Title:

GSM Mobile Phone Based Communication of Multimedia Information : A Case Study

Abstract:

Through a practical application, this paper studies the capacity of the GSM network, a wireless mobile phone network widely used in Europe and some Asian countries, for transmitting multimedia data. The application is a client-server based automobile security system which monitors the interior and exterior environments of the moving automobile by a computer equipped a digital camera, a voice capturing microphone and a GPS (Global Positioning Systems) receiver. The captured data is sent to the server computer through the GSM network. The design and construction of the system are described with parameters of the equipment and the procedures of the experiments clearly shown. Results of the experiments show that a basic system can actually be implemented even given the narrow bandwidth of the GSM data transmission system.

1. Introduction

Distant delivery is always insecure in the sense that what is going on during the delivery can often hardly be known [3]. Very often, the delivery is delayed or the delivery does not even arrive at the destination at all. Such uncertainty during delivery must be minimized. This is particularly true for the delivery of important and valuable goods such as transfer of cash between banks. One simple solution is to keep track of the remote object. Traditionally, tracing a remote mobile object usually requires another object to follow the object being traced and report to the central control unit through certain communication media such as radio. Although this is in fact a waste of resources, it seems to be the only way of doing so. With the development of GPS, this situation changes. Tracing a remote object now becomes much easier than ever before, and much more accurate too. By attaching a GPS receiver to the object being traced, the exact position of the object can be retrieved and transmitted back to the central control unit and be known to the monitoring party.

Nevertheless, being able to know the exact location of the object being traced will sometimes still not be sufficient for determining what goes wrong when the object behaves abnormally. In worst case, we will not be able to detect anything that goes wrong when the object being traced moves along a path as predicted. As a result, it will be highly desirable if more information of the object being traced can be monitored together with the positional data. This project is therefore designed and developed in response to this question by providing additional video and audio data capturing capabilities. The data captured is transmitted from the remote object to the central station through the GSM mobile phone network. The GSM network is chosen as the its signals cover more than 90% of area in Hong Kong. Such a system will be most suitable in constructing advanced automobile security systems.

2. Systems

Basically, the whole system can be divided into two parts, one being the client while the other being a server. These two geographically separated entities communicate with each other so as to achieve the objective of tracing a remote object. The client system plays the major role of gathering information about the remote object, and the server system is mainly responsible for presenting the information gathered by the client in a neat and meaningful way. The major functionality of the client system and server system will be described in details in the following paragraphs respectively.

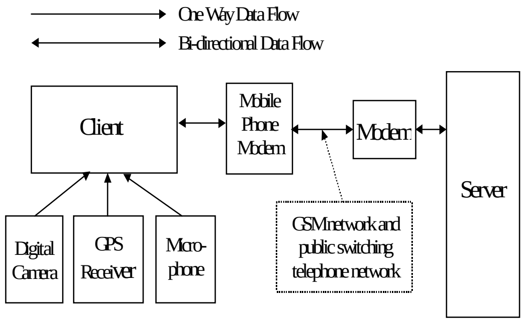

Figure 1: Client/Server Model

2.1. Client System

The client system is the one to be attached to the remote object and is responsible for capturing all useful information about the remote object. These information include the exact location of the remote object from the GPS receiver, as well as other data such as video and audio signals from other multimedia capturing devices. These captured signals will then be processed and integrated by the client system, which then sends these processed signals to the server system.

Since this client system is to be attached to the remote mobile object, it must be small in size and light in weight so as to increase its portability. Besides, since it is responsible for capturing several kind of signals and performing compression and integration on the data acquired, the client system must also have high speed and great processing power. Otherwise, smooth capture of data may not be possible and this may result in discontinuous data and loss of information, which in turns lead to poor accuracy and difficulties in comprehension.

A Pentium-233 MMX laptop computer running Windows 95 is employed here. It is equipped with a printer port for connecting a Connectix QuickCam black and white camera, a serial communication port for connecting a Garmin 45 GPS receiver and a PCMCIA port for connecting a mobile phone modem, the Ericsson Mobile Office DC 23v4. An Ericsson GH688 GSM mobile phone connects the modem to the GSM network. The modem confirms to ITU-T V.22bis and V.32 standards which facilitate data transfer at between 2,400 and 9600 bps. Besides, a signal booster is employed to amplify the signals of the mobile phone modem. Finally, a sound card connected with a microphone is also connected to the laptop for providing the sound capturing capability.

2.2. Server System

The server system is the one that will be located in a stationary place. The main task of the server system is to receive the captured signals from the client, process the received data and produce data visualization. Such data visualization includes displaying the path covered by the remote object on an electronic map and the corresponding latitude and longitude. The video and audio data received will also be processed to reproduce live video and audio signals.

The server also works as the command center and it has complete controls over the client system. It is responsible for sending command to the client to initiate or terminate its data capturing processes. The server system is also responsible for handling error during data transmissions.

A Pentium-133 MMX desktop computer running Windows 95 is employed here. It is equipped with a 14.4k bps modem for communicating with the client and a sound card with speakers for reproducing the audio data captured.

2.3. Cost

The following table shows the costs of some special equipment used in this project.

Item	Cost
Ericsson GH688 mobile phone	~US$350
Ericsson Mobile Office DC 23v4	~US$620
U.S. Robotics K56 voice modem	~US$150
Connectix B&W QuickCam	~US$130
Garmin 45 GPS receiver	~US$260
Signal Booster	~US$320
Total	~US$1830

Table 1: Costs of some special equipment used

One point worth noting is that the prices of these equipment are dropping and the cost of building such a system will be expected to be much less in the future. Besides, the equipment could be compacted in to a box when the system is actually built for practical use.

3. GPS signals

3.1. Interpolation

The GPS receiver needs at least signals from four different satellites to calculate its position accurately [3]. Very often, signals from the satellites will be blocked by high buildings. In such case, a GPS receiver may not be able to receive signals from four different satellites, and thus failing to calculate its exact position.

Besides, since the data captured by the client system is transmitted to the server system via mobile phone networks, there are the possibilities of noise in the transmitted signals, or even worse, complete loss of signals when the object being traced enters into areas not covered by the mobile phone networks. In all the above situations, the server will not be able to obtain the location of the remote object. Instead of just displaying discontinuous path in the form of disjointed line segments on the map, the server will try to estimate the missing path of the remote object using the data obtained before and after the period of no data, together with the check points of a predefined path. The check points are some operator selected points along a path on the electronic map that the object being traced will follow. By joining these check points in order, the expected path of the object can be reconstructed.

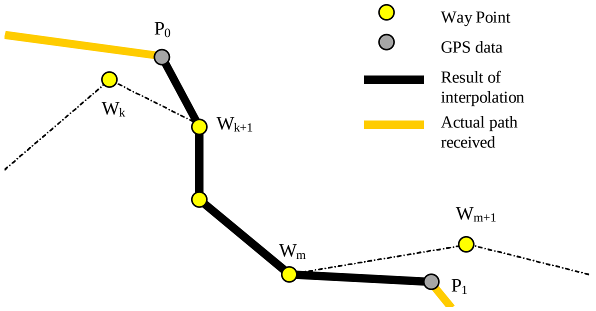

Figure 2: Interpolation of GPS data

During a period when no GPS data is available, the server will then use the latest positional information P_0 before the loss period to find a line segment formed by two consecutive check points W_k and W_{k+1} which is closest to P_0. When the server receives GPS data from the client again, the server will then use the newly received positional information P_1, and the locations of two consecutive check points W_m and W_{m+1} closest to P_1 to interpolate a path as shown in Figure 2.

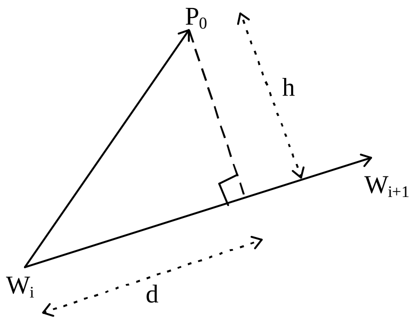

Figure 3: Calculations involved in Interpolation

The perpendicular distance h and the projection distance d from P_0 to W_iW_{i+1} is found using the following equations:

$\underline{V}_1 = \underline{W}_{i+1} - \underline{W}_i$

$\underline{V}_2 = \underline{P}_0 - \underline{W}_i$

$d = \underline{V}_1 \bullet \underline{V}_2 / | \underline{V}_1 |$

P_0 lies directly above the line segment W_kW_{k+1} if $0 \leq d \leq | \underline{V}_1 |$ and the square of the perpendicular distance is given by $h^2 = | \underline{V}_1 |^2 - d^2$

This interpolation of GPS signals works fairly well when the remote object follows a path close to the predefined path. However, it may give wrong estimations when the remote object is traveling with great deviation from the predefined path. Though not perfect, the above method does offer a feasible and reasonable solution.

3.2. Adaptive Sampling

The sampling rate of the GPS data is very important. If the sampling rate is too high we may gather a group of very closely located GPS data which means a waste of bandwidth. On the other hand, if the sampling rate is too low, the remote object might have moved too fast that the sampled GPS data will be separated widely apart. This will result in a non-smooth path plotted on the server system. As result, the sampling rate of the GPS data must be carefully adjusted for the system to work as expected. In order to make the sampling rate suits different circumstances without readjustment, an adaptive sampling method is introduced. This method will dynamically adjust the sampling rate based on the speed of the remote object being traced. When a GPS data is received, it will be compared with the last sampled GPS data. If the distance between these two positions is greater than the upper threshold value, the sampling rate will be doubled so that more positional data will be sampled. On the other hand, if the distance between these two positions is smaller than the lower threshold value, the sampling rate will then be lowered by half so that the positional data will be sampled less frequently.

4. Data Compression

The GSM mobile network provides a packet data transmission protocol and supports a data rate up to 9600 bps [6]. As a result, it will not be possible to transmit such huge volume of multimedia data from the client to the server without any compression. In our system, the Intel Indeo(R) Video R3.2 codec is employed to compress a video frame of 19k bytes (160x120 8-bit) to around 1k bytes (160x120 24-bit), giving a compression ratio of about 19. The resulting compressed video frame can then be transmitted in about 1 second to the server system. For audio signals, Microsoft Network Audio codec is employed to give a data rate of 1 kb/s (8 kHz, Mono, 8200 baud). The comparison of various compression codecs will be described briefly in the following paragraphs.

4.1. Video Compression

In this study, the compression of the video sequence is achieved by making use of the Installable Compression Manager (ICM). The ICM provides access to the interface used by installable compressors to handle real-time data, and it is the intermediary between the program and the actual compression and decompression drivers. The compression and decompression drivers do the real work of compressing and decompressing individual frames of data.

Several video compression drivers have been considered to be used in this project, and their efficiencies are compared in terms of compressed size and compression time. The result is listed in Table 1. All the compression driver are set to have a compression quality of 0% and 1 key frame for every 4 frames and each video frame has a resolution of 160 pixels x 120 pixels x 8 bit gray scale. All the tests are performed on the same Intel Pentium-233 MMX computer.

Video Codec	**Avg. time (μ sec) for key frame**	**Avg. size (bytes) for key frame**	**Avg. time (μ sec) for non-key frame**	**Avg. size (bytes) for non-key frame**
Intel Indeo (R) Video Interactive	239	1314	566	620
Cinepak Codec by Radius	228	1668	32	1416
Intel Indeo (R) Video R3.2	126	1284	56	660
Microsoft Video 1	22	2402	0	6
Uncom-pressed	0	19200	0	19200

Table 2: Comparison of video compression drivers

From the above table, it can be seen that Intel Indeo (R) Video R3.2 is well balanced between compressed size and delay and thus is chosen to be used for video compression in this project.

4.2. Audio Compression

In our system, the compression of the audio sequence is done by making use of the Audio Compression Manager (ACM). Likewise, using ACM for compression and decompression has the advantage of being more flexible and the program can choose to use newer and better compression driver when new technology has been developed without re-programming.

Several audio compression drivers have been considered to be used in this project, and their efficiencies are compared in terms of data rate. The result is listed in Table 3.

Audio Codec	Freq. (kHz)	Mono/ Stereo	data rate (kB/s)
CCITT A-Law	8	Mono	8
CCITT u-Law	8	Mono	8
Elemedia TM AX24000P music codec	22	Mono	1
GSM 6.10	8	Mono	2
Microsoft ADPCM	8	Mono	4
MSN Audio	8	Mono	1
PCM	8	Mono	8

Table 3: Comparison of audio compression driver

As shown on the above table, several compression drivers can give a data rate of 1kB/s which is suitable for this project. The one employed in the program is the MSN Audio codec since this codec is commonly available in Windows 95.

5. Experiments and Observations

The whole system had been tested several times with the client system installed on a vehicle traveling along the gray path as shown in Figure 4.

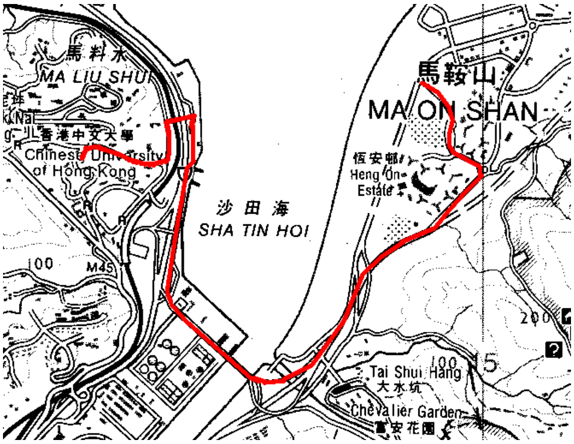

Figure 4: Test path

5.1. Experimental Results

After connection had been established between the server and client systems, all the GPS data, streaming video data, streaming audio data and still image data could be received from the client system properly. However, the line would be cut when the vehicle moved pass cells of the mobile network. Nevertheless, the client system could automatically recover from the cut-off and no human intervention was needed.

The GPS data received was used to plot the path on the server system, and the interpolation of GPS data of the server system functioned properly for the missing portion of the path being traced. However, the path might not lie exactly on the road of the electronic map, there was a small deviation from the printed roads.

5.2. Analysis and Conclusions

Although in these experiments the connection would be cut-off by the network several times, both the client system and server system could recover from the unexpected cut-off and continue to function. Such cut-off occurs when the vehicle moves from one transmission cell to another in the mobile network. The hand-over of the cells results in temporary cut-off of the line. Such problem is tolerable when the mobile phone is used for voice conversation as human brain can integrate distorted signal, missing signal and noise to recover the original information.

When the signal is too weak, a lot of noise will be resulted which causes error in the data being transmitted. The error correction algorithm of the mobile network might not be able to correct the error in the data when the signal to noise ratio is too low or when the signal is completed lost. This causes the hold-up of the data line and no data can be transmitted though the line is still in connected state. Finally when the error correction algorithm completely fails to recover from the error, the line will be cut off. In such an event, the operator monitoring at the server side should get alerted and make a connection later. In any event, if the path of the mobile object is know ahead, the operator is well prepared to shut down the monitoring system in appropriate locations along the path.

The deviation of the plotted path from the printed roads on the map might be due to the inaccuracy of the GPS receiver. The instability of the GPS receiver caused error in taking the positions of certain sample points for generating the reference coordinates of the map data file. Another possible reason is that a small error in the relative locations of the objects on the map was introduced during the digitization of the printed map into the computer using a desktop scanner.

Figure 5: The server in operation.

6. Conclusions

This aim of this project is to demonstrate the feasibility of using a low bandwidth GSM network for transmitting multimedia and GPS positional data in building a real time security system. Since the maximum data rate provided by the GSM network is limited to 9600 bps, the main concern would therefore be how to make good use of the scarce bandwidth.

Our system allows the operator to choose either streaming video, streaming audio or high resolution still image to be transmitted, while the GPS positional data will always be transmitted on a regular basis.

Each transmission frame consists of a header (2 bytes), frame type (1 bytes), data length (2 bytes), actual data plus stuffing characters, checksum (1 byte) and a tail (2 bytes). Assuming about 1% of the actual data are control character need stuffing, the total size of a transmission frame will be 1.1 x data length + 8 bytes.

For still image, 160 x 120 x 8 bits = 19200 bytes (without any lossy compression), the frame size will be 21128 bytes. Its transmission requires 21128 x 8 / 9600 = 17.6 seconds.

For streaming video, each video frame has an average size of 816 bytes after compression. The frame size will be 906 bytes and its transmission requires 906 x 8 / 9600 = 0.76 seconds. Thus the frame rate will be about 1.3 fps, but the actual frame rate would expected to be lower due to the additional time required for compression / decompression and noise during transmission.

For streaming audio, the audio buffer size for 1 second using MSN Audio codec is 1024 bytes. The frame size will be 1134 bytes, requiring 1134 x 8 / 9600 = 0.95 seconds for its transmission. Using this audio codec could theoretically produce a smooth audio output, but the test audio quality was just acceptable as silence gaps existed between samples due to time spent for compression / decompression on software level. Moreover noise in the communication channel reduces the throughput.

Finally, for GPS positional data the data size is 16 bytes. The frame size will be 26 bytes so that 26 x 8 / 9600 = 0.02 seconds are required for transmission. This delay is negligible when compared to other multimedia information.

In spite of the limited bandwidth, our system does demonstrate the feasibility of using the wireless mobile network to transmit separated multimedia data. If new technology in GSM has been developed to provide a data service up to 56k bps, then with current settings, a performance of 6.7 fps with integrated audio data can be achieved. One main drawback of using the wireless mobile network for data transmission is the high air-time cost. The system is thus designed to provide information on demand instead of full-time supervision. When to start and end the supervision and what type of information to be retrieved are completely determined by the system operator, thus the system operator can control the cost of operation.

Reference

[1] Regis J. Bates, Wireless Networked Communications, McGraw-Hill Inc., 1995.

[2] Rafael C. Gonzalez, Paul Wintz, Digital Image Processing, Addison Wesley, 1987.

[3] B. Hofmann-Wellenof, H. Lichtenegger, J. Collins, GPS Theory and Practice, Springer-Verlag Wien New York, 1994.

[4] Tom Logsdon, Understanding the NAVSTAR, GPS, GIS and IVHS, Van Nostrand Reinhold, 1995.

[5] Parkinson, Bardford W, Global positioning system: theory and applications, American Inst. Of Aeronantics & Astronantics, 1996.

[6] David J. Goodman, Wireless Personal Communications Systems, Addison-Wesley, Jan 1998.