Chapter 7
Position Estimation for IR-UWB Systems:
DPE, Multi-TOA Approach, and Their Compressive Sensing-Based Modeling

Eva Lagunas
University of Luxembourg, Luxembourg

Monica Navarro
Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), Spain

Pau Closas
Northeastern University, USA

Montse Najar
Universitat Politecnica de Catalunya, Spain

Ricardo Garcia-Gutierrez
Universitat Politecnica de Catalunya, Spain

Genís Floriach
Universitat Politecnica de Catalunya, Spain

ABSTRACT

IR-UWB has emerged as a promising candidate for positioning passive nodes in wireless networks due to its extremely short time domain transmitted pulses. The two-step approaches in which first different TOAs are estimated and then fed into a triangulation procedure are suboptimal in general. This is because in the first stage of these methods, the measurements at distinct anchors are independent and ignore the constraint that all measurements must be consistent with a single emitter location. In this chapter, the authors investigate two techniques to overcome this issue. First, a two-step procedure based on multi-TOA estimation is proposed. Second, a positioning approach omitting the intermediate known as DPE is presented. Complementarily, the authors explore the CS-based modeling of both approaches so that the temporal sparsity of the UWB received signal and the consequent sparseness of the discrete spatial domain are exploited to select the most significant TOAs and to reduce the amount of information to be sent to a central fusion unit in the DPE approach.

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INTRODUCTION

Localization and positioning represent one of the main themes that are being developed in the field of wireless communications. One of the existing technologies that offers better features related to the location applications is Impulse-Radio Ultra-Wideband (IR-UWB) (Gezici et al., 2005). This radio technology can potentially enable very accurate ranging and location applications, given the extremely short duration of the pulses.

To provide accurate position information of nodes, a number of reference nodes with known position (anchors) collect ranging information from radio signals emanating from the node with unknown position.

Range accuracy depends on the narrowness of the pulse so that a pulse having a very short duration will result in the highest time resolution, which implies the highest range accuracy. The large signal bandwidth of IR-UWB not only offers outstanding ranging capabilities but also provide a means for resolving multipath indoor components. The latter is important since dense multipath environments, which are usually the propagation conditions in indoor positioning, make the shortest path delay (containing information about the distance) difficult to be accurately estimated.

The conventional approach to solve the localization problem consists of a two-step procedure. First, some parameters of the transmitted signal are measured, and next, these parameters are combined using a simple trilateration or multi-lateration algorithm yielding the location of the target nodes. According to (Dardari, Conti, Ferner, Giorgetti, & Win, 2009), positioning systems can be divided into three main categories: Time-of-Arrival (TOA), Direction-of-Arrival (DOA) and Signal-Strength based systems. Signal-Strength method does not exploit the advantages of large bandwidth and, thus, they are not the best option for IR-UWB systems. The Angle-of-Arrival (AOA) or DOA based positioning technique involve the use of antenna arrays. Moreover, and due to the large bandwidth of the UWB signal, the number of paths may be very large, and therefore, accurate angle estimation becomes very challenging. Clearly, TOA-based techniques are better motivated for IR-UWB, due to its enhanced precision.

In this chapter, we focus on TOA-based IR-UWB positioning techniques. We first focus on two-step procedures, where proper first path detection acquires special relevance. Discrimination of the first arrival is extremely challenging in indoor environments since the first path may not necessarily be the one bearing the highest power. The performance of two-step TOA-based procedures has been shown to be very sensitive to the threshold selection used to select the first arriving path. Moreover, the high bandwidth nature of UWB systems imposes very high sampling rate requirement, which translate in high computational time, higher storage capabilities and strong constraints into the Analog-to-Digital Converter (ADC).In this context, we will introduce a TOA-based scheme that avoids the use of the threshold selection while relaxing the sampling requirements by introducing concepts from Compressive Sensing (CS) technology. CS (Candes & Wakin, 2008) provides a solution to the computational complexity issue by allowing to sample signals that are sparse or compressible under a certain basis, at a rate significantly less than the Nyquist sampling limit. Herein, exploiting the time-domain sparsity inherent in the IR-UWB signals, we consider CS techniques for compression and detection applied to TOA estimation for IR-UWB, where the basic strategy is to extract the most significant energy paths present in a frequency-domain Power Delay Profile (PDP) via CS-based reconstruction techniques.

An alternative to two-step procedure is the positioning approach omitting the intermediate step, which is known in the literature as Direct Position Estimation (DPE). DPE focuses on the direct estimation of position coordinates, which are indeed the parameters of interest to the end-user. Furthermore,

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