Chapter 12
Cooperative Positioning in Vehicular Networks

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ABSTRACT

This chapter introduces the concept of Cooperative Positioning (CP) for vehicular networks, or more precisely, VANETs (Vehicular Adhoc NETworks), as an application of DSRC (Dedicated Short Range Communication). It includes a comprehensive review of available and hypothetical vehicular positioning technologies. Amongst these, the importance of CP for Location Based Services using DSRC is emphasized, and some important issues are addressed that need to be resolved in order to implement CP successfully with standard DSRC infrastructure. The performance bounds of CP are derived. Ranging between vehicles is identified as the main hurdle to be overcome. Time-based techniques of ranging are introduced, and the bandwidth requirements are investigated. The robustness of CP to inter-node connection failure as well as GPS (Global Positioning System) dropout is demonstrated via simulation. Kalman Filter performance for CP is evaluated, and proven to be efficient under conditions such as the consistency of GPS signal availability ranging between vehicles. CP has, however, shown to increase the positioning accuracy to 1-meter level, even in the deep urban valleys where vehicles frequently become invisible to navigation. Overall, CP is proven to be a viable concept and worthy of development as a DSRC application.
INTRODUCTION

Research and development of technologies using DSRC comprise three different domains:

1. Application domain: the interface with drivers/pedestrians, e.g. the type of applications, the forms of warning and recommendation/assistance messages, etc.
2. Communication domain: DSRC boards, related electronic devices, and hardware/software are considered in this domain, using three layers of the ISO model: the application, physical, and MAC (or communication protocol) layers.
3. Positioning domain: Accurate and reliable positioning technologies are the first and foremost requirement of all DSRC Location-based services such as collision avoidance systems.

This chapter focuses on positioning, with special emphasis on reliable positioning for safety purposes, where three issues must be addressed:

1. Position availability
2. Position accuracy
3. Position frequency

Vehicular navigation is generally assumed to operate based on Global Navigation Satellite Systems (GNSS), mostly GPS (Kaplan & Hegarty, 2006). Using 24 to 32 satellites, GPS signals are available globally and GPS receivers can determine the 3D position of the user in an Earth Centered Earth Fixed (ECEF) coordinate system (Kaplan & Hegarty, 2006). The only condition for this 3D positioning is the visibility of at least four satellites at any time. The case where a receiver is capable of positioning itself based only on the GPS signals as input data, we term Individual Positioning. This method suffers from phenomena such as interference, multipath and other sources of errors including unknown delays through the ionosphere and troposphere, which result in a positioning accuracy of about 10 m (Kaplan & Hegarty, 2006).

The unavailability of GPS signals for covered or dense urban areas and the slow update frequency of the position information (at about 1 Hz) are factors negatively influencing the suitability of GPS-based positioning for some applications such as Intelligent Transport Systems (ITS), Locations Based Services (LBS), and safety systems. For example, safety systems, such as collision avoidance which needs accuracy of 1 m, cannot rely solely on GPS-based position data (Shladover & Tan, 2006). Inertial Navigation Systems (INS) (Farrell, 1998) can be used for GPS-positioning accuracy enhancement and temporary GPS outage compensation (Ciurana, Lopez, & Barcelo-Arroyo, 2009; Godha & Cannon, 2007; Hide, Moore, & Smith, 2003; Kaygisiz, Erkmen, & Erkmen, 2004; J. H. Wang & Gao, 2004). Low cost INS suitable for vehicular positioning does not improve positioning accuracy, and its benefits are during poor satellite visibility in which case the GPS accuracy can be maintained for short periods of time.

An innovative approach to achieving more accurate and reliable positioning relies on incorporating data from the sources independent of GNSS into the process of positioning; this is called Cooperative Positioning (CP). Basically, a CP system requires data communication among the participating nodes, users and servers, in a CP process. The focus of this chapter is in the context of DSRC applications. In such a scenario, the most important issue concerning CP is the ranging technique between the vehicles. After discussing this, the performance bounds of CP and its robustness in the context of static and mobile networks is evaluated. The CP algorithm as a localization algorithm is the subject of the last section.