

A General Framework Protocol for Indoor and Outdoor Location-Based Service

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Abstract. To satisfy the requirement of the increasing location-based service, there have been a lot of solutions on indoor and outdoor locating. The general data protocols for transferring outdoor location data are also mature. However, there still lack general data format and transferring protocol for indoor or hybrid indoor-outdoor location. In this paper, a general framework protocol for indoor and outdoor positioning, which includes locating data format and the transfer frame format, is proposed. The data tables and frame format of the protocol are presented and examples on how to use them are given. It is a protocol aimed to be used by different mobile devices sending locating data to the locating server. The design idea of this protocol is to use various positioning methods available at present, and different kinds of data should be combined easily according to different environment identified by the mobile device.

Introduction

With Location-based Service (LBS) fast becoming one of the standard features in mobile devices, an increasing number of studies concentrate on personal navigation for both outdoor and indoor environments [5-7]. With the aid of the Global Navigation Satellites Systems (GNSSs), e.g., GPS and BeiDou, mobile devices greatly facilitate the end users' outdoor activities. However, GNSS-based positioning technologies are not primarily suited for use in urban canyons or indoors due to the nature of GNSS design. They are continuing to struggle indoors, because of well-known problems such as the weak signal or non line-of-sight (NLOS) conditions between mobile users and satellites [1]. To address positioning and navigation in GNSS-degraded denied areas, various technologies are broadly researched, e.g., [2]. Various positioning technologies for indoor environments are proposed, including radio frequency identification (RFID), infrared, Bluetooth, Zigbee, Ultra-wide Bandwidth (UWB) and Wi-Fi [3]. The multi-network positioning system proposed in [4] improves the availability and reliability of navigation and positioning. Windows Phone, Apple iPhone and Google's Location Based Service (LBS)-enabled Android operating systems have allowed developers to introduce LBS to millions of smart device consumers. Many LBSs perform location functions by means of location data or positioning correlated parameters transfer between the smart device and the location server, e.g., gpsOne location system and Google network location system. These systems have their own location request and response data format, data field definition and transfer protocols [8]. Emerging indoor location technologies such as sensors aided positioning and RFID location make more and versatile location applications possible.

Although many indoor location technologies have standards, there are still few transfer protocols in support of location computations. Different indoor location systems often have their own private protocols for location applications, which are incompatible with each other. To the best of the authors' knowledge, a unified transfer protocol for various indoor location applications is still lacking. Considering the future possibilities and increasing requirements for various hybrid location applications, there is an urgent need for a widely applied protocol on transferring all the locating correlated data and parameters using a general and common format.

In this paper, a solution on the general locating protocol is introduced, which aims at adapting for all kinds of devices and combining different ways of positioning data and parameters. The rest of the paper is structured as follows. The architecture of 4 location data tables are introduced in Section II. The proposed frame format of the protocol is presented in Section III. In Section IV, two

examples on how the protocol transfers data and identifies environment are given. Finally, some problems about this work are discussed in the last Section.

Data Format of General Locating Protocol

The design of location data structure and tables references the RTCM STANDARD 10403.1 for DIFFERENTIAL GNSS SERVICES – VERSION 3 [9].

A. Basic Message Types

First, the Basic Message Types supporting different indoor and outdoor location service are defined as is shown in Table I. There is no coupling between any of the two message types. Every Basic Message only contains the minimum data for a particular positioning pattern but can be combined with each other for various purposes. To avoid confliction with RTCM, the message type is numbered from 200100. There's a gap of 100 between adjacent numbers to allow to use a specific message type repeatedly but fulfilled with different data.

B. Basic Message Tables

Then, each basic message type is defined in a separate table called Basic Message table, which defines the specific content of a Basic Message Type. Every message consists of four fields, in which DATA FIELD contains the parameters or data used for positioning. Each item in DATA FIELD is indexed by a DF NUMBER, and the data type and the length of each item are shown in Data TYPE and NO. OF BITS, respectively. Each basic message is designed to include the minimum data fields for a particular locating method and can be combined in different forms according to different hybrid location techniques. Take outdoor location and indoor location message as examples.

Two messages are defined for GNSS locating data. One of the messages contains four kinds of GNSS data in a unified form, and the other is only for BNSS location data. Table II shows the contents of outdoor GNSS message 200100. We use four indicators for each GNSS respectively with the location data filling in the same data field named Antenna Reference Point ECEF-X, Y, Z, which have been used to represent location in RTCM 10403.1 STANDARD. Thus, this message type could be used repeatedly for different GNSS.

TABLE I. BASIC MESSAGE TYPE

Message Type	Message Name	No. of Bits	Note
200100	Outdoor GPS/GLONASS/Galileo/BNSS /Multi-Satellite-System Locating	176	Integrated 4 GNSS data in one form that could provide GNSS independently or use this type repeatedly to combine them locating result.
200200	Outdoor BNSS Only	124	Provide BNSS locating data.
200300	Outdoor-Indoor transfer operating data	60	This type is used to judge the environment of the location and the device hardware.
200400	Wi-Fi RSSI	81	Content of a specific Wi-Fi AP's Mac and RSSI.
200500	FM Multi-Data Locating	65	Include RSSI, SNR, MULPATH, and FRQOFFEST for locating.
200600	Bluetooth RSSI	80	Content of a specific Bluetooth AP's Mac and RSSI
200700	NFC Tag Fixed Point Locating	97	Use to transfer the message from NFC Tags.
200800	ZigBee Locating Data	66	Base on CS20XX positioning method
200900	UWB TDOA Locating	88	Only provide time information for TDOA positioning method. Could use with type 200100 AOA data together for 2-way locating.
200100	UWB AOA Locating	84	Only provide time information for AOA positioning method.

TABLE II.

TABLE III. CONTENTS OF TYPE 200100: OUTDOOR GPS/GLONASS/GALILEO/BNSS

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number	DF901	uint24	24
Reference Station ID	DF002	uint12	12
Reserved for ITRF Realization Year	DF003	uint6	6
GPS Indicator	DF004	bit(1)	1
GLONASS Indicator	DF005	bit(1)	1
Galileo Indicator	DF006	bit(1)	1
BNSS Indicator	DF011	bit(1)	1
Antenna Reference Point ECEF-X	DF007	int38	38
Antenna Reference Point ECEF-Y	DF008	int38	38
Antenna Reference Point ECEF-Z	DF009	int38	38
Antenna Height	DF010	uint16	16
<i>TOTAL</i>			176

For indoor locating messages, each message only contains the necessary data fields for one specific locating method. Take Wi-Fi locating message 200400 as an example. The Wi-Fi locating method needs MAC and RSSI. So TABLE III includes three data field: Message Number, Wi-Fi MAC and Wi-Fi RSSI. In most case, we need to send more than one AP's information to perform the positioning algorithm required. By increasing Message Number automatically we can transfer different data in the form of the same type. For instance, we need 3 or 5 Wi-Fi APs to get enough data and match the fingerprint so we need to use this message type repeatedly with different Message Number. Now we code the Message Number as 200400, 200401, 200402... 200404 and send 5 different AP data in one form of message type in the frame. The 2004 stand for the Message Type. 00, 01...04 represent various data.

TABLE IV. CONTENTS OF TYPE 200400 MESSAGE

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Message Number	DF901	uint24	24
Wi-Fi MAC	DF201	bit(48)	48
Wi-Fi RSSI	DF202	bit(9)	9
<i>TOTAL</i>			81

C. Data Fields Tables

The DF NUMBER in Basic Message Type and Basic Message Tables is defined in the Data Fields Tables, which contain essential data for 10 methods of locating. 4 GNSS data are GPS, GLONASS, Galileo and BNSS. 6 indoor locating data using APs are Wi-Fi, Bluetooth, FM, Zigbee, UWB and NFC. We give part of the table in TABLE IV, in which there are two data fields named DF201 and DF202 respectively, standing for Wi-Fi Mac and Wi-Fi RSSI respectively. These two data fields are widely used in Wi-Fi positioning.

Also, we define other data fields we needed for the transferring frame structure in the Data Fields Tables.

TABLE V. INSTANCE OF DATA FIELDS TABLE

DF#	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF201	Wi-Fi MAC	0~ 2 ⁴⁸		bit(48)	Identifier for a particular network adapter
DF202	Wi-Fi RSSI	0~ 100		bit(9)	Received Signal Strength Indicator.

D. Data Type Tables

Finally, Data Type Tables include all the data type that are used in the Data Fields Tables and define the form and range of these data. TABLE V shows part of a Data Type Table.

TABLE VI. DATA TYPE TABLE

Data Type	Description	Range	Data Type Notes
bit(n)	bit field	0 or 1, each bit	Reserved bits set to "0"
char8(n)	8 bit characters, ISO 8859-1 (not limited to ASCII)	character set	Reserved or unused characters: [0x00]
int14	14 bit 2's complement integer	-8192 to +8191	
int16	16 bit 2's complement integer	± 32,767	-32,768 indicates data not available

In all, four kinds of tables are defined. They are Basic Message Type, Basic Message, Data Type and Data Fields. The final result of the 4 kinds of tables is basic messages that we will use them independently or combine them for diverse pattern of positioning.

Frame Format of General Locating Protocol

Considering that this protocol is mainly design for mobile devices sending data to server for locating, we define the General Frame Format as Fig. 1.

General Frame Format includes a series fields and be presented in fixed order. The first field is Frame Control and the last field is Frame Check Sequence (FCS). For different needs, Communicating Environment Field and Message Body only appears in particular frame.

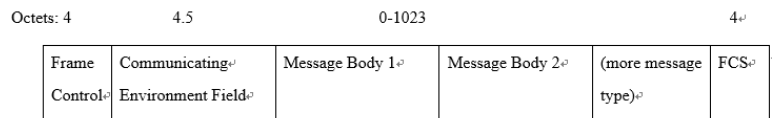


Figure 1. General frame format.

E. Frame Control Field

As the first field of general frame, this field contains necessary information which includes Protocol Version, Timestamp, Communication Mode, Number of Message and Power Management. All these data fields have been defined in the Data Fields Tables. Value of Communication Mode field determines whether general frame have locating data or not. The value 0 means that this frame is in identifying mode and no locating data is sent. On the other hands, if the value is 1, the frame will include locating data rather than identify environment. Fig. 2 shows Frame Control structure.

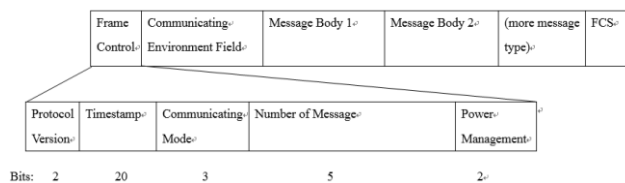


Figure 2. Illustration of the frame control field.

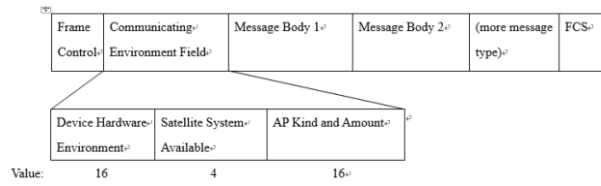


Figure 3. Environment identifying frame.

F. Communicating Environment Field

As is shown in Fig. 3, Communication Environment field includes data of mobile device's hardware condition and the indoor or outdoor environment. We will give example later to describe how it works.

Examples and Explanations

Here we will give two examples to show how the frame identify environment and transfer locating data.

G. Identify Environment Frame

Fig. 4 shows an Environment Identifying Frame. This frame is only for give some data to server for identify hardware condition and environment so this frame contains the Communicating Environment Field but have no message. The specific examples are presented blow.

Fig. 5 is an example of Frame Control. Now the protocol version is 00. Timestamp shows the time is 17:55:24.98 (hhmmssss). Communicating Mode value 0 means this frame aiming for identify rather than transfer data. Power Management is normal.

Fig. 6 is an example of Communicating Environment Field. This field contains 3 data fields: Device Hardware Environment, Satellite System Available, and AP Kind and Amount.

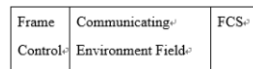


Figure 4. Example of frame control.

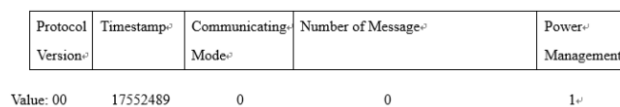


Figure 5. Example of communicating environment field



Fig. 6 example of Communicating Environment Field

• Device Hardware Environment

The Device Hardware Environment is defined as a 16-bit value show how much hardware in this device could be used and what the type of this device. As is shown in Fig. 7, every bit of Device Hardware Environment represents a kind of hardware. If the hardware can be used in a specific device, the corresponding bit will be set 1. If a device does not have this kind of hardware, the bit will be set 0. The last 2 bits stands for Device Identifier which shows the device type.

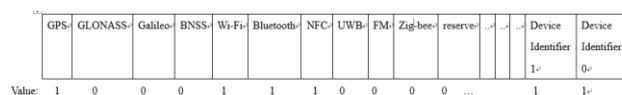


Fig7. Device hardware environment.

In the example shown in Fig. 8, we know the device has GPS, Wi-Fi, Bluetooth and NFC hardware. This device is identified as consumer electronic like common smart phone.

Device Identifier ^o	00 ^o	01 ^o	11 ^o
^o	professional devices ^o industry devices ^o	sports devices ^o ^o	Consumer Electronics ^o

Fig8.Device identifier.

- Satellite System Available Indicator

Satellite System Available is defined as a 4-bit value, with every bit representing whether a GNSS is available or not. If the GNSS could receive 4 or more satellites then we assume that this GNSS is available and the bit will set 1. Fig. 9 shows that none of the 4 GNSS could receive 4 or more signals from satellites so they are not available in this situation.

GPS ^o	GLONASS ^o	Galileo ^o	BNSS ^o
Value: 0	0	0	0 ^o

Fig9. Satellite system available indicator.

- AP Kind and Amount

AP Kind and Amount define as 16-bit value as is shown in Fig. 10. Every 4-bit stands for the amount of APs that could be sensed by the mobile device. Considering that 5 APs data which can be used in locating is reasonable, the maximum number is set to 15. If the amount is more than 15 the value still be set to 1111. Fig. 10 shows that this device can receive 15 or more Wi-Fi APs. No Bluetooth, UWB and FM (as Fig.7 shows, this device not have FM hardware) APs are found.

To sum up all the information above, we know that this is a kind of consumer electronics like smart phones and it contains the basic hardware of a smart phone like Wi-Fi, GPS, Bluetooth and NFC. This device now cannot receive signals from GNSS but could get 7 or more signals from Wi-Fi APs by which the server could judge that this device maybe in a building. Also the server gets the protocol version, the time when the frame is sent and the power state in this frame.

When we need to use seamless navigation system, we can refresh the data field of Satellite System Available and AP Kind and Amount and resend the identifying frame in some frequency to know whether the device is indoor or outdoor.

Wi-Fi ^o	Bluetooth ^o	UWB ^o	FM ^o
Value: 1111	0000	0000	0000 ^o

Fig10. AP kind and amount.

H. Transfer Frame

Fig. 11 shows a transfer frame with 5 messages in one frame. This frame does not contain Communicating Environment Field but can include it if needed. These messages are of the same type 2004 that is designed to transfer Wi-Fi information but they contain 5 different Wi-Fi AP data.

Fig. 12 shows a frame control example which gives the information like Protocol Version, Timestamp and Power Management, but Communicating Mode is set to 1 meaning that this frame will transfer messages and the frame contain 5 messages. So the Number of Message is 5.

Frame	Message Body 1 ^o	Message Body 2 ^o	Message Body 3 ^o	Message Body 4 ^o	Message Body 5 ^o	FCS ^o
Control ^o	(200400) ^o	(200401) ^o	(200402) ^o	(200403) ^o	(200405) ^o	

Fig11.Example of a transfer frame.

Protocol Version ^o	Timestamp ^o	Communicating ^o Mode ^o	Number of Message ^o	Power ^o Management ^o
Value: 00	17552536	1	5	1 ^o

Fig12.Example of a frame control.

Future Work

This protocol does not contain all the possible methods for indoor and outdoor locating. Also, it does not include all the data that have been used in aforementioned locating method. It is just a framework protocol for sending locating data from the mobile device to the server. It has to be made more completed. Still, the data and frame format for sending calculated location data from the server back to the device are not defined and need to be defined in the future work.

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