Abstract

This thesis investigates the topic of joint positioning and radio channel estimation and prediction. Both positioning and radio channel estimation have a long history of research with many publications but the combination of the two has so far at large been left unexplored. The reason for studying this topic is twofold: improvement of positioning and improvement of radio channel prediction. Positioning is of interest in many situations, such as, e.g., localization in an unknown environment. Better radio channel estimates and prediction enable improved transmission rates with fewer lost data packages in wireless networks. In this thesis, both areas are covered with analysis and simulations and the improvement in positioning performance is also demonstrated with measurements from experiments.

A well established approach for positioning is using an inertial measurement unit (IMU) which contains sensors measuring, e.g., acceleration and angular velocity. Due to noise in the sensors, the dead reckoning performance of the stand-alone unit is quickly degraded. The degradation has previously been combated by fusing the accelerometer and gyroscope signals with other sensor information such as GPS or wheel encoders in order to correct for the errors of the IMU. This is achieved by establishing a model that combines the information from the sensors. In this thesis, such a model is established between the accelerometer and gyroscope readings and the radio channel estimates obtained from pilot signals transmitted in a wireless network. The transfer characteristics of the narrowband radio channel are described with multipath components, where amplitude and angle of arrival are associated with each component. Since it is believed that the performance of the solution is greatly affected by imperfections in the receiver, its frequency error is also included in the modeled. The joint model is estimated using Bayesian methods, suitable for nonlinear systems. By simultaneously estimating the variables of the multipath components, the frequency error, and the location of the receiver, it is shown that the positioning performance using an IMU, with similar quality found in a modern day cellular phone, can be greatly improved. Since all the signals needed are present in a typical cellular phone, the proposed solution does not require any extra infrastructure. Both simulations and experiments show that the technique has a potential to give a breakthrough in positioning performance using low-cost inertial measurement units. With the established model, the variables that describe the future radio channel can also be predicted. By knowing beforehand what signal reception the cellular phone can expect, the transmissions can be adjusted in terms of modulation and transmission power to suit the future channel condition that occurs at the moment when the transmission is received. This is commonly known as link adaptation. Simulations show that the data transmission rates to the end user can be greatly improved in communication systems such as the LTE system.

The thesis also includes an investigation of performance bounds that
extends previously known results for the angle of arrival estimation problem and also contributions to joint estimation of angle of arrival and frequency error estimation. These results give an intuitive understanding of how the receiver’s trajectory of movement impacts the accuracy achievable when estimating the local radio channel landscape. In mathematical terms this can be stated as that the space-time moments of the trajectory determine the Cramér-Rao lower bound of the variables for joint estimation of angle of arrival and frequency error.