Wireless Location Positioning
From Existing Signal Level Data

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Introduction

The location of mobile radios first appeared in military systems developed during the Second World War. The idea was simple: to find people in distress, or detect and eliminate people causing distress. During the Vietnam conflict the US Department of Defense launched a series of Global Positioning Satellites (GPS) to support military operations. In 1990, during the Gulf Crisis, the signal from GPS satellites was made available to the private sector so that commercial applications could be developed. More recently, a number of commercial GPS systems have been developed to provide location information to mobile users, with applications for fleet management, navigation, military targeting, and emergency assistance.

Location Applications

In 1996, with the rising use of cell phones, the Federal Communications Commission (www.fcc.gov) introduced regulations requiring wireless service providers to locate wireless phone users for emergency situations which sparked renewed interest in radio location among commercial providers. The FCC regulation requires that all wireless service operators provide an emergency 911 caller's cell phone location to the Public Service Answering Point (PSAP) to within 100 meters 67% of the time. The FCC regulation, known as the FCC E-911 Mandate[(1)], applies to all cell phones and not just specially enhanced GPS phones.

While FCC regulations and emergency assistance applications are driving much of the current location technology development, the ability to determine the location of users within a wireless system also has significant commercial applications. For example, Location-Based Services **(LBS)** for wireless navigation, city administration, traffic, personal entertainment and a host of business applications for mobile government and enterprise workers. The market potential for such products and services is growing rapidly. According to the April 2000 Strategis Group report *'European Wireless Location Services'*, Mobile Location and Information Services are forecast to be worth US$81.9 billion by 2005"[(2, 3, 4, 5)].

A number of different cell phone location systems have been developed, using both GPS and wireless Rf transmission technologies and some have even undergone field trials with varying claims and degrees of success. Although the FCC 1st of October 2001 deadline has already passed, the phone companies have not implemented the location systems. The evaluation of several technologies is still underway and the FCC has granted temporary waivers and an extension of time.

Location Technologies

Location technology systems fall into two broad categories; GPS and non-GPS. There are a variety of stand-alone GPS systems on the market for personal navigation applications[6, 7, 8] but these systems do not work indoors and do not integrate with the phone company infrastructure and therefore do not support the E-911 mandate. Assisted GPS (AGPS) solutions[9, 10, 11] specific to mobile phone applications have been announced and are currently being evaluated by wireless operators for use in rural areas where cell coverage is not available. AGPS technologies have demonstrated good results for certain indoors applications but the customer must be prepared to purchase a special GPS phone if and when they become available.

Several radio network based systems, which measure Time Of Arrival (TOA)[12, 13, 14,15] of highly calibrated radio signals, have been developed and tested with good results. Although, due to high implementation costs, TOA solutions are limited to pilot schemes only. The various TOA systems that have been announced depend on expensive overlays of additional radio transmissions that require additional servers, antennas and hardware integrated into the cell site Base Stations. Much of the TOA solution infrastructure must be built up-front in order to deliver location services to wireless subscribers and some carrier's have received quotes of US$30,000 per cell tower site. With more than 104,000 cell site base stations in the US, the infrastructure cost for a TOA technology solution in the US could reach US$3 billion. Wireless operators are reluctant to implement such costly technology in the current depressed economy when revenues and capital expenses are under such pressure. Additionally, the high upfront cost of TOA technologies presents a questionable business case.

Signal Level Based Solutions

The most cost effective solution for location positioning is one that can use the existing radio signal level measurement from a mobile device to a series of base stations. The advantage of this approach is that, because you analyse the existing cellular signal levels, you require no new infrastructure. However, significant signal level variations inherent in cellular systems have proved a major obstacle to many developers. Adaptive schemes based on the use of on fuzzy logic, hidden Markov models, and pattern recognition [17] methods have been proposed and tested however, these schemes have not been efficient or cost effective for deployment on a nationwide basis.

More recently, Digital Earth Systems researchers, working with wireless technology developers, have successfully completed field trials of signal-level based location positioning. This technology is being commercialised as GeoMode™, an economical, accurate and simple to install 100% software solution for wireless location positioning using freely available signal-level data. GeoMode™ does not require any additional network infrastructure changes or cell site add-ons and is therefore less costly and less complex to implement and manage.

GeoMode™ Technology

The GeoMode™ software solution utilizes existing network data only and has none of the complexities of network overlays. GeoMode™ system consists of two components:

- The first is the location determining software, which may be installed either at the wireless carrier's facility or, independently of the carrier, at a GeoMode™ Location Service Data Center. This system collects wireless network data and calculates the physical location of a cell phone. The system can also control the phone to transmit that Information over the data channel when requested or automatically when triggered by a local event. This sophisticated software, using patented algorithms and 'self training' *neural* networks, receives the transmitted data and calculates the position. The software also has the ability to add differential correction based on a transmitted reference, this can be used to refine the position accuracy of the mobile. One other unique feature is the location software has the ability to discover and update itself by self-adding new installed cell sites to its database and making corrections for other environmental changes.

- The second component is the Map Information Data Center which integrates the X,Y data into a digital map and/or converts the X,Y location into a street address list. This location data, including the complete geographic display, can then be provided to any Internet Location-Based Service application or Emergency Dispatch Center. This location data can also be fed to any standard GIS (Geographical Information System) in any format. Alternatively, the data can be transmitted to and used by any dynamic LBS application.

The GeoMode™ system runs on standard hardware and can be deployed in the carrier's network or independently of the network in a data center. The GeoMode™ location software has an API for most popular client databases and also supports location-positioning data from GPS devices. For commercial LBS and emergency applications across a complete coverage area, the ideal solution will be a hybrid of GeoMode and a GPS based solution.

GeoMode™ technology fully meets the USA Federal Communications Commission (FCC) Mandate for enhanced emergency services. This mandate requires that all wireless service providers have the ability to locate 911 emergency callers to within 100 meters at least 67 percent of the time. GeoMode™ tests on a GSM network demonstrated location accuracy of within 50 meters in metropolitan areas 92% of the time.

Wireless carriers, using GeoMode™ technology can now deliver location-based services to standard unmodified mobile phones, PDAs and other wireless devices. Additionally, wireless phone users can now accurately locate themselves and tap into new applications. These applications include mobile yellow pages, enhanced safety calling, roadside assistance, location sensitive billing, personal navigation and tracking services. Using network data provided by the wireless carrier, GeoMode™ can calculate the geographical position of a standard unmodified wireless phone and provide this location data or street address to Emergency Dispatch Offices or any Location-Based Service application.

GeoMode™ And How It Works

In a GSM and similar digital systems, the signal data between every mobile device and all recognized base stations is measured at sub-second intervals to facilitate handover. GeoMode software analyses the signal level data to determine the exact location of the phone. The signal level data required is available from the base stations (via BSC or MSC) and the configuration and location of the GeoMode server will vary depending on the network provider and the operator preferences.

In an ideal free-space environment, signal level contours are represented as perfect circles around base stations and the location of a mobile device is the unique intersection point of three circles. In the real world however, practical propagation conditions, especially in urban areas, are far from free-space propagation, and signal level contours are not circles. GeoMode software is based on filtering algorithms and a patented network signal level modelling process that overcomes these variations and provides a cost effective solution to wireless location.

LBS & Public Safety Applications

GeoMode™ is a proven technology for wireless carriers and suppliers of location enabling platforms on mobile networks. The service is designed to provide location positioning integrated with map data and other location 'aware' applications such as:

- Public Safety E-911* Emergency Dispatch
- Fleet Management / Vehicle Security
- Roadside Assistance
- Dynamic Traffic Conditions
- Real-Time Diving Directions
- Asset / Package Tracking
- Entertainment Services
- Mobile Commerce platforms
- Coastal Marine Safety
- Refrigerated Container monitoring
- Logistics Transportation Systems
- Personnel monitoring for Police, security, medical & prisoner
- Industrial plant, process & equipment monitoring & control

A fully secure Internet location, monitoring and control application has been developed for map servers and will support any Internet based location-based service application.

Field-testing has been conducted in conjunction with the global wireless carrier Vodafone. Tests in metropolitan areas demonstrated that GeoMode™ technology will locate a standard wireless phone or device to within 20-50 meters at least 92 percent of the time.

In the US, the development of the above services is being encouraged by the Federal Communications Commission's (FCC's) mandate (E911) that all US wireless operators must provide the location of mobile emergency callers to safety officials and emergency dispatchers. There are many regulators in other countries worldwide that are beginning to explore mandating wireless location also, including France, Ireland and Canada.

AVL, Telemedicine & Control Applications

In addition to E-911 and LBS applications, GeoMode™ is ideally suited to remote control applications such as vehicle telematics, public transit management, asset security, telemedicine or any other remote control function where location or change in location is also a factor.

In the AVL and automation control market, the GeoMode™ Security Network Unit (SNU) has the combined capabilities of communications and control functions. The SNU consists of a GSM modem fitted with GeoMode™ input/output capabilities, which can simultaneously send and receive data and output this via a full serial port. The SNU has multiple analogue I/O ports for direct remote control and monitoring functions. The cost of the GeoMode™ SNU technology is projected to be considerably less than the combination of technologies typically required to provide this functionality.

By using only the coverage of GSM, GPRS or any digital cellular telephone network, GeoMode™ SNUs can provide 24-hour World wide location, monitoring, tracking and remote control functions. This gives the SNU enormous potential and opportunity for use in a multitude of industrial, security, life sciences, commercial and personal monitoring and control applications.

There are 300 digital cellular networks installed in nearly 142 countries, which gives the unit the unique ability to operate almost worldwide. The SNU can provide instant information and control of any equipment or person to which it is attached. It can provide status reports whilst monitoring and controlling hundreds of operational functions from a remote base station anywhere on the cellular network.

The ability to automatically locate and accurately establish the positioning of cellular phone or equipment anywhere in the country as well as exchange data, messages and voice communication and have remote control functions is of great importance in many business areas and mobile applications. All this is possible with a single technology.

This AVL and control concept equally applies to other types of equipment and property such as pleasure boats/yachts, long haul trucks, cargo/parcels, transport containers, remote patient tracking and monitoring and many types of dispatching and distribution systems. Latter

developments now mean that a low cost personnel communication system called a " Smart Phone " is being developed for use with police, security staff and other operators where personnel are at risk.

When compared to GPS AVL technologies, the GeoMode™ technology will provide superior performance and accuracy in urban areas for less cost. However, the GPS may be more suitable in rural areas where the cell coverage may be sparse. A GPS location system also requires a clear line of sight and is therefore unreliable when moving in urban areas with high buildings, inside buildings, in mountainous terrain, and in any other enclosed or covered spaces.

GeoMode™ Advantages

The integration of positioning and communication into a single software system is a goal not achieved in any contemporary positioning systems. The GeoMode technology offers the advantage of integrated positioning, communication, monitoring and control functions on a single world standard wireless technology platform.

GeoMode represents a very elegant and low cost approach to integrated automatic positioning, communication and control. This technology uses the existing network data to achieve location, real time tracking, status monitoring and control of a mobile unit and communication of this data to one or more remote base stations and other parties. This technology can monitor and control any number of units Worldwide in areas covered by digital cellular networks.

GeoMode™ New Developments

The integration of GeoMode technology into asset / package and commercial shipping systems is another application area under development where smart labels contain all shipping and manifest data and these are tracked by a vehicle based GeoMode SNU connected via wireless technology to corporate and Internet based systems.

Medical and Life Science applications are also possible with GeoMode technology, especially for patient monitoring that includes location (see www.geomedic.com).

The GeoMode technology is also suitable for low cost dedicated emergency phones, for children, travellers and other people at who may be at risk. The GeoMode™ service allows permission-based access to visually monitor the map location of a GeoMode™ device online.

Conclusion

All location techniques have their limitations and, in the real world, unsatisfactory performance will be experienced in varying propagation environments, no matter which technique is used. From an operational point of view, the benefit of the GeoMode approach is that a wireless location positioning solution can be implemented today which meets FCC mandate requirements and requires no infrastructure modifications.

With GeoMode, improved performance can be continuously derived from mobile reference measurements in the field. The required reference data is freely and always available. The wider bandwidth of 2.5G/3G technologies will also deliver significant improvements

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