CARRIER-CLASS ORIENTED HIGH PRECISION INDOOR LOCATION STANDARDS, SYSTEMS AND TECHNOLOGY

运营商级高精度室内定位标准、系统与技术（英文版）

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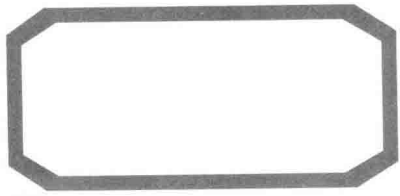

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前言 / Foreword

Location information is playing a more and more important role in people's life. There are many application scenarios depending on positioning in the future 5G communications, such as Virtual Reality (VR), Internet of Things (IoT), Internet of Vehicles (IoV) and so forth. Especially, indoor positioning has attracted more attentions because of its huge business potential while there are no mature and versatile solutions. This white paper aims to identify the requirements of indoor positioning in the future work, present the potential network architecture and key technologies that can fulfill the requirements, and research the localization network programming and deployment.

By now, there have been various positioning technologies corresponding to different requirements and scenarios. Generally,

indoor positioning faces the challenges of location accuracy, cost, coverage range, latency and the complexity of indoor environments resulting from multipath propagation and frequent environment changes. A brief summary of the main challenges and solutions is given below.

Localization network architecture design

- A universal positioning architecture includes two parts of information extraction and position calculation.
- The integration of multiple positioning functionalities seems inevitable and requires the convergence of positioning standards that ensure multi-stand and multi-vendor interoperability.

Signal measurement method

- Wireless positioning systems estimate the location by mapping the signal features to the space location.
- These approaches need to extract the wireless signal features, such as RSS, TOA, TDOA, and AOA.

Localization algorithm

- In wireless positioning system, the location estimation method is the core component which aims to mapping the signal metrics (RSS/TOA/TDOA/AOA) into 2D/3D location.
- The typical wireless positioning techniques include trilateration, triangulation, fingerprinting (also known as scene analysis), and proximity.

Synchronization technologies

- Synchronization technology is one of the key research areas/technologies for high accuracy positioning systems. Approximately every 3ns of synchronization precision decreasing leads to 1 meter distance-measuring error.
- Some candidate techniques are considered on the whole in order to control the end-to-end time error in synchronization networks include enhanced GNSS technique, enhanced reference time source, enhanced auxiliary frequency technique, enhanced PTP technique, etc.

Channel modeling

- The implementation of the channel simulation is helpful in decreasing the amounts of manpower, material and the cost of time. Besides, it is important to realize the high-precision positioning and the elements layout.
- A representative technology in certain models is the ray tracing technique, which is based on the geometrical optics theory.

Tracking and map matching

- The continuous and dynamic location estimation (or tracking) is essential, and is modeled to be a state sequence estimation. The system can adopt the Bayesian estimation method to analyze and optimize the estimation problems.
- The positioning system usually has the map information to display the location content. The map typically includes the roads, structures, facilities and various landmarks, which can be used to constrain the target's movement or correct the estimation error.

Intelligent hybrid localization

- The new-generation indoor localization technology combined with multiple locating information sources including the pressure sensor, direction sensor and optical image sensor etc., has become the focus of further research.

Prediction of localization technologies in future 5G communications

- With the emergence of D2D communication, each mobile device can make additional short-distance range measurements with respect to its nearby devices, and cooperates with those neighbors for positional inference.
- With the development of full duplex technology and combination of round-trip time technology, the distances between the nodes in wireless networks can be obtained in a much more efficient manner. All inter-node distances and clock offsets can be obtained through only two frames of communications, i.e., request and response frame.
- Since a 2-D (planar array) or 3-D (conformal array) massive MIMO array can be divided into several subarrays providing spatial cooperation in localization,

a single massive MIMO system can realize the localization task.

Finally, this book provides some solutions about the positioning equipment research and deployment, and the network programing. Additionally, some test and validation cases are presented for reference.

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Chapter 1

Introduction

Positioning is to determine the geographical location of an object in certain coordinate system.

The rapid development of the localization technologies is enhanced by the emergence and popularization of the Global Positioning System (GPS), which was used in military at first. In 2000，America cancelled the interference to the civilian channel of GPS, and the average accuracy of GPS can come to 6.2m for civilian uses. As a result, the GPS industry and application has set off an upsurge.

The localization technologies based on the wireless network originated from the E-911 Terms of Service (ToS) proposed by Federal Communications Commission (FCC) early in 1990s,

aiming to provide the accurate and reliable localization information. E-911 promoted the development of localization technologies for the mobile terminals based on the wireless communication network, making the applications of localization technologies extend to all aspects of people's lives.

With the continuous improvement of intelligent life needs, users' business requirements need the hybrids of different wireless network to offer high quality services. Specially, Location Based Service (LBS) means to get the location information through satellite communication, wireless cellular communication or Wireless Local Area Network (WLAN) to provide location based personalized services.

The wireless localization technologies in outdoor scenarios refers to GPS, assisted-GPS (AGPS), and the localization systems based on the cellular networks, such as cell-ID, Enhanced Cell-ID (E-CID). Since GPS signals are heavily attenuated and reflected by building structures, the system does not provide sufficient availability or accuracy localization in indoor environments. Recently, scholars and research institutes at home and abroad use wireless network including WLAN, Radio Frequency Identification (RFID), Ultra-Wide Band (UWB) and Bluetooth, etc, to satisfy the performance requirements of indoor LBS, with the positioning accuracy of meters. Using the UWB can achieve the accuracy of centimeters. The expansion of LBS markets and the wireless

localization technologies are independent and mutually promotive. The performance improvement of wireless localization technologies can promote the improvement of LBS service quality, while the expansion of LBS applications can further increase the depth and breadth of researches on the wireless localization technologies.

This book aims at identifying requirements and objectives of the positioning systems, providing the potential solutions to fulfill the requirements. The book discusses the network architecture and key technologies, prospects the future positioning technologies in 5G, and finally gives the advices of localization network programming and deployment.

Chapter 2

Current Status, Challenges and Requirements

2.1 Current Status of Indoor Positioning

2.1.1 Standard Evolution

3GPP Service and System Aspects (SA) working group has focused on the LBS standardization for a long while, referring to wireless positioning methods, LBS service standards and the LBS architecture. The group mainly concentrates to provide the LBS applications and developments through cellular networks, which

cover logistics management, navigation, traveling, hotspot search and commercial advertisement pushing, etc. 3GPP Radio Access Network (RAN) working group gave the standards of the network architecture, new network units for positioning, positioning process and positioning methods in cellular networks. The positioning technologies include Cell-ID, enhanced Cell-ID, Time Difference of Arrival (TDOA)[1], network associated GPS, etc.

The basic positioning method "Cell-ID (CID)" was proposed in Release 8[2], which utilized the cellular network knowledge serving for users. In Release 9 [3], Observed Time Difference of Arrival (OTDOA), using the reference signal time difference measurements conducted on downlink Positioning Reference Signals (PRS) received from multiple base stations, was defined with the accuracy of 50~100m. Uplink TDOA (UTDOA), an alternative method to OTDOA, was standardized in Release 11 [4]. From Release 12[5], the positioning accuracy was considered to satisfy the FCC demands (67% of accuracy is less than 50m, i.e. <50m@67%). The indoor positioning, which used WiFi, Bluetooth, barometer and TBS, was proposed in Release 13[6], and their positioning accuracy demand in altitude is less than 3m. In Release 14, enhanced positioning methods with higher accuracy (<3m@80%) and less time delay (initialization time is less than 10s and subsequent positioning response time is 10 ~15ms) will be studied and discussed in 5G networks. The evolution of positioning