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Re:	IEEE 802.16m-07/040, “Call for Contributions on Project 802.16m System Description Document (SDD)”
Abstract	This contribution proposes a section/sub-section to describe hybrid location estimation and tracking system in the Table of Contents (ToC) of IEEE 802.16m SDD to provide better accuracy of location estimation for mobile devices than current IEEE 802.16 system.
Purpose	Propose to have a section/subsection “Mobile Station Location Estimation and Tracking” in TGm SDD ToC.
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Location Estimation and Tracking System for Mobile Devices in Project 802.16m SDD

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I. Introduction

Wireless location technologies have drawn a significant amount of attention over the past few decades. Different types of location-based services (LBSs) have been proposed and studied, including the emergency 911 (E-911) subscriber safety services [1], the location-based billing, the navigation system, and applications for the intelligent transportation system. Due to the emergent interests in LBSs, it is required to provide enhanced precision in the location estimation of mobile device under different environments. A variety of wireless location techniques have been studied and investigated [2] [3] [4]. These techniques can be classified into the network-based and the satellite-based location schemes. The representative algorithms for the network-based location techniques are the time difference-of-arrival (TDOA) and the angel-of-arrival (AOA). The TDOA scheme measures the time difference of signals coming from different wireless base stations; while the AOA technique observes the arriving angle of signal from the mobile device. The well-adapted technology for the satellite-based location method is the global positioning system (GPS). It measures the time-of-arrival (TOA) of the signals coming from different satellites. It has been studied in several researches [5] [6] that the performance of the location techniques listed above varies under different environments. Due to weak incoming signals or shortage of signal sources (e.g. at rural area), the network-based (i.e. TDOA, AOA) methods result in degraded performance for the location determination of mobile devices [7] [8]. On the other hand, the major problem for the satellite-based (i.e. GPS) method is that the performance considerably degrades while the satellite signals are severely blocked (e.g. at urban valley area).

In order to achieve better accuracy for location estimation, a hybrid approach should be considered to satisfy the requirements under different environments (i.e. urban, suburban, and rural areas). In this contribution, a hybrid location estimation and tracking system is proposed for the mobile stations (MSs). The proposed location scheme determines the MS's location by combining the outcomes from both the network-based and the satellite-based techniques. In addition to the longitude (x) and latitude (y) of the MS can be estimated, the altitude (z) information of the MS is also obtainable from the proposed system. The performance of the proposed hybrid location scheme is evaluated via simulations under different environments.

The rest of this contribution is organized as follows. The ensuing section describes the system architecture. In Section III, we provide some numerical simulation results for comparison. Then, some concluding remarks are given in Section IV. Finally, proposed sections/subsections in the table of content (ToC) for IEEE 802.16m SDD are described in the last section.

II. System Architecture

The hybrid location estimation scheme proposed in this contribution can be applied to either MS-based or MS-assisted system. The choice between these two types of systems depends on the requirement of the communication bandwidth and the computation power of the MS. The following two subsections describe the proposed system architectures based on these two types of system:

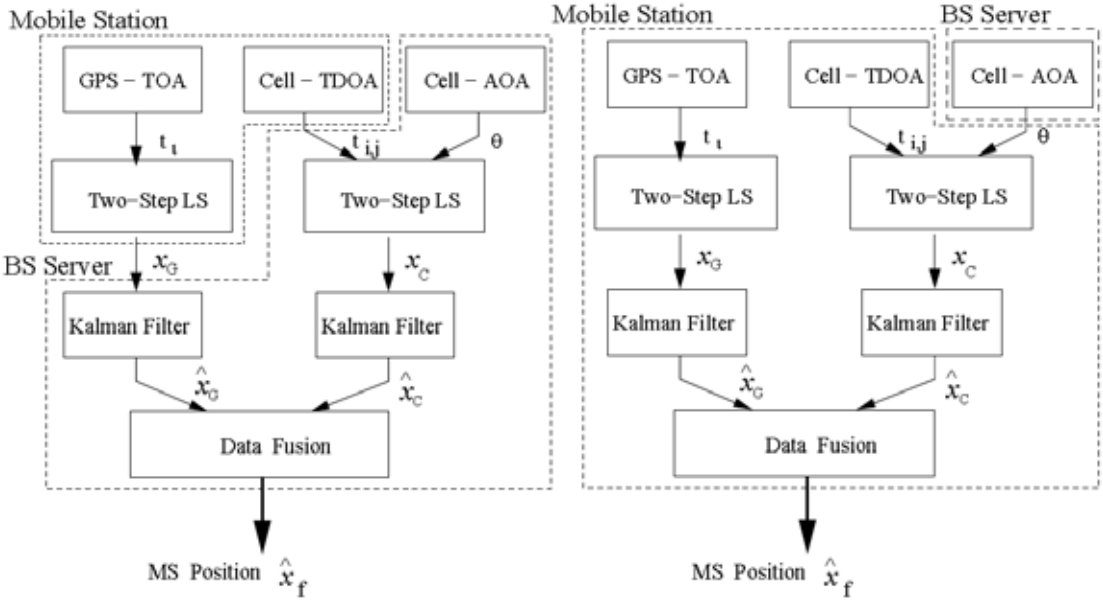

Figure 1. The hybrid location estimation scheme based on both the mobile-assisted system (left) and the mobile-based system (right)

1) The mobile-assisted system: The left schematic diagram of Fig. 1 shows the proposed algorithm that implements on the MS-assisted positioning system. This type of architecture is suitable for the MS with insufficient computation capability. The following steps describe the procedures of the proposed scheme for the MS-assisted system: (1) The GPS-equipped MS receives signals from the satellites and conducts TOA measurement ($\boldsymbol{t}_t$). The GPS receiver processes the TOA measurement and estimates the three-dimensional position (i.e. $\boldsymbol{x}_G=[x_G\ y_G\ z_G]^T$) of the MS using the two-step least square (LS) method. On the other hand, the TDOA measurement are calculated at the MS by obtaining signals from its home Base Station (BS) and the neighboring BSs via the forward-link pilot channel. (2) These two sets of information, the location estimation ($\boldsymbol{x}_G$) from the GPS system and the TDOA measurements ($t_{i,j}$) from the cellular network, are transmitted back to the home BS via the reverse-link pilot channel. (3) The AOA measurement ($\boldsymbol{\theta}$) conducted at the home BS by receiving the signals from the MS via the reverse-link channel. (4) The location server at the home BS performs location estimation by combining the AOA and the TDOA measurements. The two-step LS method is utilized to estimate three-dimensional position ($\boldsymbol{x}_C$) of the MS. (5) The BS location server performs Kalman filtering technique to smooth out the measurement noises and track the position data both from the TOA and the TDOA/AOA channels. (6) Data Fusion is performed to incorporate both of the filtered estimations ($\hat{x}_G$ and $\hat{x}_C$) from the TOA and the TDOA/AOA measurements based on their signal variations. The fused position estimate ($\hat{x}_f$) of the MS can be obtained.

2) The mobile-based system: The right schematic diagram of Fig. 1 shows the proposed scheme for the MS-based positioning system. This type of architecture is suitable for the MS that possesses adequate computation

capability. The major characteristics of the Mobile-based system are that most of the computations are conducted within the MS, except for the AOA measurement. The AOA measurement (θ) is obtained from the home BS and is transmitted to the MS via the forward-link pilot channel. The final position estimation ($\hat{x}_f$) is acquired after the fusion algorithm.

III. Simulation Results and Comparison

Simulations are performed to show the effectiveness of the proposed hybrid location scheme. The MS is assumed to travel at a constant speeds of (3, 4, 0) m/s along the *x* and *y* directions, i.e. (*x*, *y*, *z*) = (27 + 3*t*, 36 + 4*t*, 300) in meters. The effectiveness of using the Kalman filtering technique can be observed from Fig. 2. It eliminates measurement noises and smoothly tracks the MS's position and velocity in the longitude, latitude, and altitude directions. Fig. 3 shows the performance of the proposed hybrid location system (measured in RMS error) comparing with the GPS and the cellular system under urban, suburban, and rural environments. It can be seen that the GPS system has the worst performance comparing with the other two systems in the urban area; while the cellular system causes degraded results in the rural area. The hybrid system is capable of adjust itself to accommodate different situations, which provides consistent performance comparing with the GPS and the cellular systems.

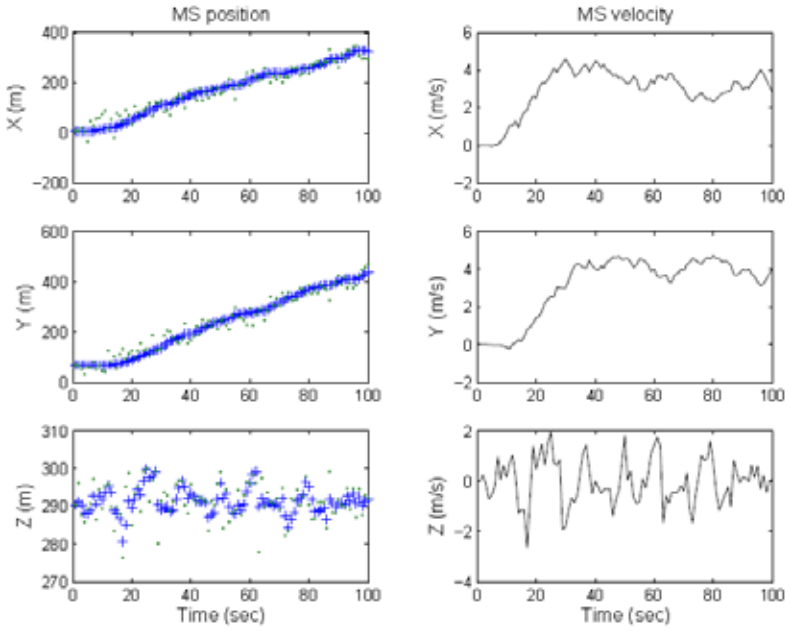

Figure 2. Left plots: Performance comparison before (dots) and after ('+' marks) using the Kalman filtering technique; Right plots: The velocity tracking of MS using the Kalman filtering technique

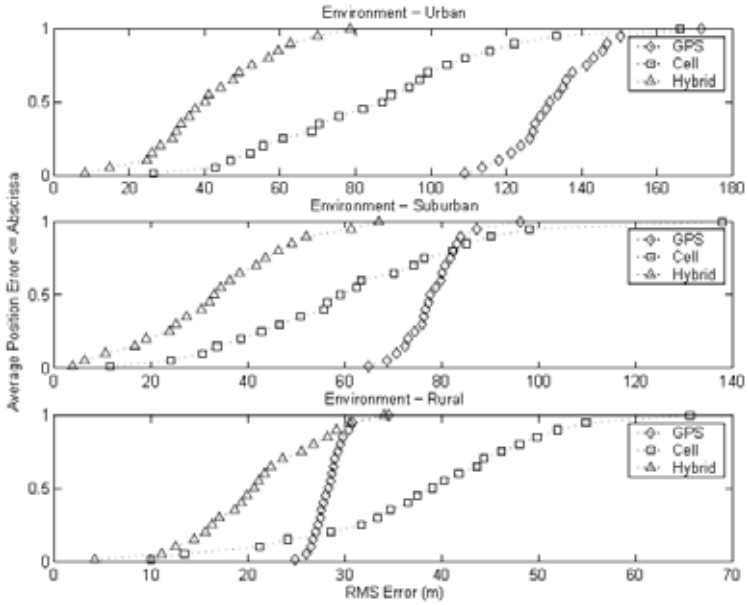

Figure 3. Performance comparisons between the GPS, the cellular, and the proposed hybrid system in urban (top), suburban (middle), and rural (bottom) areas

IV. Conclusion

A hybrid location estimation and tracking system is introduced in this contribution. The system is capable of estimating the three dimensional position and velocity of the mobile devices. It is shown in the simulation results that the proposed scheme provides consistent location estimation accuracy under different environments. However, the consistent location estimation accuracy will only be obtained in the condition that the both systems, the satellite-based systems and network-based systems, have sufficient signal sources simultaneously.

V. Proposed Sections/Subsections in the Table of Content (ToC)

This contribution is to present a hybrid method of location estimation and tracking for mobile devices. According to IEEE 802.16 standard documents, current system does not support the function of location estimation and tracking for mobile devices. Therefore, it is suggested to include this functionality in IEEE 802.16m system to enhance the accuracy of location estimation and tracking for mobile devices. Required modifications to current system and proposed sections/subsections in ToC are shown as follows.

Proposed sections/subsections:

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[*Editor's Notes: add the following into the TGm System Description Document*]

x.y Mobile Station Location Estimation and Tracking

[*Although the GPS technology is widely used in position, not all of the MSs will be equipped with it. In order to support this functionality, therefore, three location estimation and tracking schemes are proposed to provide location-based service.*]

x.y.1 GPS based MS Location Estimation and Tracking

[*A system with GPS receiver can determine its location, speed, direction and time by utilizing microwave signals from a constellation of move than 24 medium Earth orbit satellites. GPS receiver can calculate its 3D position, speed and direction by measuring the time-of-arrival (TOA) of the signals coming from at least four GPS satellites; on the other hand, its 2D location information can be obtained from signals coming from at least three satellites. Additionally, the receiver would utilize GPS satellites' atomic clocks to correct its clock error.*]

x.y.2 Network-assisted MS Location Estimation and Tracking

[*Various types of information (e.g. the signal traveling distance, the received angle of the signal, or the received signal strength (RSS)) from MS's neighborhood BS could be involved to facilitate the location algorithm design. The representative algorithms for the network-based location techniques are the time difference-of-arrival (TDOA) and the angel-of-arrival (AOA).*]

x.y.3 Hybrid MS Location Estimation and Tracking

[*It has been known that the performance of the GPS based and network-assisted MS location systems vary under different environments. As a result, a hybrid location scheme, which combining the outcomes from both the network-based and the satellite-based techniques, is proposed to adaptation to various scenarios for location estimation. It adopts the existing infrastructure and can provide consistent location estimation accuracy under different environments.*]

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