Chapter 5
Multi-Sensor Multi-Network Positioning

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ABSTRACT
This chapter discusses methods for positioning utilizing multiple sensors and networks. For achieving seamless positioning and navigation in a smartphone from satellite signal denied areas such as indoors to everywhere outdoors, various technologies to replace and assist satellite navigation, and flexible integration algorithms for measurement fusion are necessary. Merging positioning technologies and network infrastructures together is necessary for attaining ubiquitous navigation and mobile location aware services. The key is to utilize multiple technologies - sensors and networks. This chapter discusses fusion methods for smartphone positioning utilizing the various available technologies to provide location and motion information. Self-contained sensors, wireless technologies, and satellite navigation are briefly summarized, after which their fusion methodologies introduced. Sensor hardware aspects are also discussed as well as the currently achievable performance of existing solutions. Reliability monitoring is also introduced as well as aspects needed to be taken into account in mobile platform implementation. Finally, an overview of future directions and trends within multi-sensor multi-network fusion for mobile positioning are given.

INTRODUCTION
The objective of this chapter is to introduce methods for positioning with multiple sensors and networks in smartphones. High-sensitivity GNSS (Global Navigation Satellite System) approaches require no pre-installed infrastructures but can only to some extent function indoors and in deep urban areas. In addition, GNSS is heavily compromised in performance with respect to both accuracy and availability where degraded signal environments are concerned. Wireless network coverage with for example WLAN (Wireless Local Area Network),
on the other hand, exists after a dedicated wireless infrastructure has been constructed – either indoors or outdoors in a larger scale. However, utilizing wireless networks for positioning requires typically a specific training phase to generate a fingerprint radio map to know how the available access points are heard at specific reference points with known locations. Thereafter, the WLAN functions as a localization system with signal strength indicators as the measurements with an accuracy typically several meters depending on the access point infrastructure and the radio map quality and resolution. Cellular mobile phone networks can be widely utilized both indoors and outdoors, but they provide limited positioning accuracy, typically down to 50 meters with high base station density. Self-contained sensors such as accelerometers, digital compasses, and gyroscopes provide relative position and user motion information, but, drift heavily in time and are easily disturbed by the environment requiring calibration continuously with an absolute position update. Without the absolute positioning system coupled to the self-contained sensors, only relative motion information can be retrieved. Integrating sensor information of this kind by utilizing a motion model with various wireless and cellular network derived location and satellite navigation maximizes the probability of available and accurate user location information.

Nowadays, smartphones increasingly carry GNSS receivers, accelerometers, digital compasses, gyroscopes, Bluetooth, and WLAN technology suitable for being utilized for an integrated seamless navigation solution. This chapter discusses the fusion and hybridization of various smartphone positioning technologies, integration approaches and algorithms, reliability, hardware design aspects, and presents some performance examples of what can be achieved especially for pedestrians. In addition, commercially available solutions and future outlooks are considered.

OVERVIEW OF POSITIONING TECHNIQUES

In this section, the available technologies for retrieving position and motion information of a mobile smartphone user are briefly reviewed.

GNSS

Widely available Global Navigation Satellite Systems (GNSS) provide nowadays globally accurate and continuous positioning wherever satellite signal access is sufficient. The US Global Positioning System (GPS) is currently most widely used and fully operational with its constellation of 31 Space Vehicles (SVs) orbiting the Earth at an altitude of about 20200 km (USNO, 2011). Each GPS SV makes two complete orbits each sidereal day repeating the same ground track each day. The GPS is a code division multiple access (CDMA) direct sequence (DS) spread spectrum (SS) system allowing messages from individual satellites transmitting on the same frequencies (currently L1 and L2) to be distinguished from each other based on unique encodings for each satellite. A low bit rate message data is encoded with a high-rate pseudo-random sequence different for each satellite onto the carrier signal. GPS is undergoing modernization and will increase the amount of frequencies and codes transmitted with improved features. The Russian GLONASS (GLObalnaja NAVigatsionnaja Sputnikovaja Sistema) currently employs 24 operational satellites (IANC, 2011) orbiting the Earth in middle circular orbits at a 19100 km altitude at a period of 11 hours and 15 minutes. GLONASS is currently a 15-channel frequency division multiple access (FDMA) system with each satellite having a unique transmission frequency unlike the GPS which differentiates the satellite signals based on unique codes modulated onto the carrier. The GLONASS satellite constellation is accommodated with only 15 channels spanning either