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Research on Location Technology in Building Fire Rescue

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Abstract

Based on the study of the security risks in fire rescue of buildings and the application of location technology in building fire rescue, a more reliable location service system in building fire rescue is given. The system makes use of long waveform, which has higher penetration factor and longer distant transmit ability, to transmit the signal. IEEE standard is supported in the system's wireless network. The Fire Command Center or headquarter can view all the firemen's location in the design drawings of the building through a Monitoring Terminal. To be convenient to view the current status of the fire rescue, Monitoring Terminal can be a pad or mobile device. It validly ensures the quick and reasonable response for the fireman in a predicament, and put out the fire efficiently. However, to be more reliable, the system should pre-installed lots of Positioning-Assistant Device, which costs a great deal in both finance and time.

Keywords: Location Technology, Building, Fire Rescue, Wireless Network;

1. Introduction

With the development of the economy, a growing number of large-scale buildings with sundry structures are emerging in the cities in China. And the more complex building architecture brings the higher security

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risks in fire rescue. The unknown fire rescue environment and intricacy of the building put of paramount danger for the firemen. As the fire command center (FCC) or headquarter can't exactly get the location of the fireman who stuck in the fire and the distribution of the nearby firemen, it is embarrassing that FCC can't do the quick rescue response to the SOS-needed fireman. If there were some practical method to know the real-time location of all the firemen, combination with the design drawings of the building, the FCC or headquarter could do the reaction to any fireman in a short time and quickly redeploy the firemen reasonable to put out the fire efficiently. In a word, location technology plays an important role in fire rescue, especially in a complex fire fighting rescue environment.

Global navigation satellite systems (GPS or GNSS) are the most widely applied technology in location service. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) within a few meters using time signals transmitted along a line-of-sight by radio from satellites. Trilateration is exploited to calculate the precise position of the devices. However, since microwaves will be attenuated and scattered by roofs, walls and other objects, GPS (GNSS) are generally not suitable to establish indoor locations.

Besides, A-GPS, which uses data available from a network, depends too much on the mobile stations. To magnify the signals of mobile devices, micro mobile stations are set in large-scale buildings. However, once fire emergency happened, the power supply of the building would be closed, and the unemployed micro mobile stations would result in the fragmentary signals inside the buildings. Thus, A-GPS is also not suitable for location service in fire rescue.

Currently, many other wireless technologies are also used in indoor positioning services, such as ZigBee, Wifi. And almost all of them use high frequent waveforms with a lower penetration factor. Thus, a great number of hotspot should be installed inside and outside the building to insure the correct positioning. It costs a lot and the positioning service would not work once the hotspots are destroyed or stopped in the fire.

Some research on utility of location technology in building fire rescue has done. [1] set up a fire ground positioning rescue system based on Ituran in Shanghai. As Shanghai is the only city equipped with Ituran positioning system, it is not able to promote in China. A location technology system of fire area was discussed based on ZigBee network and UWB in [2]. However, it's not stable when fire happened because of the short transmitted wareforms, and lots of ZigBee hotspot should be placed. [3] discussed the possible application of wireless sensor network in fire rescue, and GPS was used in the architecture.

This paper presents an indoor positioning solution for building fire secure, where long waveform is used to transfer the signal, Trilateration is used to calculate the location. It has excellent penetration factor and long distant transmit ability, which ensures the location services in building fire rescue.

2. Architecture

Based on the study of the issues on location service in fire rescue, the architecture of a fire rescue location system is designed. As showed in Fig 1, the system mainly consists of five modules: mobile positioning device, positioning-assistant terminal, wireless data gateway, data center, and monitoring terminal.

A wireless network, called Positioning-Assistant Terminal Network, is setup automatically during the Positioning-Assistant Terminals. It's the transmission medium for the Mobile Positioning Device. Mobile Positioning Device sends its raw location information to the Wireless Data Gateway through the set-up Positioning-Assistant Terminal Network. Wireless Data Gateway receives the original data and converts it to accurate location. The location data is sent to and stored in Data Center. Data Center stores the data in a database, and provides accessing interface for Monitoring Terminals. Monitoring Terminal gets the locations from the Data Center, draws the each Mobile Positioning Device on the design drawings and shows in graphic

views for the headquarters. Besides traditional computer server, Monitoring Terminal supports Mobile Devices, such as pad and mobile.
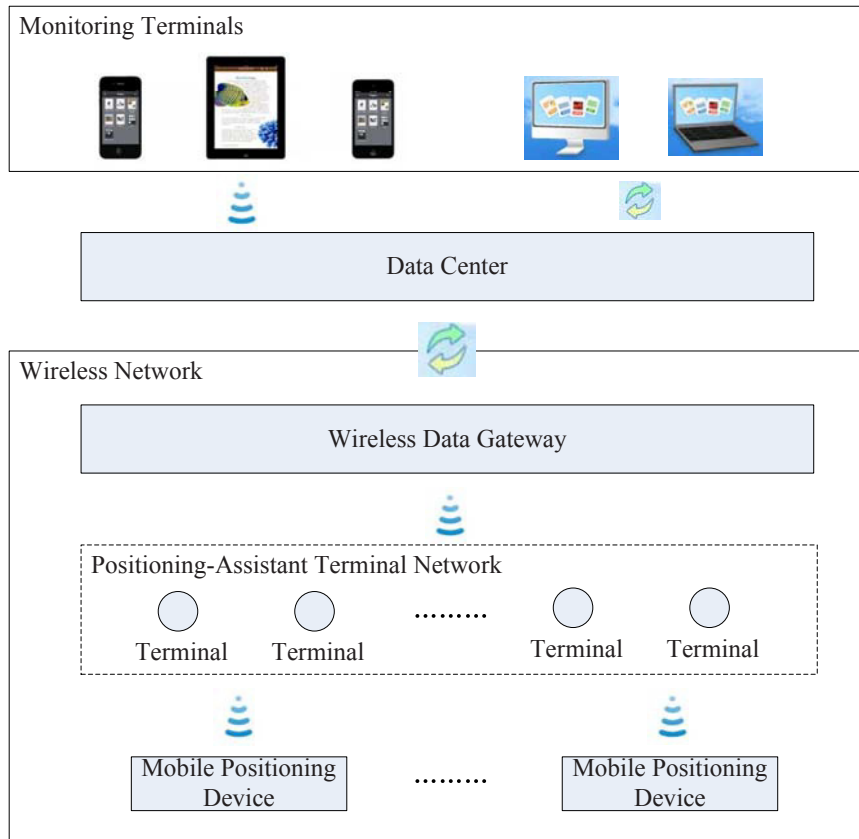

Fig. 1. Architecture of the System

2.1. Mobile Positioning Device

Mobile Positioning Device can be treated as a location sensor in the system. It radiates its timestamp to the approachable Positioning-Assistant Terminals in a short cycle. The Positioning-Assistant Terminals receive the data, and sends it with its own timestamp and location to the Wireless Data Gateway. Usually, Mobile Positioning Device is encapsulated in a small box and carried by the fireman. And the system locates the fireman's location by calculates the longitude and latitude of the Mobile Positioning Device.

2.2. Positioning-Assistant Terminal

Positioning-Assistant Terminal is a key facility in the system. They are pre-installed according to the building. In order to ensure a reliable location service, Positioning-Assistant Terminals are expected to be placed outside the building and around every floor to avoid being destroyed or unemployed in the fire. It's

battery-supported. When it receives the timestamp from the Mobile Positioning Device, it attaches the receiving timestamp and its location information to the raw data, sends to the Wireless Data Gateway.

2.3. Wireless Data Gateway

Wireless Data Gateway collects the raw data from Positioning-Assistant Terminals. It analysis the data, calculates the location of the Mobile Positioning Device and sends the result to the Data Center. To calculate the detail location of the Mobile Positioning Device, DTOA[4] (Different Time of Arrival) is used and Trilateration is applied. And each time when the Wireless Data Gateway receives packets through four or more than four Positioning-Assistant Terminals from the same Mobile Positioning Device with the same sent timestamp, the location of the Mobile Positioning Device is worked out, and stores to the Data Center. To avouch the location service, each Mobile Positioning Device should approach to at least four Positioning-Assistant Terminals.

2.4. Data Center

Data Center receives the location data from Wireless Data Gateway through a wired cable. It uses relevant database and supports Oracle, SQL Server and DB2. Data Center provides web services interfaces to the Monitoring Terminals. In order to be compatible with varied of Monitoring Terminals, Data Center provides specific interfaces in web service. Standard three-layer architecture is exploited to develop the web service.

2.5. Monitoring Terminal

Monitoring Terminal displays the structure of the building in the fire, and shows the location of all the firemen in the structure drawings. It helps the FCC or headquarter scheme out the rescue actions. Taking advantage of the location technology, graphic technology, database technology, and software application technology, Monitoring Terminal provides real-time positioning service, emergency alarm service, and history moving trace service.

2.5.1. Real-time Positioning Service
Monitoring Terminal pulls the real-time location data of all the firemen in the monitoring area from the Data Center, and draws the location on the building design drawings. When a firemen moves, the corresponding point changes in the Monitoring Terminal.

2.5.2. Emergency Alarm Service
When fireman encounters emergency, a SOS signal, which would finally receive by the Wireless Data Gateway, is sent out through the Mobile Positioning Device. Once the Data Center gets an alarm packet, it pushes the alarm to all the connected Monitoring Terminals. The FCC or headquarter can be aware of the emergency, and do the prompt response. Also, if a Mobile Positioning Device stay steady for some setting time, an alarm would still be triggered.

2.5.3. History Moving Trace Service
As all the location information is stored in the database, the history moving trace of each Mobile Positioning Device can be replayed. And the status of all the firemen of any history time can recur.

3. Deployment

Fig. 2. Typical Deployment of the System

Positioning-Assistant Terminals are installed around the building. Often, they are set up outdoor, such as fire truck. When the fireman enters the fire rescue area, a Mobile Positioning Device is carried to help locates his location. The Positioning-Assistant Terminals will setup a Wireless Positioning-Assistant Network automatically. And the raw location information of the fireman (with Mobile Positioning Device) will be sent to the Data Gateway which installing in the fire truck through Wireless Positioning-Assistant Network. The Data Gateway processes the raw data and stores the real location information in the Data Center through a cable. FCC or headquarter can monitor all the firemen's location in graph through Monitoring Terminal. Monitoring Terminal can connect to Data Center through cable or wireless network. Recommend, a Monitoring Terminal and Data Center are deployed in a same computer server. Mobile Monitoring Terminals connects to the Data Center through existed wireless network, such as WIFI and 3G network. A typical deployment of the system sees in Fig 2.

The system helps to locate the fireman. It reduces the risks of the fireman in a fire rescue activity. Once a fireman became bogged down, headquarter can quickly do the rescue with the help of the location service provided by the system.

4. Conclusion

With the increasing scale of the buildings and the more complicated of their structure, more security risks have been imposed on the firemen. Once fireman was in a predicament, the traditional fire rescue system couldn't get where the fireman he was, it's impossible to provide assistance. On this point, it's senseful to introduce location technology to the fire rescue system. It provides all the firemen's location details, and helps the FCC or headquarters to scheme the fire rescue.

Based on the study of the current location technology and its application in building fire rescue, this paper presents a reliable location scenario. It mainly contains five parts: mobile positioning device, positioning-assistant terminal, wireless data gateway, data center, and monitoring terminal. Mobile Positioning Device, Positioning-Assistant Terminal and Wireless Data Gateway compose of a wireless network, which uses short waveforms to transmit the signal, exploits IEEE standard to transfer the data. Data Center and Monitoring Terminal can be installed in a same computer server.

As the system uses the short waveforms, it has high penetration factor and long distant transmit ability, and ensures the location services in building fire rescue. However, to make the location more reliable, more Positioning-Assistant Terminal should be pre-installed, which makes the project costs a lot more both in finance and time.

Acknowledgement

References

[1] Hou Zhonghui, The Fire Ground Positioning Rescue System Construction based on Wireless Measurement and Control Network. Computer Security, 2010; 09:67-9.
[2] Zhang Yuanxiang, Ning Yu, The Application of Space Location Technology in Fire Fighting Rescue. Fire Science and Technology, 2009; 28:62-6.
[3] Kewei Sha，Weisong Shi，Orlando Watkins, Using Wireless Sensor Networks for Fire Rescue Applications: Requirements and Challenges. 2006 IEEE International Conference on Electro/information Technology, 2006; 239-244.
[4] Yu Lina，Zeng Liansun，Jin Zhihua, Research of Wireless Location Algorithm and Accuracy Analysis Based on DTOA. Computer Measurement & Control, 2006; 14:1247-9.