LOCATION TECHNOLOGIES FOR ITS EMERGENCY NOTIFICATION AND E911*

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BIOGRAPHIES

Robert L. French, principal of R. L. French & Associates, is a physicist (BS, Murray State University, MS, Vanderbilt University) and is the inventor of map matching for automobile navigation. As a consultant in navigation and intelligent transportation systems (ITS), he advises automotive, electronic, cartographic, and transportation organizations in the United States, Europe, and Japan. Government clients include the U.S. DOT as a member of the Technical Review Team for the National ITS Architecture Program. Mr. French has authored over 75 publications on vehicular navigation and ITS. In addition to the ION, where he serves on the Council as Land Representative, he is a member of the RIN, IEEE, lTE, SAE, WFS, and ITS America.

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ABSTRACT

The ITS (Intelligent Transportation Systems) National Program Plan and a Notice of Proposed Rule Making (NPRM) issued by the Federal Communications Commission (FCC) in October 1994 promulgate independent but somewhat similar requirements for automatically determining the originating location of messages sent by wireless communication to emergency dispatch centers. In the case of ITS, the wireless communication is between in-vehicle devices and emergency response centers. This requirement is one of 29 ITS user services defined by the Program Plan that are being addressed by the National ITS Architecture development program, which is scheduled for completion in July 1996. The NPRM would extend E911 service to cellular phones and other portable/mobile communication devices irrespective of whether they are installed in vehicles. The FCC is expected to issue rules or take other action on wireless 9 11 caller location in 1996.

In the meantime, cellular and personal communication service licensees are assessing alternative means for responding to the anticipated FCC requirements. In addition, manufacturers and wireless communication services providers are beginning to team with security monitoring services in commercial operations that offer emergency notification services similar to those promoted by the ITS Program Plan. This paper compares the ITS and NPRM requirements, summarizes potentially applicable location technologies, and describes related ITS field trials and commercial ventures.

INTRODUCTION

Personal security outside the home is a major concern among the general public, and is thought to be a major motivation for the purchase of many cellular phones. At the same time, public-safety agencies are concerned about degradation of the overall level of existing E9 11 services by the rapid proliferation of cellular phones that, unlike home or office phones, cannot be identified with a specific location when an emergency call is received. These concerns are being addressed by similar but essentially independent initiatives by the National Intelligent Transportation Systems (ITS) Program and the Federal Communications Commission (FCC).

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A variety of technologies have potential for satisfying the requirements for determining the location of portable/mobile devices used for emergency calls. In some approaches, the caller's location is determined at the emergency site and transmitted by the calling unit. In other approaches, the caller's location is determined by radiolocation techniques or special processing at the receiving site or other locations within the infrastructure. The later approach, in most cases, does not require any modification to the calling device.

The ultimate choice among location technologies for widespread use may be strongly influenced by final **rules** from the FCC. For example, if the FCC requires wireless network operators to provide 9 11 call location for all cellular phones, this will probably necessitate an infrastructure-based approach to accommodate existing phones. If rules only apply to new subscribers, location subsystems could be added to the phones. The choice of location technologies may also be influenced by the outcome of ITS operational field trials of Mayday systems now underway, and by the success of early commercial ventures that have potential for establishing de facto standards.

The following paragraphs describe the location requirements promulgated by the ITS and FCC initiatives, summarize alternative location technologies, outline Mayday operational field trials, and discuss commercial emergency notification services.

ITS EMERGENCY NOTIFICATION AND PERSONAL SECUIUTY

"Emergency Notification and Personal Security" is one of 29 ITS user services specified by the National ITS Program Plan [I] that are addressed by the National ITS Architecture, which is being developed by a 3-year, $20-million U. S . Department of Transportation project [2]. This user service focuses on reducing the time from occurrence of an emergency incident until the notification of the appropriate response personnel, and on providing an accurate estimate of the location of the vehicle in need of assistance. It includes two subservices:

1. Driver and Personal Security - Provides the ability to manually initiate the notification of emergency and non-emergency incidents such as mechanical breakdowns, fire, non-injury accidents, or injury accidents where a person on the scene is able to manually initiate the notification.

2. Automated Collision Notification - Provides automatic notification of automobile crashes. This subservice has the goal of reducing the response time for assistance in incidents where serious injury has oc**curred** to the vehicle occupants rendering them unable to initiate manual incident notification.

The Emergency Notification and Personal Security user service directly addresses the ITS goal of improving safety by improving the timeliness of emergency medical services (EMS) and roadway services responses, thus reducing the number of fatalities and severity of injuries resulting from a collision, and reducing the number of pedestrian and vehicle collisions secondary to an accident. In addition, driving stress is reduced by providing a means of summoning assistance in the event of an emergency.

Location determination and wireless communications are key enabling technologies for Emergency Notification and Personal Security. Although subject to change before the ITS architecture is finalized in mid-1996, the architecture calls for location to be determined by in-vehicle subsystems with an accuracy of 6-91 meters for automatic transmission with emergency messages. The ITS Architecture proposes three alternative means for communicating emergency messages from the vehicle:

1. Cellular Digital Packet Data (CDPD) - This would require an extension to the current CDPD standard as well as special software to be deployed by cellular carriers to implement that standard.

2. Low Earth Orbit (LEO) Satellites - This would provide complete rural coverage once LEO satellite communication systems have been deployed.

3. Information Service Provider (ISP) - This would require that users subscribe to a commercial ISP that offers routing of emergency messages along with other services such as dynamic routing information for vehicles. ISPs are expected to offer a variety of communication Pinks such as cellular and ESMR (Enhanced Specialized Mobile Radio).

According to the ITS Program Plan, an incident notification message could be automatically routed to the appropriate response provider (i.e., mechanical breakdown to a repair or towing service, medical emergency to EMS dispatcher, or criminal activity to the police department). Another approach would be to utilize a centralized dispatch facility that would decide on the appropriate response provider and relay the message accordingly.

However, both the ITS Program Plan and the ITS architecture development team suggest that the Emergency Notification and Personal Security user service could be

linked to the existing infrastructure of Public Safety Answering Points (PSAPs), which are communication centers operated by agencies responsible for answering 911 emergency calls. Basic 9 11 services direct emergency phone calls to the appropriate PSAP, but some call transferring may be needed to reach the proper emergency response agency.

OPERATIONAL FIELD TESTS OF ITS MAYDAY SYSTEMS

Operational field tests performed in a real-world environment are an important bridge between ITS research and actual deployment of proven technologies. In addition to evaluating technical performance, field tests are also crucial for evaluating institutional arrangements among various public and private sector organizations that must work together in the deployment of most forms of ITS. Two of the some 70 ITS operational field tests that are currently underway deal with Mayday systems [3].

The Puget Sound Help Me (PUSHME) Mayday System operational field test was started in November 1994 in Northwest Washington State, and is scheduled for completion in November 1996. It is a $2.5-million joint project of the Federal Highway Administration (FHWA), Washington State Department of Transportation (WSDOT), Washington State Patrol, David Evans and Associates, Motorola, IBI Group, Sentinel Communications, Response System Partners, and the University of Washington.

The primary objective of the field trial is to assess operational, institutional and technology requirements for implementing a regional Mayday system that would allow a driver to send an immediate notification of an incident, its location, and need for assistance to a response operator. GPS receivers and cellular technologies are being used in two alternative schemes. One scheme uses a GPS receiver, modem, and cellular phone in a device integrated by Motorola. The second scheme connects a GPS receiver with a two-way pager-like device that uses CDPD for communication.

The second ITS Mayday field test, which is underway in Colorado, has a rural focus. In addition to the FHWA, its partners include NAVSYS Corporation, ESRI, Cellular, Inc., Colorado State Patrol, Castle Rock Consultants, and members of the ENTERPRISE group, which is a consortium whose membership includes the Department of Transportation of Colorado and several other states. The project, which is estimated to cost $3.8 million, started in October 1994 and is scheduled for completion in December 1997.

The project will evaluate the use of GPS for vehicle location and cellular phone for two-way communications in order to provide emergency and non-emergency assistance to travelers operating in an area of over 12,000 square miles in north-central Colorado. The test will involve up to 2,000 vehicles equipped with a low-cost location device called TIDGET. The TIDGET sensor receives but does not fully process GPS satellite signals. Instead, key GPS data from which position can be derived are forwarded by cellular phone to a central location which completes the processing to determine the location of the vehicle.

The primary objective of this test is to evaluate the impact of an infrastructure-based GPS system and response network on emergency response activities, time, and public safety. In addition, this test will identify the necessary structure, responsibilities, and service levels of a traveler assistance center to commercially operate such a system and to eventually return control of the system to the center [4].

FCC NOTICE OF PROPOSED RULE MAKING ON WIRELESS E911

Enhanced 911 (E911) services have been deployed voluntarily in most U.S. population centers to provide for more efficient handling of wireline emergency calls. The E9 11 services for wireline phones incorporate Automatic Number Identification (ANI), Selective Routing of the call to the proper Response Agency, and Automatic Location Identification (ALI) to facilitate dispatching response to the proper location even when the caller is unable to give that information. With the ANI feature, a computer retrieves and displays the fixed address (location) for the caller's telephone number and identifies the appropriate agency for response.

Thus the addition of ANI and the equivalent of AL1 to cellular phones would allow PSAP personnel to determine the registration and location of cellular 911 callers. Indeed, this is the thrust of what a Notice of Proposed Rule Making (NPRM) issued by the FCC in October 1994 [5] proposes to phase in as a requirement for cellular service operators over a five-year period.

The NPRM proposes that operators of cellular phone and mobile radio services that offer PSTN (public switched telephone network) interconnection make it possible to locate callers to support E911 emergency response. This initiative is largely the result of earlier concerns expressed by public-safety agencies that the rapidly increasing (estimated 30% per year) number of cellular phones in use will degrade the overall level of existing E9 11 services. In particular, the National

Emergency Number Association (NENA) and the Association of Public-Safety Communications Officials (APCO) submitted comments to the FCC in 1992 in response to a NPRM for PCS (Personal Communication Services) that emphasized the need for PCS to provide caller location information.

The FCC responded in an October 1993 Second Report and Order amending PCS rules by acknowledging the need for location information and encouraged industry and standards organizations to direct attention to supporting E911 [6]. Although not requiring location capability at that time, the FCC stated "We contemplate initiating a proceeding in the future to address E911 and related issues with regard to PCS, cellular, and any other relevant mobile services."

The NPRM subsequently issued by the FCC in October 1994 proposed that wireless ALI be implemented in three steps [5]:

1. 1st Year - Identify cell site and sector for cellular calls

2. 3rd Year - Determine caller's distance from the cell site

3. 5th Year - Determine location within 125 meters in three dimensions

Some 130 responses to the NPRM were submitted by wireless network operators, public safety organizations, industry trade associations, and other interested parties. Responses submitted by wireless operators typically argued that enactment of rules should be deferred until wireless caller location technologies are more mature and issues such as liability for network operators and means for recovering implementation costs are addressed. Public safety organizations such as NENA and APCO argue that AL1 for wireless 9 11 can be effectively implemented in less than the proposed five-year period and that deferring the enactment of rules will have a negative impact on public safety.

It is expected that the FCC will take action regarding wireless 911 in the first half of 1996. Possible actions include adopting an order for the rules proposed in the NPRM, issuing a revised NPRM, or establishing an industry advisory committee to further study the issue.

ALTERNATIVELOCATIONTECHNOLOGIES

Due to the escalating number of cellular 911 calls and difficulties associated with responding to these calls in a timely manner, APCO and the State of California Telecommunications Division commissioned C. J. Driscoll & Associates to conduct a study of location systems and technologies that could, in principle at least, be used to locate wireless 911 callers. The resulting report and a subsequent update [7] identified some 20 manufacturers (or would-be manufacturers) with integrated systems in various stages of development that potentially could support wireless E9 11.

The technological approaches used in these systems generally fall in two broad categories:

1. Infrastructure-Based Radiolocation Systems - These systems make measurements on signals transmitted by a wireless phone. The caller's location is computed at a central location and passed through to a response agency. These systems do not require modification of the wireless phone and, thus, could support the installed base of over 30 million cellular phones in the U.S. today. Examples include:

   a. Systems that compute caller location by measuring the angle of arrival (AOA) of cellular phone transmissions at two or more base stations. KSI, Inc. of Annandale, Virginia has developed and patented the Direction Finding Localization System^{tm} (DFLS) which, according to KSI, can compute the caller's location with an accuracy of 50 meters. The system can pass the caller's location and phone number through to the PSAP.

   h. Systems that compute the location of the caller using Time-Difference of Arrival (TDOA) measurements on signals from the wireless phone. The Associated Group, Inc. of Bala Cynwood, Pennsylvania, has introduced the TruePosition ^{tm} Cellular Location System that makes TDOA measurements on signals received at TruePosition base stations, which are usually installed at cellular base stations. TruePosition has reported two-dimensional accuracy of 120-150 meters. The company claims in the future the system will be capable of supplying three-dimensional accuracy of 12 meters.

   c. Some companies are developing hybrid systems which compute location based on a combination of AOA, TDOA, signal strength measurements or other measurements on signals from mobile or portable phones. One company has conducted research on technology to approximate the caller's location without any modification to the cellular phone or additional network infrastructure. This system uses a combination of measurements on transmissions between the phone and cellular base station, including signal strength, word or bit error rate, power correction,

signal-to-noise measurements and time differential of round trip digital packets. The developer claims that these techniques typically enable the caller's location to be resolved to within 15-20 percent of the cell radius.

2. Mobile/Portable-Based Radiolocation Systems -l This category of systems depends primarily upon subsystems integrated with, or connecting to, the transmitting cellular phone or other mobile communications device and requires no additional network equipment. Examples include systems that use GPS to compute the caller's latitude and longitude and pass these coordinates over the wireless network to response center. As GPS signals to not penetrate buildings, the use of GPS to support wireless 911 will general be limited to outdoor applications.

Another example is a system call PINS being developed by Terrapin Corporation, which uses signals from commercial FM radio stations to compute the caller's location with typical accuracy of 20-30 meters. Terrapin claims that the characteristics of FM radio signals make it possible to compute the caller's location indoors as well as outdoors.

In addition to wireless AL1 systems based on network infrastructure and those using radio signals to compute location at the phone, some companies are developing systems that use a combination of a minor modification to the phone and a low cost add-on to the network. One major corporation feels this is the best approach to achieving reliable in-building performance, which is considered important due to the high percentage of portable phones.

The ITS architecture approach to Emergency Notification and Personal Security falls in the mobile/portable-based location category. In-vehicle location determination is assumed because the location technology may be shared with other in-vehicle uses such as navigation and route guidance and, in the case of commercial vehicles, automatic vehicle location reporting. GPS augmented by dead reckoning and map matching is commonly used for automobile navigation and route guidance systems, whereas GPS alone is often used for commercial vehicle location reporting [8].

COMMERCIAL EMERGENCY NOTIFICATION SERVICES

Recent unilateral moves by industry have the potential of setting de facto standards for ITS Emergency Notification. The following are selected examples of recently announced Mayday products and services for motorists:

- Ford's RESCU (Remote Emergency Satellite Cellular Unit), a GPS and cellular-based emergency response service using Motorola hardware and Westinghouse security monitoring that will go on the market in 1996 [9].

. An emergency response service to be offered in 1996 by ADT Security Systems using Rockwell International GPS receivers for location and the RAM digital packet data network for communications [l0].

- AutoLink, an emergency notification service to be offered in mid-1996 by Prince and SkyTel that uses Motorola GPS receivers and pagers in conjunction with SkyTel's recently introduced two-way paging and messaging service [l l].

= LifeNet, a GPS and cellular-based emergency response service offered (initially to corporate security clients) since May 1995 by Holmes Protection Group [12].

These business moves signal a high level of confidence in the potential market for emergency notification. For example, in introducing RESCU, Ford claimed "Market studies have shown a growing desire by our customers for safety and security features [13]." ADT and Rockwell claim that nearly a year of market research indicated that motorists overwhelmingly desired the additional security of the emergency response network they plan to offer. Approximately 92% of the people surveyed said that personal security outside the home was a source of concern. Market penetration of 3-5 % in 5 years, 8-15% in 10 years, and 15-30% in 20 years is assumed by the National ITS Architecture development team for Emergency Notification and Personal Security user service.

CONCLUSIONS

The National ITS Architecture, which defines the overall framework and relationship of Emergency Notification and Personal Security to other ITS user services, is scheduled for completion in mid-1996. The National ITS Program Plan calls for deployment of Emergency Notification and Personal Security to begin in 1997 and for continuation of operational tests and development of guidelines and standards through 1998.

The FCC is expected to issue rules or take other action on wireless 9 11 caller location in the first half of 1996. Wireless industry standards bodies and public safety organizations are currently developing standards for transmission of caller location and other emergency-related data to PSAPs.

Thus, particularly in view of the commercial emergency notification activities already getting underway to address needs that seem to be recognized by the general public as well as by public safety officials, there is an urgent need to harmonize the ITS initiatives with public safety, wireless industry, and FCC initiatives to assure compatibility and eliminate unnecessary duplication. Serious thought also needs to be given to the proper role of commercial emergency notification services interacting with public safety, to assure the fastest possible emergency response.

Finally, caution must be exercised in setting standards to allow flexibility for coverage in rural areas where cellular communications may not be available and for coverage in buildings where GPS signals are not available.

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