Chapter 8

Analysis of Real-Time Hybrid-Cooperative GNSS-Terrestrial Positioning Algorithms

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ABSTRACT

This chapter analyzes some hybrid and cooperative GNSS-terrestrial positioning algorithms that combine both pseudorange measurements from satellites and terrestrial range measurements based on radio frequency communication to improve both positioning accuracy and availability. A Simulation Tool (ST) is also presented as a viable tool able to test and evaluate the performance of these hybrid positioning algorithms in different scenarios. In particular, the ST simulates devices belonging to a Peer-to-Peer (P2P) wireless network where peers, equipped with a wireless interface and a GNSS receiver, cooperate among them by exchanging positioning aiding data in order to enhance the overall performance. Different hybrid and cooperative algorithms, based on Bayesian and least squares approaches proposed in the literature, have been implemented in the ST and simulated in different simulation scenarios including the vehicular urban one. Moreover, all these algorithms are compared in terms of computational complexity to better understand their feasibility to achieve a real-time implementation. Finally, the sensitivity of the hybrid and cooperative algorithms when pseudorange measurements are affected by large noise and in presence of malicious peers in the P2P network is also assessed by means of the ST.

INTRODUCTION

Nowadays, various applications in wireless communication networks are based on mobile positioning. In fact, data collected or communicated by a wireless node is often useless if it is not associated to the node’s location. For example, a generic wireless sensor network (WSN) monitoring application (Garcia-Hernandez, Ibarguengoytia-Gonzalez & Perez-Diaz, 2007), where nodes collect data such as temperature, humidity, etc., requires the nodes’ location to recognize where the data come from.
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from. Moreover, location-based technology allows the deployment of many other applications, including asset tracking, intruder detection (Yan, He & Stankovic, 2003), healthcare monitoring (Budinger, 2003), emergency 911 services (Caffery & Stuber, 1995) and so forth (Liu, Darabi, Banerjee & Liu, 2007).

Typically, positioning techniques infer the position of unknown nodes by applying a two-step estimation process (Caffery & Stuber, 1998). In the first step, ranging estimation is performed by means of various techniques such as received signal strength (RSS) (Hashemi, 1993; Laitinen, Juurakko, Lahti, Korhonen & Lahteenmaki, 2007), time of arrival (ToA) or time difference of arrival (TDoA) (Caffery & Stuber, 1998). Then, the position of the unknown nodes are inferred in a two or three dimensional plane by applying a localization algorithm, which takes as inputs the range measurements and the positions of anchor peers, whose coordinates are known a priori.

Recently, much attention is focused on the signal-of-opportunity (SoO) approach (Yang & Nguyen, 2009) which consists in the exploitation of terrestrial communication systems (e.g., WSN, ultra wide-band (UWB), Wi-Fi, cellular networks, etc.) with a purpose other than navigation in order to guarantee and improve the global navigation satellite systems (GNSS)-based services and enhance the robustness of the overall GNSS end-user performance. In general, GNSS can provide accurate position estimation when the receiver’s antenna is able to acquire at least four satellites (Del Re, 2011). This condition is generally verified in open sky outdoor environments. On the contrary, in GNSS-challenged environments such as urban canyons, under dense foliage and indoors, the line of sight (LoS) between the satellites and the receiver’s antenna is often obstructed and the GNSS-based localization performance degrades or fails completely. Therefore, in such environments, different aiding/augmentation approaches have been proposed and adopted. Satellite-based augmentation systems (SBAS), such as wide area augmentation system (WAAS), European geostationary navigation overlay service (EGNOS) and multi-functional satellite augmentation system (MSAS), use a number of known global positioning system (GPS) receiving stations to improve the positioning accuracy (Diggelen, 2009). Ground-based augmentation systems, such as Assisted-GPS (A-GPS) and differential-GPS (D-GPS), adopt ground based networks to locate the users (Monteiro, Moore & Hill, 2005) with enhanced performance. In addition, (Retscher & Fu, 2007) investigated active RFID in combination with GNSS and dead reckoning solutions by means of odometers or inertial sensors for pedestrian navigation. However, these systems rely on the deployment of an infrastructure that provides the augmentation service. Moreover, in most cases, they require a unidirectional information flow from infrastructures to receivers. The main focus of this chapter is to study and analyse GNSS assisting schemes that rely on the cooperative paradigm and do not require a fixed infrastructure. In cooperative localization systems, each node voluntarily shares its own positioning data and information with its neighbours, with the aim to enhance the location accuracy and availability.

The rest of this chapter is organized as follows: first section 2 overviews the state of art regarding hybrid and cooperative positioning algorithms; section 3 presents the main structure of the ST including simulation results and complexity analysis; after that section 4 presents future research directions while conclusions are drawn in section 5.

BACKGROUND

Recently, many hybrid and cooperative GNSS/terrestrial localization approaches, which combine both pseudorange measurements from GNSS satellites and wireless-based ranging measurements from neighbouring peers, have been proposed in the literature to improve both positioning availability and accuracy. (Caceres, Penna, Wymeersch