

Implementation Results and Service Examples of GPS-Tag for Indoor LBS and Message Service

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Abstract— In previous paper, our GPS-Tag design scheme has shown promise as an effective way to provide the location information and the supplemental service information at the same time. Conventional ground type GPS application to provide both position information and service message have shown its limitation in service speed and information type so our GPS-Tag system was designed to have better transmission performance and flexibility in service message type [1]. In this paper, Implementation results about GPS-Tag hardware and Control platform will be discussed and message service examples of GPS-Tag system will be offered for indoor LBS (Location Based Service) and message service.

Keywords— LBS, Pseudolites, Indoors

I. INTRODUCTION

Today, lots of researches have been carried out to provide the continuous indoor-outdoor position service. Most of studies are based on the GPS positioning for outdoor and the positioning method using signal resource information like Wi-Fi access point map for indoor based on their availability and performance.

The GPS is the most widely spread positioning system for the open space LBS service in the world. But the GPS service is not allowed to use inside building nor underground, where GPS signals are blocked by obstacles.

Positioning by radio resource information like Wi-Fi is known to provide relatively good positioning performance in indoor – even room level accuracy – based on wide spread of Wi-Fi network. However Wi-Fi positioning performance is mostly depends of AP (Access Point) density so accuracy is dramatically degraded if AP is not sufficiently or properly installed and LBS method based on radio resource information needs preceding step to make a signal resource map or database which are used to calculate user position later. Those are the major hindrances in the Wi-Fi based indoor LBS service development.

If we want to use the two or more different algorithm to provide seamless position, we must develop a proper algorithm to harmonize the heterogeneous methods, which is quite challenging problem. So many researchers have been tried to use the GPS for the indoor or ground based LBS services and the PL (Pseudolite) system and modified PL

system like IMES of Japan to provide some additional information was developed.

Previously we described the drawback of current PL application service - the long service delay caused by low transmission rate and the limited information service by fixed message format - and showed our GPS-Tag design scheme to solve those problems. In this paper, we present the implementation results of Our GPS-Tag system and provide examples of the additional information service.

II. GPS GROUND APPLICATIONS

The GPS is one of popular LBS system based on GNSS (Global Navigation Satellite System) technologies. GPS utilizes the concept of TOA (Time of Arrival) triangulation measurements from multiple satellites to calculate the user position. A GPS receiver must have at least four clear LOSs (Line Of Sight) to different satellite signals to measure the signal travel time from a satellite at a known orbit position to the receiver. The distance between a satellite and a receiver is obtained by multiplying the signal propagation time and the speed of the signal. By measuring the distances between multiple transmitters, one can narrow the possible area and decide the receiver position.

A GPS receiver has to receive a satellite's navigation information from each satellite to determine satellite position in its orbit. The navigation message is spread by the PRN (Pseudo Random Noise) code which is allocated to each satellite uniquely according Code Division Multiple Access (CDMA) algorithm. Then GPS signals are transmitted on two radio frequencies, L1 (1575.42MHz) and L2 (1227.60MHz).

Each GPS satellite has two unique PRN codes - C/A (Coarse/Acquisition) code and encrypted precision code (P(Y)) - and C/A code is the standard code used for free open access service for civilian users. The C/A code is a sequence of 1023 chips and the code is repeated each ms giving a chipping rate of 1.023MHz and modulated onto the L1 carrier. A GPS signal is composed of three parts - carrier, Navigation Message, PRN code. The navigation data on L1 have a bit rate of 50 bps and the message consists of words of 30 bits so it takes 0.6s to read one navigation message word [2], [3], [4].

Pseudolites are ground-based augmentation system designed to transmit GPS-like signals so that increase accuracy, integrity and availability of the GPS system and

improve geometry of the satellite constellation. Pseudolites allow continuous and uninterrupted positioning indoors, in urban canyon or underground where GPS signal is blocked or seriously degraded. Pseudolites however require extra clock module and synchronization technique to work properly and need to operate Pseudolites at carefully chosen location to have a content positioning performance [5], [6].

One enhanced application of ground type GPS application from Pseudolites is Japan's Indoor Messaging System (IMES). IMES was developed to give Pseudolites more flexibility and functionality with the advent of enhanced signal characteristic and modifications of message signal structure. IMES enable user with a GPS-featured phone to have seamless positioning service by using satellite signals outside in the usual way but using modified IMES signal from IMES system indoors, where GPS signal is unreachable. Beside location information, IMES also provide user with the additional information like floor number by modification of GPS navigation message format [7].

Because there is no modification in GPS transmission signal format, GPS receiver can receive ordinary GPS signal and IMES signal directly and use both GPS navigation message and IMES service message by slight modification of the navigation message decoding block in GPS receiver firmware, so that IMES system have GPS interoperability and assist GPS positioning service where GPS signal is not available in a seamless way.

IMES transmitter sends an RF signal similar to that of GPS and the Japanese QZSS (Quasi-Zenith Satellite System), providing the position of the center of its cell coverage zone and additional information by predefined message type configuration. 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 uses the L1 frequency and modulation method same with GPS and utilizes the dedicated spread code from the same family of GPS codes, PRN code 173-182 from the C/A code allocation. Those codes are used for the IMES-compatible GPS receiver to de-spread the spread spectrum modulation and to decode the navigation message. Not like ordinary GPS system, IMES directly provides the designated position of IMES transmitter to user so pseudo-ranging or time determination is not necessary.

IMES holds GPS signal format so the message consists of words of 30 bits. The number of words in a frame to define four different types of IMES message for indoor locationing and message services can vary between one and four.

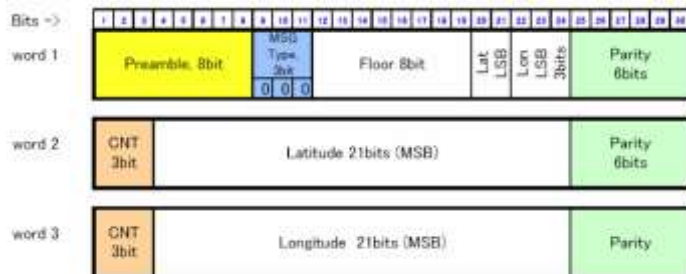


Figure 1. IMES Message Type 0

Message type 0, 1 are used to deliver location information like latitude, longitude and height or altitude directly and message type 3, 4 are used to provide identifier to address additional data such as maps and route guidance. IMES Message type 0 is shown in Figure 1 [8].

III. GPS-TAG SYSTEM

Even though IMES can provide user with location information and additional information like floor number using GPS-compatible receiver, its ability and feasibility are quite restricted to limited application and it takes a little bit long time to receive the whole IMES message because IMES abides by conventional GPS transmission scheme and inherits the poor transmission rate of GPS system.

So we developed an indoor LBS application system called 'GPS-Tag' that is based on the GPS technology. We designed our GPS-Tag system to improve the transmission performance and enhance the flexibility in information service type while to maintain interoperability with GPS system.

In normal cases, each GPS satellites transmits its navigation message spread by the PRN code which is uniquely allocated to each GPS satellite then modulated signals are mixed up in the air. GPS receiver extracts the navigation information of each satellite with designated PRN code from received signal.

We changed the sequence of the GPS transmission procedure to enhance the feasibility of GPS signal transmitter by applying parallel information transmission and modified GPS word size, transmission unit size to have compatibility with common information storage unit.

By procedure change, we can provide multiple navigation messages simultaneously in one transmission channel to have higher transmission rate and efficiently remove the duplicative overhead bits like preamble bits and error correction bits which are essential for individual transmission scheme. We clearly showed in previous paper that parallel transmission scheme still holds good correlation properties of the GPS spread code.

A. GPS-Tag Design Scheme

Because GPS-Tag has the same signal structure with GPS system to have interoperability with GPS, the RF characteristics of GPS-Tag are the same with GPS L1 C/A. GPS tag signal is modulated using the same carrier of 1575.42MHz (L-Band). The C/A has a chipping rate of 1.023MHz with a code period of 1.023ms.

Table 1 shows summarized signal properties of GPS-Tag.

TABLE 1. GPS-TAG SIGNAL PROPERTIES

Item	GPS-Tag
Carrier Frequency	1575.42 MHz
PRN Code	159-210
PRN Chip Rate	1.023 MHz
PRN Chip Length	1 ms
Data Rate	50 bps $\times$ No. Ch.
Modulation	BPSK

However GPS-Tag has modified message structure to provide location information directly and service additional message for user efficiently. GPS-Tag provides information using multi-channel message transmission scheme to improve the poor transmission rate of GPS system.

GPS-Tag system also accommodates 32bits slotted structure to improve compatibility with common information representation and storage unit. By changing size of word from 30bits to 32bits, we could have consistency with the character-based representation which are usually multiple of 8bits. If we operate GPS-Tag using 5 channels to send message then user can receive 160 bits (20 bytes) in 0.64s, which is relatively high data rate for GPS based application.

Depends on user configuration, our GPS-Tag frame can be composed of up to four slots and periodically broadcast the GPS-Tag frame to provide a variety of information.

Figure 2 shows a configuration example of GPS-Tag frame with four slots and five channels multi-transmission scheme providing ordinary message information and location information.

The first channel is used to deliver a GPS-Tag slot header which represents setting and usage of other channels. GPS-Tag slot header is composed of frame sync field, GPS-Tag frame field, slot sequence field, user data index field, location information field, message type field and error correction code.

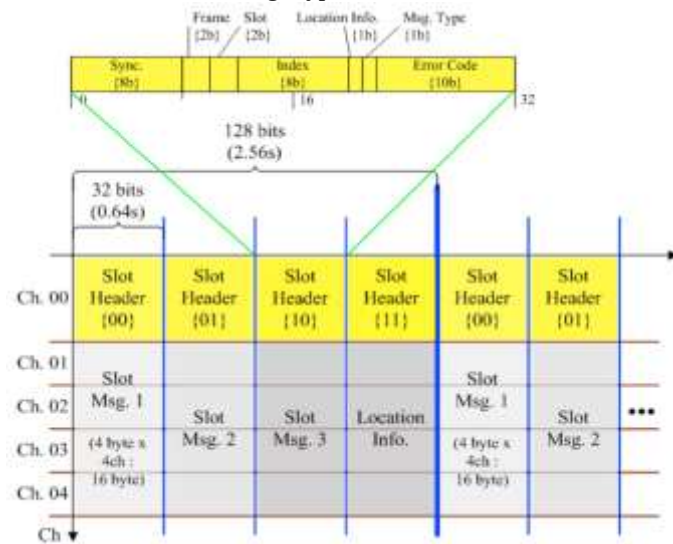


Figure 2. GPS-Tag Frame structure and Slot Header



Figure 3. GPS-Tag transmitter(Left) and receiver(Right)

Slot sync field is the first eight bits of the header used to indicate the start point of GPS-Tag frame. GPS-Tag frame represents total number of slots that compose the whole GPS-Tag frame and slot sequence indicates slot number which is currently transferred. User data index is used to support a message combination method using slot message and codebook message. Service provider can compose their advertisements or marketing phrase efficiently using the combination method of the short keyword in message slot and the predefined 256 useful sentences in codebook. Location information field indicates whether the GPS-Tag frame includes location information or not. If the location information is served then last slot is allocated to deliver the location information. Message type field is used to indicate the character form. With this field, we can tell whether slot message is saved in single byte letter or double byte letter. Error correction code is the last field in GPS-Tag frame to correct transmission error.

Other channels except the GPS-Tag slot header compose the slot message frame which delivers text type message, location information and link information for additional information.

B. GPS-Tag System Implementation and Results

Figure 3 shows a prototype of our GPS-Tag transmitter and receiver based on the above design principle. Because it is impossible to modify the built-in GPS firmware of commercial smartphone, we used our standalone GPS receiver for the experiment and modified the navigation message decoder firmware to handle both GPS signal and GPS-Tag signal.

We implemented GPS-Tag transmission board as a double layered add-on-board style, one main control board with a RF module board and implemented it using FPGA by HDL programming. GPS-Tag transmitter is configured and controlled by service provider control software which is interfacing transmitter through the serial interface.

GPS-Tag receiver is designed to receive both GPS and GPS-Tag signal. The GPS-Tag receiver is connected to the smartphone through a Bluetooth interface. When GPS-Tag signal is received, the location information and message information from GPS-Tag Frame is retrieved and delivered to GPS-Tag application by NMEA data format.

The service provider's control platform which is connected to GPS-Tag transmitter through serial interface controls GPS-Tag transmitter and allows service provider to easily change the configuration of transmission scheme and service message of GPS-Tag system.

The number of slot consisting GPS-Tag frame can be from one to maximum four by the service provider's setting and each slot can be configured to work as a message slot or a link slot. Message slot means that current slot contains pure character-based message and expresses eight characters of two byte code. This short keyword message can be combined and served with the predefined useful sentences for advertising or marketing in codebook to achieve higher message representation capability. Icon representation with message is also supported on the basis of predefined icon table method.

Link slot means that slot information is a shorten type URL link for the additional information service. Supplemental service information like floor map, product brochure and so on can be provided from the information server or associative homepage can be accessed directly using the link. The control software for GPS-Tag transmitter is depicted on figure 4.

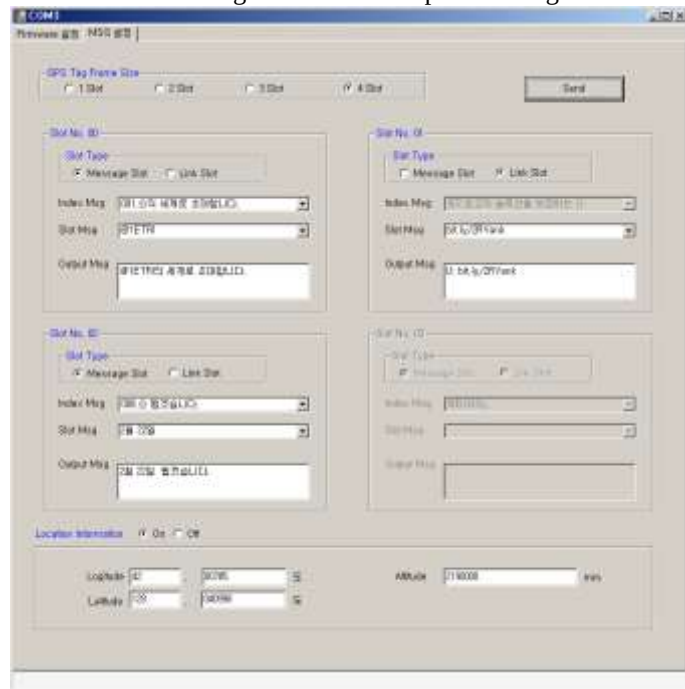


Figure 4. Control software for GPS-Tag transmitter

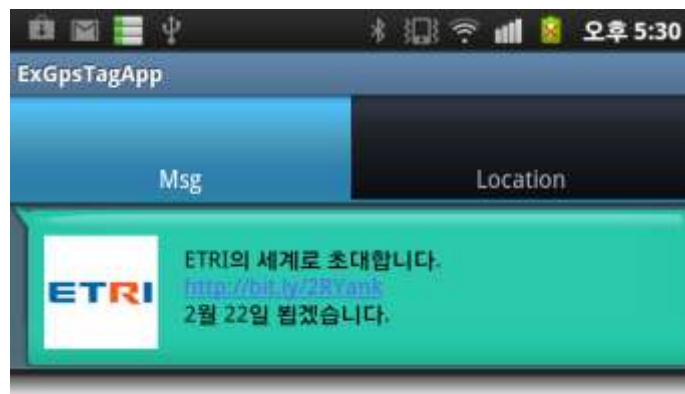


Figure 5. Example of the associative message service



Figure 6. Example of Location Information Service

Slot information can be served independently or served as one associative message which consists of multiple slot information. Figure 5 shows example of associative message service which combines three slot messages to one service message.

Location information of GPS-Tag which is usually assumed to be installation position of GPS-Tag transmitter also can be configured through control software. If location information is configured to serve then last slot of GPS-Tag frame will be set to hold the location information. By this configuration, GPS-Tag application on smartphone can easily retrieve the location information for the GPS-Tag frame and provide the location information with other application program. Figure 6 is the example of the location information service of GPS tag system.

IV. CONCLUSIONS

This paper delivers the design scheme and implementation result of our GPS-Tag system to provide location information indoors and to enhance messaging functionality. By achieving higher transmission rate than any other PL applications and supporting various types of message based on slot based delivery method, we could make our GPS-Tag system more feasible to indoor information service.

We prototyped our GPS system and developed control platform to configure the GPS transmitter. We also designed and tested various types of information service so that we concluded our GPS system is suitable for indoor location and information service.

Constant research, service upgrade and field experiments for GPS-Tag service will be followed and additional research to solve problems like near-far problem which is one of serious obstacles when deploying PL type application indoors is wished to be conducted later.

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