Chapter 1
New Methods for Improved Indoor Signal Strength Positioning

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ABSTRACT

This chapter focuses on positioning based on received signal strength measurements and radio path-loss modeling. Typically, receiver signal strength from a device such as a smart phone is used to calculate the path-loss and thus estimate distances using a loss model calibrated in an offline process. With known positions and ranges to WiFi access points or simple devices using Bluetooth or Zigbee for data communications, the mobile device position can be estimated. However, due to the complex multipath propagation indoor environment, distance estimation and position determination using current methods are not very accurate. Based on knowledge of the nature of indoor signal propagation and algorithms especially designed for mobile applications, new methods show that positional accuracy of a few meters is possible, even with non-line-of-sight propagation through many intervening walls. Given the current widespread deployment of WiFi indoors, simple software-only solutions are feasible for applications such as general personal navigation and tracking within buildings.

INTRODUCTION

A range of technologies have been utilized for positioning, but radio positioning is probably the most important one, especially due to the various military and civilian applications and services associated with global navigation satellite systems (GNSS). In radio positioning, five basic signal parameters have been widely considered for position determination, namely signal strength, time-of-arrival, frequency difference-of-arrival, carrier phase, and angle-of-arrival. The methods based on these different measured parameters have different strengths and weaknesses, so in general there must be a tradeoff between

DOI: 10.4018/978-1-5225-3528-7.ch001

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complexity, the associated cost and positional accuracy. Receiver signal strength positioning is simple to implement and can use existing radio infrastructure such as WiFi access points, but using current techniques the positional accuracy and reliability is too poor to be of practical use in non-line-of-sight (NLOS) severe multipath conditions at typical ranges required of 30 meters or more. However, new techniques described in this chapter show that positional accuracy of 2-3 meters in indoor situations should be possible, thus opening up new applications of indoor positioning and navigation.

Signal time-of-arrival can be used to generate pseudo-range measurements such as for GNSS-based coarse positioning, and precise ultra-wide band positioning can exploit round-trip time measurements. Time-difference-of-arrival can be simply derived from time-of-arrival data to account for the unknown time offset between the two communicating nodes (typically a base station and a mobile device) (Chan & Ho, 1994)). Frequency difference-of-arrival (also called differential Doppler) can be applied for scenarios where there exists relative motion between two nodes so that significant Doppler shifts can be observed, such as by an airborne receiver. The first navigation satellite system (also known as the TRANSIT system) provided navigation for naval ships, commercial shipping and private light aircraft, and was also used by surveyors for determining coordinates of remote ground marks between the late 1960s and early 1990s.

Angle-of-arrival measurement requires a directional antenna and/or antenna array. A two-dimensional position of a mobile device can be estimated using two angle-of-arrival measurements made at two different base stations. A single base station can be used to estimate a mobile position by using both angle-of-arrival and distance measurements. The more accurate VHF omnidirectional range (VOR) used in aircraft for route navigation is based on determining the phase of a specially encoded signal transmitted from a ground station. Another more recent application of precise carrier phase measurement enables precise position determination such as in GNSS (Juan *et al*., 2012). For instance, the GPS L1 signal has a wavelength of about 19cm. If the phase measurement accuracy is of the order of one-fifth of the wavelength, the ranging accuracy can be as good as 4cm. However, in many cases including GNSS, determining the integer cycle ambiguity is an issue that must be resolved. Furthermore, multipath interference can corrupt the phase information, hence applications are limited to outdoor applications in clear open areas, such as in the case of surveying.

Nearly all modern communication devices or receivers include Receiver Signal Strength Indicator (RSSI) functionality. Typical implementation is a diode detector in the IF of the receiver, and thus is cheap to implement. However, note that RSSI only gives an *indication* of the signal strength, and is not intended to be an accurate measurement of the signal strength at the antenna port of the device. As the measurement is not directly of the RF signal, some form of calibration is required. Specifications for standard common consumer radio systems such as WiFi, Bluetooth and Zigbee (as used for measurements described in this chapter) only require the measurement is within a specified range; for example, the Zigbee IEEE 802.15.4 specification has an accuracy range of ± 5 dB. Such imprecision in raw RSSI measurements must be taken into account if RSSI positioning is to achieve a reasonable accuracy.

In many indoor environments such as offices, hospitals, hotels, shopping centers and other similar large buildings, there are often many WiFi access points (AP) and Bluetooth devices which can provide short-range wireless communications. Note that these technologies are designed for data communications, with indoor signal range being limited to less than 10 m for Bluetooth, and perhaps 30-40 m for WiFi. Devices such as mobile phones include a RSSI measurement as a standard part of the API access to the device operating system software. This software access can be exploited by radiolocation applications on the device. There are two main types of such applications. One is based on using multiple

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