Chapter 4
RFID Positioning

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ABSTRACT
This chapter investigates the techniques and algorithms for low-cost and portable ubiquitous indoor/outdoor personal positioning systems that use Radio Frequency Identification (RFID) based multi-sensor integration. This includes, for example, integrating RFID with Micro-Electro-Mechanical Systems (MEMS), Inertial Navigation System (INS), and/or GNSS. Different positioning scenarios and technologies are discussed and assessed. Their principles of operation and the factors that affect signal strength measurements are analysed in detail. This is followed by an in-depth investigation of the achievable positioning accuracies and the corresponding application scenarios. Results of static and kinematic experiments conducted in indoor and outdoor environment show that positioning accuracies at the meter level can be achieved using RFID based integrated systems. The algorithms developed can be readily deployed in portable multi-sensor positioning systems for LBS.

INTRODUCTION
Position information is vital to human activity in all conditions and environments. Typical personal positioning applications include, tracking miners underground, monitoring athletes, locating first responders, guiding the disabled and providing other general LBS. Studies have shown that people tend to lose orientation much easier within buildings than outdoors (Fontaine & Denis, 1999; Lemberg, 1996). However, the provision of high accuracy seamless positioning from the outdoor to indoor is still a challenging task. Outdoor positioning has been widely studied and accurate positioning can usually be achieved by well established GNSS techniques. However, these techniques are difficult to use indoor since GNSS signals are either too weak to be received or non-existent. Alternative techniques including those based on radio-based pseudolites, Wireless
Local Area Networks (WLAN), Bluetooth, Ultra Wideband (UWB), infrared, ultrasonic and inertial sensor technologies can be used for indoor positioning but they all have limitations. For example, inertial sensors are prone to drifting caused by accumulating errors of measured acceleration and radio-based techniques can be significantly affected by obstruction and multipath effects on the transmitted signals. Therefore, accurate and reliable methods are required to address the limitations of the current indoor positioning techniques in order to provide high accuracy seamless indoors. The main objectives of this chapter are therefore, to investigate algorithms for low-cost and portable indoor personal positioning systems using RFID and its optimal integration with other sensors.

Radio signals are used for automatic identification of objects in RFID systems. In this chapter the fundamentals and basic principle of operation of an RFID system is introduced. This is followed by a discussion of the strategies for positioning methods using RFID. For location determination one scenario is that RFID tags are placed at active landmarks or known locations in an area of interest. The tag ID and additional information (e.g. the 3-D coordinates of the tag) are retrieved if the user passes by with an RFID reader and within the communication range of tags. In the second scenario readers are installed at specific waypoints in the areas of interest (e.g. entrances to buildings, storage rooms, shops, etc.) to detect relevant proximate objects. For this purpose an RFID tag is attached to or incorporated in the object to be located. This approach is primarily used in warehouse management and logistics as well protection of goods in shops, e.g. from theft, and for tracking of containers and goods.

In general, for RFID positioning in urban and indoor environments three primary methods may be employed. Firstly, cell-based positioning (i.e., RFID Cell-of-Origin, CoO) can be used where continuous positioning is not required. The positioning accuracy of this method depends on the size of the cell which is given by the maximum propagation range of the RFID signals. Two approaches, namely the deterministic or probabilistic CoO, can be used. Another method is lateration using ranges to the surrounding RFID transponders. Obtaining ranges from the Received Signal Strength (RSS) measurements, however, is a non-trivial task as the RSS is influenced by the dynamic environment. The third method is location fingerprinting where positioning is implemented based on the RSS levels of the RFID signals. RSS values at certain locations are obtained and stored in a database during the off-line training phase. The RSS values observed are matched with the values in the database and the location of the user is then determined in the positioning phase.

In this chapter the above three methods are discussed and analysed in detail. The integration of RFID with other technologies is also elaborated. A typical combination of multiple sensors is to integrate RFID with other relative positioning technologies such as MEMS INS to bridge the gaps between RFID tags for continuous positioning applications. The results of experiments demonstrate that the performance can be significantly improved by integrating multiple sensors with RFID for personal positioning applications. It is feasible to use the algorithms described in a portable RFID-based multi-sensor positioning system to achieve metre-level accuracy in the indoor/outdoor environments.

**FUNDAMENTALS OF RFID TECHNOLOGY**

The RFID technique was originally designed as a contactless and low energy consumption device to replace conventional smart card systems which were prone to problems of wear and damage by frequent contact (Finkenzeller, 2003). Automatic identification of objects can be performed using RFID devices. The application of this technique has been predominantly in logistic industries for transferring object identification to monitoring