An Experimental Evaluation of IEEE 802.15.4a Ultra Wide Band Technology for Precision Indoor Ranging

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ABSTRACT

Ultra Wide Band (UWB) wireless transmission has recently been the object of considerable attention in the field of next generation location aware wireless sensor networks (WSNs). This is due to its fine time resolution, energy efficiency and robustness to interference in harsh environments. This paper presents a thorough applied examination of prototype IEEE 802.15.4a impulse UWB transceiver technology to quantify the effect of line of sight (LOS) and non line of sight (NLOS) ranging in real indoor and outdoor environments. The results included draw on an extensive array of experiments that fully characterize the 802.15.4a UWB transceiver technology, its reliability and ranging capabilities for the first time. The goal of this work is to validate the technology as a dependable wireless communication mechanism for the subset of sensor network localization applications where reliability and precision positions are key concerns.

Keywords: IEEE 802.15.4a UWB, Line of Sight (LOS), Non-Line of Sight (NLOS), Reliability, Two Way Ranging, Ultra Wide Band (UWB)

1. INTRODUCTION

For a wide range of sectors of WSN applications: searching, healthcare, home-automation or military, the utilization of sensor location information is an excellent tool to improve productivity and to optimize inventory management. Real-time localization is becoming a more important concept in WSNs as the sensing data without knowing its sensor location is meaning-
less. Because most of WSN applications occur at indoor environment, the requirements of reliability and precision of ranging or localization become the key concerns of the development of indoor location system. GPS, which is widely used in outdoor applications such as vehicle navigation, has been proved that cannot be implemented in an indoor environment (Hein, Rodriguez, Wallner, Eissfeller, & Hartl, 2007). For short to medium range, various wireless systems such as the WiFi, ZigBee, and RFID may provide ranging or location information with different levels of precision (Liu, Darabi, Banerjee, & Liu, 2007; Gu, Lo, & Niemegeers, 2009). Ultra Wide Band (UWB) stands out providing high accuracy of ranging estimation due to its fine time resolution, energy efficiency. IEEE 802.15.4a UWB transceiver technology is emerging as an ideal fit for the requirements of the next generation wireless sensor network (Di Benedetto, Kaiser, Molisch, Oppermann, Politano, & Porcino, 2005). IEEE has recognized the need to standardize UWB technology for use in personal area networks (PANs) and has established the IEEE 802.15.4a standard specifying a new UWB physical layer for WSNs (IEEE, 2007).

Accurate range-based localization depends on a precise ranging measurement of the wireless sensor systems. Generally, distance estimates can be computed out based on the measurements of different parameters such as received signal strength (RSS), angle of arrival (AOA) and time of arrival (TOA) of every two signals exchanged between them. However, UWB techniques employing RSS methods cannot obtain accurate ranging estimates due to its strong dependence on the channel parameters, which makes the received energy more sensitive to distance changes in NLOS areas. AOA methods can facilitate accurate ranging when the UWB signal bandwidth is increased, but it needs multiple antennae that make system larger and costly. TOA parameter based methods provide more accurate range estimates but lower cost compared to the RSS and the AOA. The IEEE 802.15.4a standard based on an impulse UWB signal supports a TOA ranging mechanism (IEEE, 2007). Extensive researches have focused on the design of distance estimation algorithms based on UWB signals in the last few years (Dardari, Conti, Feroni, Giorgetti, & Win, 2009; Güvenç, Sahinoglu, & Orlik, 2006; Sahinoglu, Gezici, & Güvene, 2008; Yu, Montillet, Rabbachin, Cheong, & Oppermann, 2006). In general, these studies proposed scenarios for optimizing the accuracy based on the time of arrival method. Only a few studies mention practical aspects such as the design of real ranging architecture and reliability of distance estimation.

Some UWB based systems can already be found in the market such as the UBISENSE UWB location system; these expensive systems utilize UWB for distance estimation with different methods and algorithms. Employing prototype fully IEEE 802.15.4a compliant transceiver technology, the world’s first IEEE 802.15.4a UWB wireless packet was transmitted and successfully coherently received in real-time in March 2009 (Connell, 2009). This impulse UWB prototype transceiver technology can easily be placed in the next generation Wireless WSN category and reduce the cost and complexity of the system deployment.

The goal of this paper is to examine the characterization, reliability and ranging precision of IEEE 802.15.4a impulse UWB based transceiver for both indoor and outdoor environments. A real ranging implementation based on double sided two way ranging algorithm as part of this work is described in detail. To fully test the reliability of the IEEE 802.15.4a UWB ranging system, a distance measuring experiment is firstly implemented in an indoor environment to investigate the case of LOS with multi-path, and also the case of NLOS with different materials, for instance, chair, counter, door and walls; secondly, the outdoor open field case is evaluated with reflections are presented at the receiver. These aspects are not usually considered in the existing studies, but have an important impact on the implementation of real system ranging data processing and supplying real results for the next ranging optimization work.
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