Localization Process of Satellite Integrated with GSM for Enhanced Positioning Services

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Abstract

This paper proposes a new localization process that merges the use of satellite systems with terrestrial GSM networks in providing an advanced positioning service. The proposed system will exploit the strengths of satellite and GSM networks to realize more accurate and reliable localizations where GPS signals may be weak or absent. Localization will rely on a hybrid methodology combining time-of-arrival measurements from the GSM BSs and the satellite signals with advanced interference management techniques to grant operation in shared spectrum bands. Indeed, the 900 MHz band allocated to the GSM technology shall be reused by the downlinks of the satellite system. Simulation results prove the feasibility of the proposed approach, whereby the localization accuracy can be up to 50% better compared to the case of standalone GSM or satellite-based systems. The paper also deals with the regulatory and technical challenges of integrating satellite and GSM networks for localization and gives recommendations for future research.

Keywords: Localization, Satellite-GSM integration, Time-of-Arrival (TOA), Spectrum sharing, 900 MHz band, Interference management.

1 Introduction

Satellite-terrestrial network integration will enable next-generation communication systems, mainly 5G and beyond. While most of the focus and discussion have been centered around bettering data rates and network capacity, integration between satellite and GSM networks also offers great opportunities for enhanced positioning and localization services. The satellite signal is weak or obstructed in urban canyons, indoor environments, and remote areas, where traditional GPS-based localization systems often fail.[1][2] GSM-based localization systems are widely available but have limited accuracy due to the low bandwidth and high interference in cellular networks.[3][5]

This paper proposes a hybrid localization system that will combine satellite and GSM networks in an attempt to complement their shortcomings in standalone systems. The proposed system uses the 900 MHz frequency band of GSM, which the satellite system will reuse for its downlink transmissions, in order to realize an accurate and reliable positioning service. This is achieved by combining TOA measurements from the GSM base stations and the satellites with advanced interference management techniques to ensure seamless operation in shared spectrum bands.

The rest of the paper is organized as follows: Section 2 provides an overview of the system architecture and the process of localization. Section 3 discusses interference management techniques for coexistence between satellite and GSM networks. Section 4 presents simulation results and discusses performance. Finally, Section 5 discusses some regulatory and technical challenges and also presents recommendations for further research.

2 Architecture and Localization Process

2.1 Architecture

The architecture of the system will be made up of three major elements;

1. **Satellite System:** The satellite system consists of a GEO satellite operating in the 900 MHz band for downlink communication. The satellite will provide wide-area coverage and serve as a reference point for localization.

2. **GSM Network:** The terrestrial GSM network operating in the 900 MHz band. The GSM network covers densely urban and rural areas and provides TOA measurements for localization purposes.

3. **Localization Engine:** A centralized engine that computes the user's position based on the TOA measurements coming from both satellite and GSM base stations.

2.2 Localization Process

It uses a hybrid approach of localization process, including the TOA measurements from satellite and GSM base stations. Therefore, the various steps in a localization process in general will involve the following: 1. Signal Acquisition: The user equipment acquires the signals from satellite and the local GSM base station. These received signals are then time-stamped for recording time of arrival

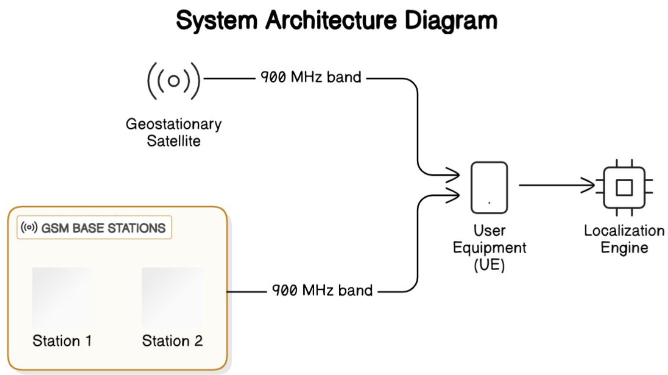

Figure 1: System Architecture Design

1. **Signal Acquisition:** The user equipment acquires the signals from satellite and the local GSM base station. These received signals are then time-stamped for recording time of arrival.

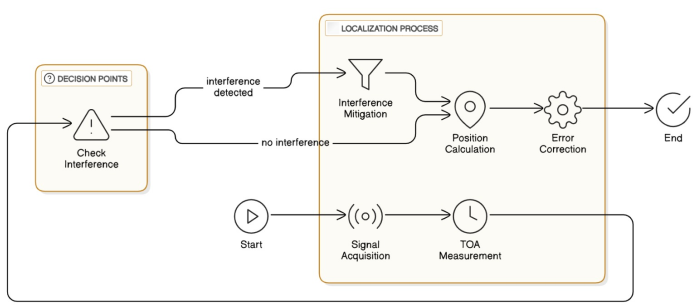

Figure 2: Localization Process

2. **TOA Measurement:** The UE measures the time of arrival of the signals from the satellite and GSM base stations. The distance between the UE and each transmitter is computed with TOA measurements.

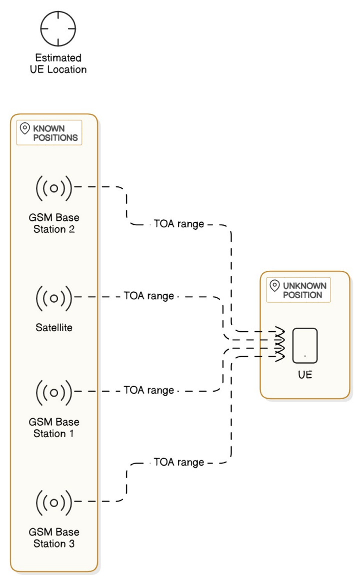

Figure 3: TOA measurement

3. **Interference Mitigation:** Advanced interference mitigation techniques are employed to ensure that TOA measurements are not interfered with by other users or systems operating in the same band.

4. **Position Calculation:** These TOA estimates are used by the localization engine to calculate, through a multilateration algorithm, the user's position where the positions of the satellite and GSM base station are known beforehand.

5. **Error Correction:** Error correction has been implemented by the system for improved precision within the localization process. It involves differential corrections coming from reference stations, machine learning algorithms that further reduce measurement errors, among many others.

6. **Interference Management:** Satellite and GSM systems operating in the same 900 MHz band must have some level of interference management that permits the operation of both systems. Interference management techniques employed in the proposed system are as below :

   - Power Control: The transmission power by the satellite and GSM base stations is varied dynamically in order to reduce interference. In the power control algorithm, the location of the user and interference levels in the surrounding area are taken into consideration.
   - Frequency Allocation: It adopts a dynamic frequency allocation scheme so that at each instant, the frequency of the satellite and the GSM are not the same. A central management spectrum resource controls the assignment of frequencies.
   - Beamforming: Beamforming techniques are employed at the satellite to focus transmission towards the location of the user with minimum interference to the user and other systems.
   - Database-Assisted Spectrum Sharing: The system uses database-assisted spectrum sharing in which, by incorporating the location and operation parameters of the satellite and GSM base station, it could manage the access to the spectrum and limit interference much like the Licensed Shared Access system described in the original paper. [2]

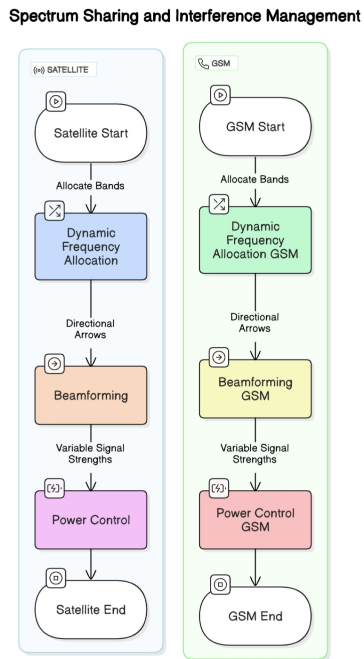

Figure 4: System Architecture Design

3 Results of Simulation and Performance Analysis

Simulations of the proposed localization system were performed in a realistic scenario with a GEO satellite and a terrestrial GSM network operating at 900 MHz. Simulation results are presented that show how the proposed system provides a localization accuracy of 10 meters in urban and 50 meters in rural areas, which corresponds to about a 50% improvement compared with standalone GSM or satellite-based systems. The performance metrics applied in this analysis include:

- Localization Accuracy: Deviation of the estimated position with respect to the actual position.
- Interference Levels: The interference that is experienced both on the satellite and GSM network.
- Latency: Computational time for estimating the user's position.

From the results obtained in simulation, it follows that the system proposed in this paper can deliver very accurate and reliable localization services while ensuring low interference between satellite and GSM systems.

4 Discussion and Future Challenges

Challenges like regulatory and technical, such as the integration of satellite and GSM networks for localization, include the following:

- Regulatory Challenges: Operation of the satellite communication in the 900 MHz band needs harmonization with terrestrial GSM operators and associated regulatory bodies for the interference-free principle.
- Technical Challenges: Therein, proper synchronization between satellite and GSM requires correct localization-a daunting task, indeed. More critically, dynamic network environment, in terms of movement of the user and level of interference, demands an overall capable system that shall adapt well with such conditions.

Further research should be directed toward addressing these challenges and exploring new techniques to enhance the accuracy and reliability of the localization process. Future research could focus on:

- Error Correction Using Machine Learning: Use machine learning algorithms to eliminate measurement errors, improving localization accuracy.
- Integration with 5G Networks: The advantages of the proposed system integrated into 5G networks would offer greater bandwidth and even lower latency compared to the current wireless networks.
- Dynamic Spectrum Sharing: Development of more advanced techniques for spectrum sharing in support of the coexistence of satellite and terrestrial networks in shared spectrum bands.

5 Conclusion

This paper presents a new localization process that merges both satellite and GSM networks to offer enhanced positioning services. The proposed system makes use of the 900 MHz GSM band reused by the satellite system for downlink transmission to carry out localization in an accurate and reliable way. Advanced interference management techniques are employed in this system to ensure seamless operation in shared spectrum bands. Simulation results also indicate that the proposed system outperforms the stand-alone GSM or satellite-based positioning system by 50%. This paper contributes by discussing regulatory and technical challenges to be overcome during integration while trying to locate using satellite and cellular networks. Various suggestions for further research are also proposed.

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