Chapter 6
Cooperative Localization in Wireless Networks

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ABSTRACT

This chapter describes cooperative localization in wireless networks, where mobile nodes with unknown positions jointly infer their positions through measuring and exchanging information with each other. The technique of cooperation localization, efficiently even in harsh propagation environment, enables amounts of location-based services that rely on high-accuracy position information of mobile nodes. After a brief introduction of cooperative localization, the Cramer-Rao lower bound is given as a standard metric for performance. Then the information in the temporal and spatial domain is illustrated with geometrical interpretations. Two classes of cooperative localization algorithms, namely, centralized and distributed algorithms, are presented to show the implementation of the cooperative localization in a wireless network. Then the performance of cooperative localization under non-line-of-sight condition is analyzed. Lastly, numerical results are given to illustrate the performance of cooperative localization algorithms.

INTRODUCTION

The availability of absolute or relative position information is essential in many applications, such as localization services in cellular networks, search-and-rescue operations, asset tracking, blue force tracking, traffic monitoring and autonomous vehicles (Win et al., 2011). Automatic localization of the nodes in a wireless network is a key enabling technology which, mainly because the availability of the node position is highly relevant to the value of the data it collects. With the integration of global positioning system (GPS) into cell phones, in conjunction with other common commercial signals, such as global system

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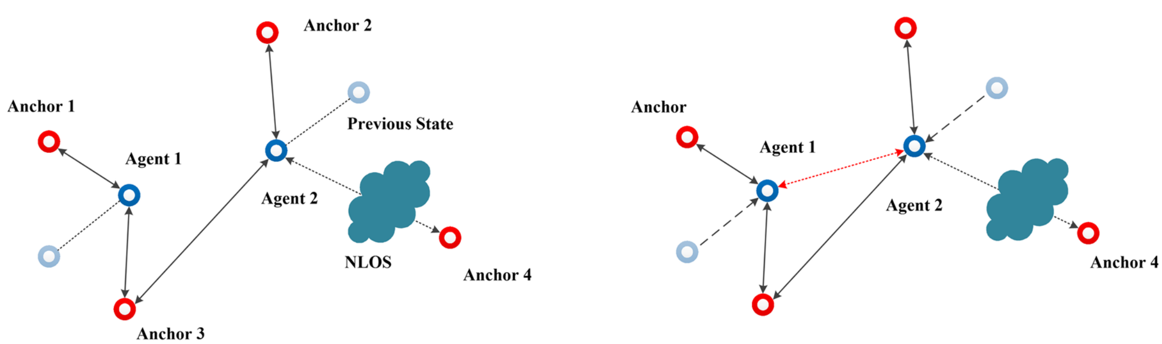
for mobile (GSM), WiFi, Bluetooth and LED, the ubiquitous location-aware services with sub-meter accuracy are envisioned in the near future, bringing new opportunities for many wireless applications in commercial, public safety, and military sectors. The wide range of potential applications will also motivate an increasing research interest in localization and tracking technologies for wireless networks.

Location-aware networks generally consist of two kinds of nodes: anchor nodes and agent nodes, where anchors have known positions while agents have unknown positions. Two common examples of anchor-based techniques include the GPS and beacon localization. In GPS, an agent determines its location based on the signals received from a constellation of GPS satellites. However, GPS does not operate well in harsh propagation environments, such as indoors or in urban canyons, since the signals suffer from severe attenuation when across obstacles and non-line-of-sight (NLOS) signals will degrade the localization accuracy severely. Beacon localization, on the other hand, relies on terrestrial anchors, such as WiFi access points or GSM base stations. In areas where network coverage is sparse, e.g., in emergency situations, localization errors can be unacceptably large. Therefore, there is an urgent need for localization systems that can achieve high accuracy in harsh propagation environments with limited infrastructure requirements.

Figure 1 illustrates an example of comparison between traditional and cooperative localization/navigation in a simple network with two mobile agents and four static anchors. Conventionally, each agent determines its position based only on the range measurements to at least three anchors, e.g., Figure 1-(a), which is also known as triangulation. These techniques often fail to localize an agent (e.g., Agent 1) when there are insufficient neighboring anchors within the communication range, or fail to provide satisfactory localization accuracy (e.g., Agent 2) when the range measurements are subject to large errors due to NLOS propagation. However, when the agents cooperate in both spatial and temporal domains, they are able to not only localize themselves with enough line-of-sight (LOS) signals, but also significantly improve the localization accuracy with more valid constraints e.g., Figure 1-(b).

If the agents with unknown locations can make measurements among themselves, such as relative ranges and relative angles, the additional information gained from these measurements between pairs of agents can enhance the accuracy and robustness of the localization system. We call this type of coopera-

Figure 1. A network with two mobile agents (blue rings) and four static anchors (red rings) in two time steps, in which light blue and dark blue rings denote the agents in the previous and current time step. Inter- and intra-node measurements are denoted by red and black arrows, respectively. Anchor 4 provides NLOS signals due to harsh propagation conditions while other three anchors provide LOS signals. (a) Before spatiotemporal cooperation. (b) After spatiotemporal cooperation.



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