Abstract

Internet of things (IoT) is an emerging technology which enables integration of billions of objects and complex systems over internet with the help of many technologies such as Wi-Fi, ZigBee, Bluetooth, UWB etc. Position estimation has become an essential and crucial factor in various monitoring applications of IoT. Precision localization and positioning has become an attractive area of interest for many new applications and business solutions. Although, the global navigation satellite systems (GNSS) can provide good performance and positioning in outdoor systems, they are not very accurate when it comes to indoor locations or in GNSS-denied environments. With the ease of availability of commercial transceivers and the demand for accurate positioning systems by various industries, the research interest towards indoor positioning and navigation systems based on ultra-wideband technology (UWB) has been immense.

Good localization accuracy can be achieved by using UWB pulses due to their high temporal resolution and multi-path immunity. Apart from achieving high accuracy, UWB can also provide larger coverage and ranging capability as well as the capacity to penetrate walls. A typical UWB indoor localization system consists of some anchor nodes (i.e. nodes with fixed location) and the target node/s whose position is to be determined.

In this thesis, we present an ultra-wideband impulse radio (UWB-IR) based positioning system for indoor applications. The UWB systems can be operated in unlicensed band in the frequency range of 3.1 - 10.6 GHz. The operation in unlicensed band makes it even more exciting and accessible for different commercial applications. However, several GHz of Nyquist sampling rate is required to sample such a large bandwidth signal. A sampling rate of few tens of GHz is suggested for resolving large number of multi-path in UWB based systems. Sampling at such a rate is an expensive solution and thus practically limited by cost and complexity of the required hardware and thus, it is a bottleneck in designing low cost sensor nodes employing UWB systems.

To overcome the high sampling requirements, in this thesis we use an equivalent time sampling (ETS) mechanism to recover the channel impulse response, with resolution in the order of sub nanoseconds, with much reduced ADC sampling rate, in the order of few MHz (to be specific 2-3 MHz).

Moreover, it is interesting to note that while using equivalent time sampling, the mathematical formulation of equivalent time of arrival (termed E-TOA) obtained

using ETS technique is different from the conventional time of arrival methods. This thesis presents the detailed analysis and experimental verification of the novel E-TOA analytical equation. Specifically, the time scale of the reconstructed signal obtained by such techniques, that require periodic transmission of the same signal repetitively, is severely affected by the variations in transmitter clock as well as receiver clock. Therefore, we need a mechanism to obtain accurate TOA, for implementing such schemes in real world wireless sensor network (WSN) without using costly equipment and setups.

In addition to the above, while using time of arrival or time difference of arrival based ranging schemes, a very stringent time synchronization is required to obtain very precise time of arrival measurements, in the order of sub-nanoseconds. Obtaining and maintaining such a precise synchronization requirement is not feasible in mobile wireless sensor nodes.

In this thesis, we therefore propose a differential time difference of arrival algorithm, which fundamentally changes the TDOA scheme by removing the synchronization requirement among the nodes. Thus, combining E-DTDOA with equivalent time sampling remove synchronization requirement on one hand while still providing precise ranging and accuracy between the nodes. This approach can be very feasible for practical deployment of asynchronous wireless sensor nodes.

This thesis further demonstrates the proposed mechanism using in house designed sensor nodes. The test-bed consists of 4 anchor nodes with multiple target nodes. The results show that very precise ranging and localization, in the order of few cm, can be achieved with efficient use of low cost anchor nodes and target nodes with low cost crystal clock which can be useful for various real world low cost and energy constrained applications.