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Flexible Technical System Design for Indoor and Outdoor Seamless Positioning System with GPS Technology

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Abstract

The prime concern for GPS-based positioning systems such as car navigation are that they are not allowed to use inside building nor underground, where GPS signals are out of range. To increase flexibility for providing such services, both indoor and outdoor seamlessly, the seamless positioning system (SPS) with a number of independent transmitters that send GPS-equivalent signals to receivers and GPS satellites was designed. The system will meet the needs of public domain such as disaster management and emergency rescue, where quick and accurate personal location information dramatically makes difference. The application may further be extended to commercial activity as well for personal store navigation and customized sales promotion considering customer ' s characteristic and present location. A prototype of SPS has been implemented in the real world environment and several experimental applications have been investigated. Our SPS has shown its flexibility in a variety of circumstances.

Introduction

Even though location-based services (LBS) were predicted to become the killer application of mobile commerce, their dominance has not yet materialized, but is predicted to do so soon. The LBS market size has been predicted to grow exponentially from 2006 to 2010. Within this four-year time span, Asia's LBS market side is expected to increase from $291.7 million to $447 million, Europe's market from $191 million to $622 million, and the U.S. market from $150 million to $3.1 billion (Iris 2008). LBS have been available for several years. Initially, location determination for cellular phones was solely cell-based, and location accuracy was determined by the cell size. Whereas cell-based approaches do not require modifications to the handset or network, other location techniques, such as WiFi-based, picture-based, or GPS-based require modification to give increased location accuracy.

The GPS-based positioning system is the most widely spread for the LBS in the world. The prime concern for GPS-based positioning systems are that they are not allowed to use inside building nor underground, where GPS signals are out of range. To increase flexibility for providing such services, both indoor and outdoor seamlessly, we are developing novel SPS which enables GPS-equipped receiver to communicate without extra hardware both indoor and outdoor seamlessly with technical and business designs. This paper presents technical design of our SPS system. Business design is described another paper (Minato, 2010).

Technical System Design

The key technology of our SPS is Indoor Messaging System (IMES) designed by Japan Aerospace Exploration Agency (JAXA) and several companies (Kogure 2008). IMES uses satellite signals outside in the usual way, while using signals from IMES transmitter indoors, where satellite signal quality is reduced. IMES signal structure is similar to that of GPS satellites signals, expect for the data of the navigation message. Therefore, the same receiver can be used both indoor and outdoor as shown in Figure 1.

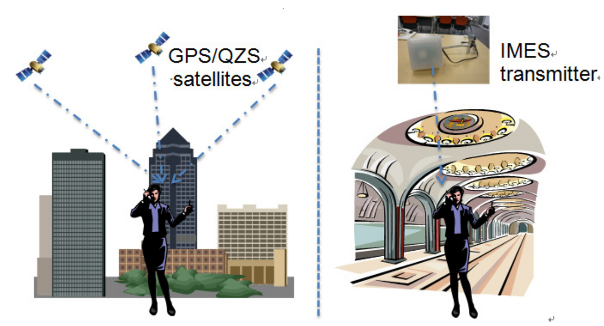

Figure 1. SPS for a GPS-equipped Receiver.

IMES transmitter sends an RF signal similar to that of GPS and the Japanese Quasi-Zenith Satellite System (QZSS), giving its three-dimensional position, the position of the center of its cell coverage zone (Manandhar 2008). The position and additional information in the IMES navigation message is periodically broadcasted instead of the ephemeris data, clock corrections, and so on contained in the GPS message. IMES assumes that positioning accuracies of ten meters will satisfy users who would like to know where they are in indoor places such as rooms, underground shopping areas.

Table 1 shows signal properties of IMES. The RF characteristics of IMES are the same as the L1 C/A code for GPS and QZSS. Transmitted at the GPS L1 center frequency (1575.42 MHz), IMES has a bandwidth of 2.046 MHz or more including the main lobe. In the current interface specification for GPS, the U.S. government has approved allocation of the Pseudorandom Noise (PRN) code 173 to 182 for use by other GNSS allocations such as IMES. The IMES receiver uses the codes only for de-spreading the spread-spectrum modulation and as a step to decoding the navigation message. Pseudo range or time determination is not necessary because the desired position is read directly out of the navigation message. This gives simpler equipment architecture than when using pseudolites.

Table 1. Signal Properties of IMES.

RF Center Frequency	1575.42MHz
PRN Code Rate	1.023MHz
PRN Code Length	1ms
PRN ID	173 to 182
Navigation Message Rate	50bps
Modulation	BPSK
Polarization	RHCP

The SPS will meet the needs of public domain such as disaster management and emergency rescue, where quick and accurate personal location information dramatically makes difference. The application may further be extended to commercial activity as well for personal store navigation and customized sales promotion considering customer's characteristic and present location.

Realizing the System in the Real-World Environment

We investigate and modify a seamless positioning system (SPS) with reference to the results of an experiment hypothesising the public services of evacuation and rescue activities during a disaster and an experiment that hypothesises the commercial services of store guidance and sales promotion activities (Kohtake 2010). At the present stage, a SPS is being constructed as a prototype that targets a complex building in Yokohama, which is made up of commercial institutions such as restaurants, sports clubs, and a day-care center; cultural and university facilities; and also the surrounding outdoor area. Approximately 1000 people come to the building per day and as a large-scale research-use server is in operation and a network infrastructure is constructed in the building and surrounding area, systems are easily constructed. The fact that feedback can be obtained from users as necessary is also advantageous.

At present point in the demonstration experiment the investigation of system architecture focusing on the consideration of positioning algorithms for seamless location information acquisition both inside and outside is being carried out together with the implementation of several applications and the usability is being evaluated. As an example, the demonstration experiment conducted in October 2009. A summary of the results is given below.

Two mobile applications were developed in this demonstration experiment. These applications were developed to support the movements of visitors around the campus and the inspection of the research demonstration experiment within the complex building. One was an application to indicate current location in accordance with the movements of the visitors both indoor and outdoor, and to present local information in relation to location. The location of the other users of this application was also displayed and communication facilitated between users. Figure 2 shows a snapshot of the screen displayed in the mobile device.

Figure 2. Snapshot of the Mobile device Display.

The other was an application whereby a cell phone self-recognised those roles and functions according to position location information, surrounding environment information and user characteristics. Through this application it was possible for users in possession of an authorised ID to control information appliances existing in specific locations and an arrangement was created whereby start-up and stop operations for research demonstrations were triggered by the visitor’s movements.

The system was primarily composed of IMES transmitters installed inside and a data server, a GPS/IMES receiver (NovAtel Super Star II) with an antenna, and mobile devices made from cell phones (NTT docomo/Toshiba T-01A). The GPS/IMES receiver connects to the mobile device via USB interface. The mobile devices exchanged the appropriate data with the data server by means of wireless LAN. Pole-type, stand-type and clip-type stands were prepared for the IMES transmitter installations according to the floor environment, with location and orientation determined upon measuring the reception strength at the receiver. Figure 3 shows a prototype of a mobile device. A mobile device during the demonstration experiment and an IMES transmitter is shown in Figure 4.

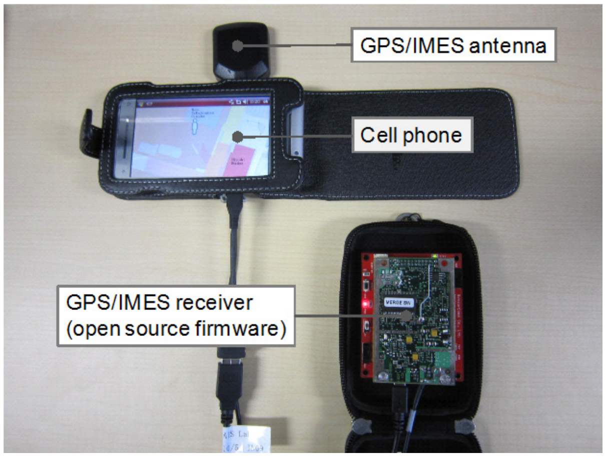

Figure 3. Prototype of Mobile Device.

Figure 4. Experiment (left) and IMES Transmitter (right).

The main purpose of this demonstration experiment was the development and verification of the algorithm for seamless switching between indoor and outdoor positioning methods. Major feature was the use of GPS receivers that could freely change proprietary algorithms using open source firmware. The GPS receiver inside the T-01A cell phone was not used in this time because the software on the GPS receiver in this cell phone is not open source firmware.

A step-by-step development approach to progressively improve the algorithm was adopted for this demonstration. The following scheme was adopted in order to smoothly provide seamless location information both indoor and outdoor in accordance with the movement of the user. First, four from the twelve reception channels used were allocated to the acquisition and tracking of the signal from the IMES transmitter with the remaining eight channels allocated to acquiring and tracking the signal from the GPS satellite. In the case an IMES signal is received, the location information is output from the short ID read from the IMES signal. As the IMES transmitter is designed such that the L1 band centre frequency is suppressed to an offset of less than 0.2ppm, it is important to grasp the frequency offset of the receiver to restrict the frequency search range during capture. The clock offset information of the receiver is retained from the outside positioning results and used in the frequency bin specification at the commencement of IMES signal search inside. These kinds of construction succeeded in shortening the time required for location acquisition from a maximum of over 30 seconds at the start of the experiment to around 3 seconds under the conditions of the demonstration experiment.

In the next phase experiment, it is planned to implement and investigate the results of a method called Network-assist IMES by which to send PRN code number information for adjacent IMES transmitters to the mobile device by means of network server via communication line.

Potential Applications

Figure 5 shows a disaster response system on SPS infrastructure that we are designing as one of SPS applications. In this system, the emergency data from the government to the mobile device via network or signal from QZS satellite is filtered based on the location of the mobile device. The user of the mobile device can receive suitable information in case of emergency.

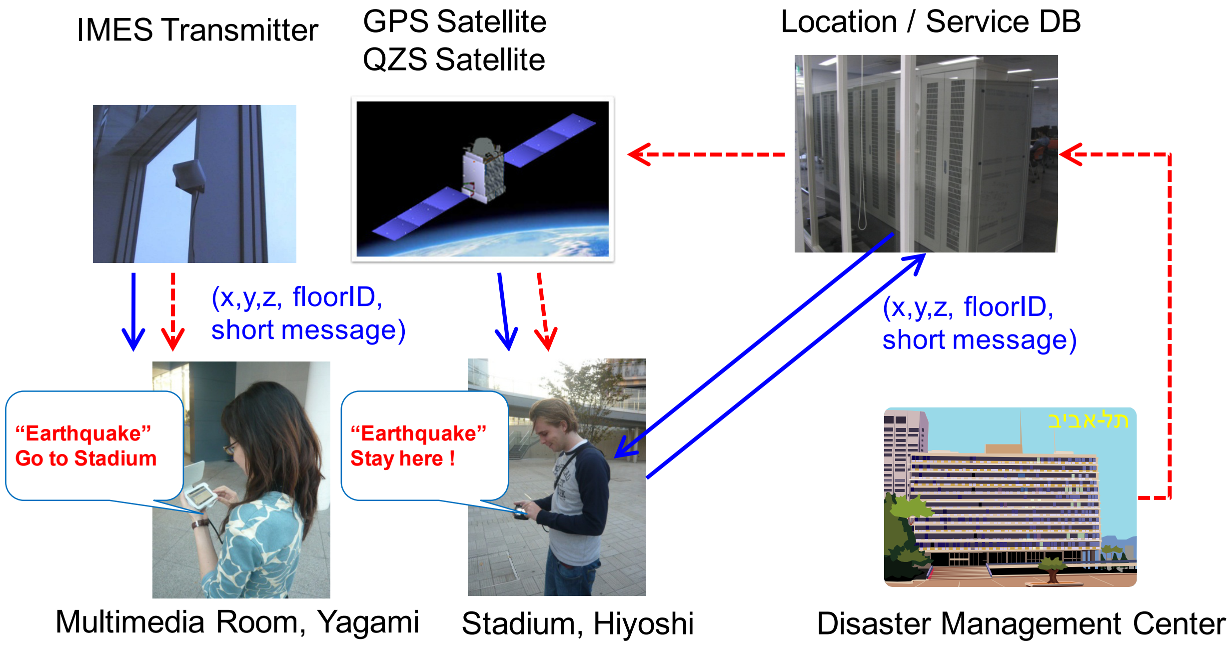

Figure 5. Disaster Response System on SPS.

The objective of this application is to construct a real-time disaster prevention system through the application of SPS, which can be applied in necessary locations during a disaster when information is necessary and conditions are limiting. The advantage of applying SPS is the resistance of man-made satellites to the disaster, as they do not directly receive the impact of a disaster on the Earth's surface, and their ability to monitor and broadcast to a wide area on the Earth's surface.

Disaster prevention activities are cooperative actions that require accurate information gathering and decision-making. Wide area disasters particularly require measures that respond to conditions in various locations regarding the minute-by-minute development of disaster conditions and facilitate real-time information gathering and decision-making by the response teams. Also during a disaster, cooperative actions under various restrictions, such as being unable to make use of the usual communications infrastructure or the mobilisation of persons not necessarily accustomed to an IT environment such as senior citizens and children become necessary.

This application makes use of the widespread GPS receiving function equipped mobile telephones and car navigation systems, and constructs a real-time disaster prevention system that can provide disaster information in response to the location of a user by receiving local information and small-capacity data broadcast by IMES from a GPS satellite and a QZSS planned for launch this year.

Conclusion

The realization of a SPS for both indoor and outdoor is a research development theme not just for Japan, but also common to the world. We will endeavour to further refine this technology such that it can spread around the world in an age where not just cell phones, but also various information devices such as PCs and game consoles are becoming equipped with GPS functions. Concerning the improvement of the positioning usage range and time, technology of SPS with IMES will expand to areas such as inside or underground shopping malls, which are out of range of transmissions from satellites, and the diffusion of appropriate technology is expected to bring about great benefits for our everyday life.

We wish to continue research and development and demonstration experiments in a real environment in order that this technology becomes widespread and many people can experience its convenience.

Acknowledgement

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References

Iris A. Junglas, and Richard T. Watson. 2008, Location-based Services. Communication of ACM 51(3): 65-69 (2008).

Kogure, S, Maeda, H, Ishii, M, Manadhar, D, and Okano, K. 2008, The Concept of the Indoor Messaging System, The European Navigation Conference (ENC-GNSS), Toulouse, April 2008.

Kohtake, N, Minato, N, and Makino, Y. 2010, Indoor and Outdoor Seamless Positioning System for a GPS-equipped Receiver, 22nd Annual Systems & Software Technology Conference (SSTC 2010), Salt Lake City, April 2010.

Manandhar, D, Okano, K, Ishii, M, Torimoto, H, and Kogure, S. 2008, Development of Ultimate Seamless Positioning System based on QZSS IMES, ION GNSS, Savannah, September 2008.

Minato, N, and Kohtake, N. 2010, Flexible Business System Design for Indoor and Outdoor Seamless Positioning System with GPS Technology, Glogift 2010, To Appear, July 2010.

Biography

Kohtake Naohiko is an Associate Professor and current Director of Aerospace and Intelligent Systems Laboratory at Keio University where he is responsible for space system engineering and intelligent systems. He has worked in research and development on avionics systems for the H-IIA rocket at Japan Aerospace Exploration Agency (JAXA), ubiquitous computing systems at Keio University, and on-board software at European Space Agency. He was a visiting researcher of user interfaces at Sony Computer Science Laboratories and an associated senior engineer at Digital Innovation Center in JAXA working on software independent verification and validation for satellites and the international space station.

Nobuaki Minato is currently an Assistant Professor of Graduate School of System Design and Management, Keio University, Japan, where he teaches business system dynamics and also serves as Deputy Director of Aerospace and Intelligent Systems Laboratory. He studied at Ecole Superieure de Commerce de Toulouse, France, and acquired Aerospace MBA with Best Performance Award. After spending 10 years in aerospace industry at Japan Aerospace Exploration Agency (JAXA), he became a faculty member of Keio University in 2009. His current research areas are sustainable air transport system, space business system, business system dynamics and model-based simulation and optimization for socio-economic systems.