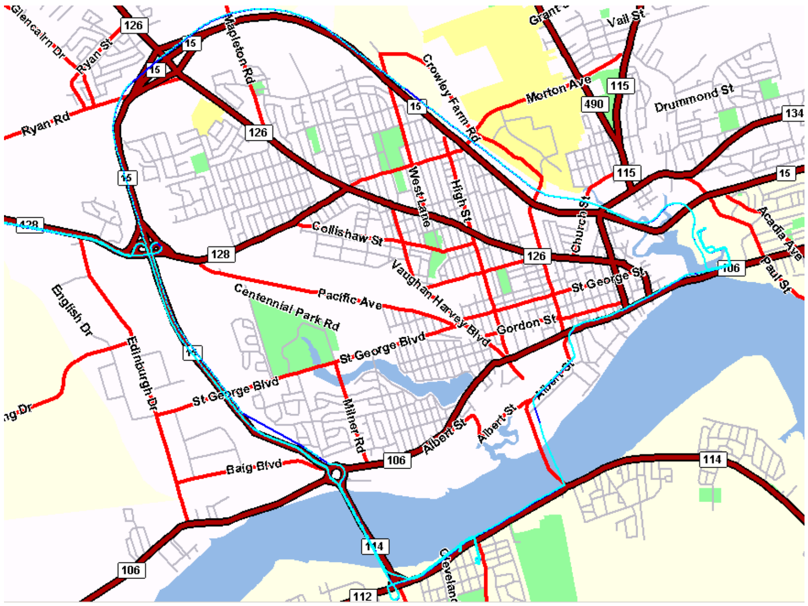

Figure 15: Real Time Tracking Test, 26th April 2002 – Test 7, displayed with Fugawi Tracker Software and Canada Street Map source – Moncton, New Brunswick.

Example III - Digital Elevation Model (DTM) of test area

A digital elevation model was used to display the track of two tests. The data-source of the Digital Terrain Model (DTM) was provided from Service New Brunswick (established 1990). This database was compiled digitally at typical 1:10000 scale standards directly from arial imagery using a computerized photogrammetric process. The Digital Topographic Database (DTDB) consisted of two different parts, the Digital Terrain Model (DTM) and the Enhanced Topographic Database (ETB). The DTM provided elevation without attributes in 3-D and the content of ETB were natural and cultural events, e.g. rivers, roads, NB outline, counties, in 2-D. Arc Scene, a sub-software of ArcGIS (produced by ESRI – Environmental System Research Institute) has been used to compute the digital model of the surface. Each DTDB file consisted of 11 files, each was representing a particular theme in GIS format. This project was only interested in elevation and roads, so only two different GIS formats had to be downloaded from the database server. Then these files were converted from ASCII to GIS format (3 files = database, elevation, AUTOCAD), merged into one ArcGIS file and then a Triangulated Irregular Network (TIN) was created, which meant to build a model of the surface. After it roads were inserted in this 3-D image and then the coordinates of this project file were converted to a Projected Coordinate System (NAD83 CSR Stereographic Projection New Brunswick). Afterwards text files were made, which were composed of latitude and longitude information of two track files. These files have to be converted to the same Coordinate system as the surface and so it was possible to insert the track file into the Digital Elevation Model. Some modifications on the road display have been done to show only the roads of interest.

12 different sub-files of the Service New Brunswick database had to be downloaded to gain the area of interest (see figure 52). Each file covered an area of 0.1 degree in longitude (7.5 km) and 0.05 degree in latitude (5.5 km).

The result of this computation was a 3-D model of an area north of Fredericton with inserted tracking points to display the relationship between elevation, shape of surface, position of cell towers, predicted coverage, and actual coverage obtained in previous tests. Figure 16 provides an overview of the tracking route in green, the red colour indicates in-building CDPD coverage, the pink one street coverage and yellow 3 Watt booster coverage. The blue dots in the image are showing the position of cell-towers with CDPD capable radio modems. There was one cell tower east of the tracking route, one south-east, one south, and the last south-west of the chosen track route.

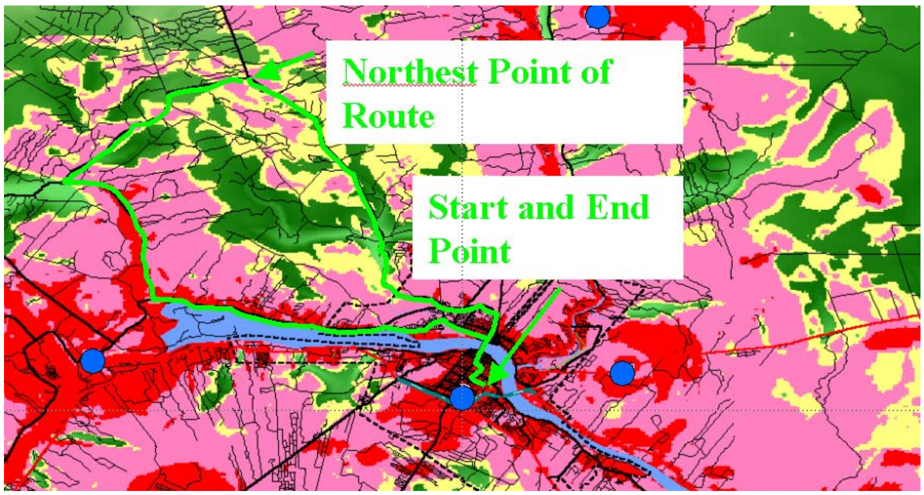

Figure 16: Map of Fredericton and area north of the city with CDPD coverage indicated

The Digital Terrain Model (DTM) in figure 17 shows the track embedded in the surface. The elevation varied about 300 metres; the legend left of the image provides meaning of colour. The chosen track followed the street 620 north, just a few kilometres north of Fredericton was an area with a valley with a depth of nearly 200 metres. This circumstance caused the CDPD modem to quit sending packets in this area. As figure 16 indicates, the dedicated network coverage showed no coverage along the tracking route on road 620 north, but beside this valley the modem was capable of sending position information via cellular network to the Monitoring Station. It seemed that the used CDPD modem was able to get weakest signals in areas with nearly no coverage, in particular much better than the service provider assumed it.

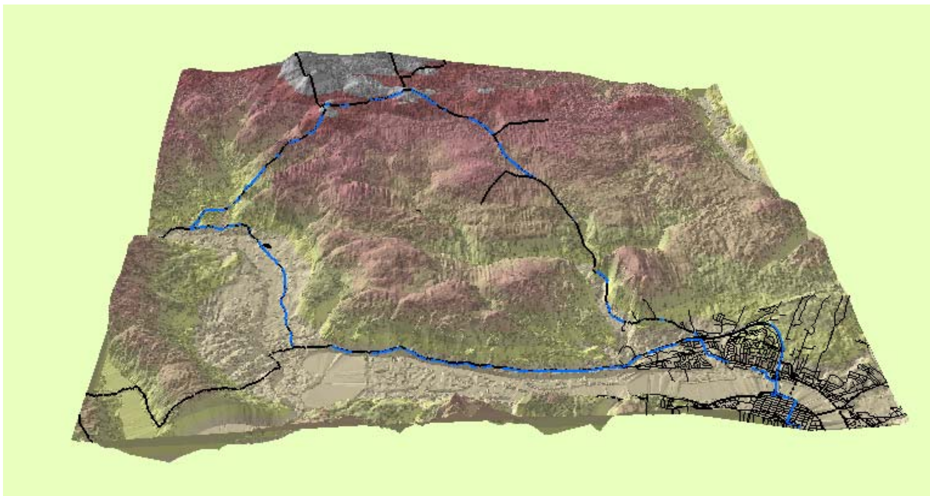

Figure 17: DTM and inserted tracking route.

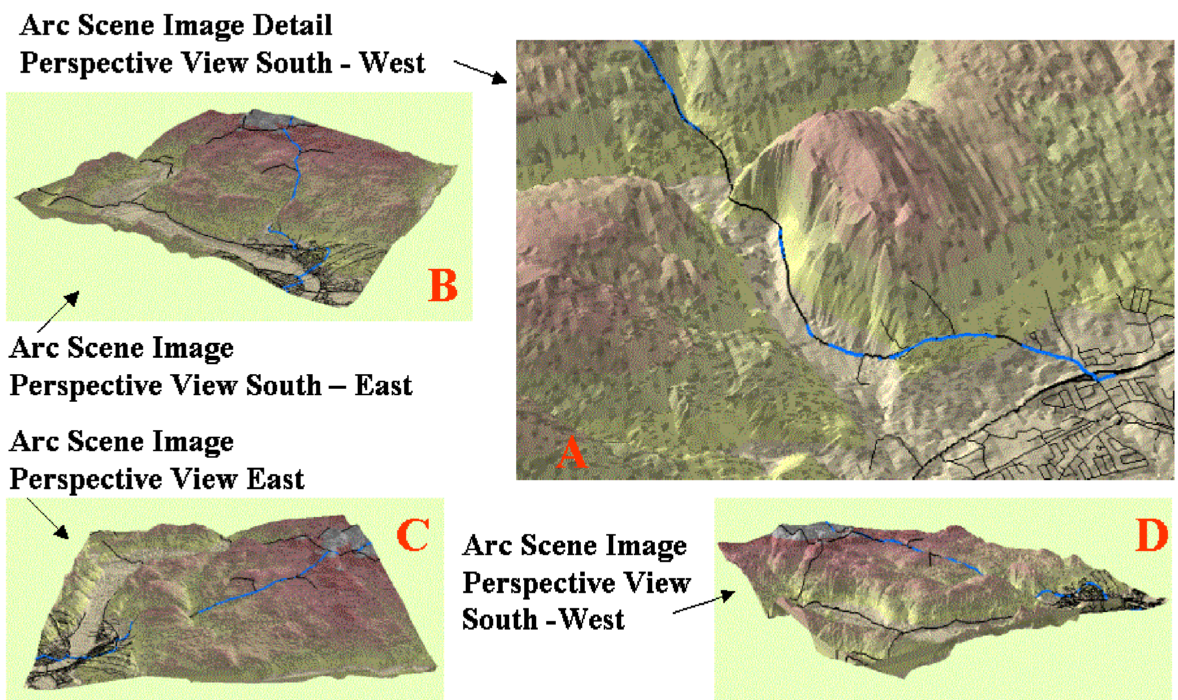

Figure 18: Screenshot of Arc-Scene Images to display the correlation between cell towers and tracking route.

Figure 18-A shows a detail screenshot of the ArcGIS DTM model north of Fredericton. The street winded through a small valley and network coverage was lost in this area. Even stopping the car and waiting for a connection did not work, there was no way to get connectivity to the cellular network. Figure 56-B,C, and D provides the view of the surface from the cell towers situated around the track. The valley is situated in a way that no cell tower is possible to obtain coverage inside it. There was no way to prove the reason for data gaps along the tracking route, but it sounds potential that the shape of surface was the reason for gaps beside the fact that this area had poor network conditions.

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