Chapter 8
Node Localization in Ad-hoc Networks

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ABSTRACT

This chapter introduces node localization techniques in ad-hoc networks including received signal strength (RSS), time-of-arrival (TOA) and direction-of-arrival (DOA). Wireless channels in ad-hoc networks can be categorized as LOS and NLOS. In LOS channels, the majority of localization techniques perform properly. However, in NLOS channels, the performance of these techniques reduces. Therefore, non-line-of-sight (NLOS) identification and mitigation techniques, and localization techniques for NLOS scenarios are briefly reviewed.

I. INTRODUCTION

Node localization in ad-hoc networks have emerging applications in homeland security, law enforcement, defense command and control, emergency services, and traffic alert. These systems promise to considerably reduce the society's vulnerabilities to catastrophic events and improve the quality of life. Typical examples include emergency 911 (E911) (Mayorga, C.L.F. et al. 2007), tracking a fire fighter (Ingram, S.J. et al. 2004), battlefield command and control (Venkatesh, S. et al. 2008), vehicle safety, etc. These techniques also help to enhance wireless routing (Stojmenovic, I. 2002), (Karimi, H.A. et al. 2001) and resource alloca-

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tion (Haddad, E. C. et al. 2003) performance in ad-hoc networks.

In E911, the cell phone starting an emergency call is localized with an error that is in the order of 100 meters (for 95 percent of calls). In a building on fire, it is hard for fire fighters to find their position and their way out. While if fire fighters' 3-dimentional (3-D) position can be tracked by commander or fire fighters themselves, then they can make their way out by themselves or under the commander's guidance. In battlefield, soldiers' position information allows commanders to maintain central command procedure. In addition, it allows them to monitor the health of soldiers, and provide support in emergency situations.

Accordingly, many localization methods have been proposed. Examples include GPS (global positioning system) plus communication (Karimi, H.A. et al. 2001), received signal strength indication (RSSI) (Bulusu, N. et al. 2000), (Konrad L. et al. 2005), time-of-arrival (TOA) fusion (Goud, P. et al. 1991), time difference-of-arrival (TDOA) fusion (Gillette, M. D. et al. 2008), direction-of-arrival (DOA) fusion (Girod, L. et al. 2006), (Niculescu, D. et al. 2003), joint TOA-DOA estimation (Tong, H. et al. 2007), and multi-node TOA-DOA fusion (Wang, Z. et al. 2009), etc.

In all of these systems, usually two types of nodes are available: (1) Target nodes which their position should be found, and (2) Base nodes which enable finding the position of target nodes. In some techniques, such as RSSI, target nodes' position is calculated by themselves and can be reported to base nodes. In some techniques such as TOA fusion and joint DOA-TOA estimation, base nodes are in charge of finding the position of target nodes. These systems are usually categorized as *active remote positioning system*, because target nodes actively contribute in the process of remote positioning.

RSSI incorporates the signal strength of multiple beacon-signals generated by base nodes at the target node. Here, the base nodes are also called anchor nodes as their positions are assumed known. Two RSSI localization approaches have been proposed: (a) based on the communication of the anchor nodes and target nodes: If a target node communicates with an anchor node, then the target node would be in the coverage area of the anchor node. When the target node communicates with multiple anchor-nodes, the target node is localized at the centroid (Bulusu, N. et al. 2000) or weighted centroid (Shen, X. et al. 2005) of these anchor-nodes with respect to a reference point; and (b) based on mapping the measured signal strength set (signature) into a premade received signal strength map of the environment (Konrad L. et al. 2005). Here, the environment should be perfectly known, and a signal strength map should be available.

Techniques that are based on range measurement consist of two categories: (a) those that measure the distances between target node and base nodes to determine multiple circles with their center at base nodes via TOA estimation (Goud, P. et al. 1991). In this case, the target node is localized at the crossing point of these circles; and (b) those that are based on measuring the range differences between pairs of base nodes and the target node (TDOA) to determine multiple hyperbolas with focal points at the two base nodes (Gillette, M. D. et al. 2008). The target node is localized at the crossing point of multiple hyperbolas.

In the techniques based on angle measurement, either the angles of the target node with respect to base nodes is measured by base nodes via DOA estimation (Girod, L. et al. 2006) or the angle of base nodes (beacon nodes) with respect to the target node is measured at the target node (Niculescu, D. et al. 2003). The target node is localized at the crossing point of multiple lines determined by the base nodes position and the measured angles. In this technique, the nodes that are in charge of DOA estimation should be equipped with antenna arrays. Antenna arrays are an array of antennas, e.g., dipole antennas, which are usually located at a fixed distance from each other.

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