Chapter VI
MAC and Routing Protocols for Vehicle to Vehicle Communications

Xiaobo Long
Rensselaer Polytechnic Institute, USA

Biplab Sikdar
Rensselaer Polytechnic Institute, USA

ABSTRACT
Numerous efforts are currently under progress to enhance the safety and efficiency of vehicular traffic through intelligent transportation systems. In addition, the growing demand for access to data and information from human users on the go has created the need for advanced vehicle-to-vehicle and vehicle-to-roadside communication systems capable of high data rates and amenable to high degrees of node mobility. Vehicular communications and networks are expected to be used for a number of purposes such as for enabling mobile users to transfer data and information from other networks such as the Internet and also for implementing services such as Intersection Decision Systems (IDS), Automated Highway Systems (AHS), and Advanced Vehicle Safety Systems (AVS). In this chapter the authors describe medium access control (MAC) and routing protocols for vehicular networks and the various factors that affect their design and performance.

INTRODUCTION AND BACKGROUND

PHY Layer Issues
Vehicle-to-Vehicle (V2V) communication systems, as part of future Intelligent Transportation Systems (ITS), require bidirectional communication between road-side beacons and individual vehicles. A recent standard for vehicle-to-vehicle communication is the 5.9 GHz Unlicensed National Information Infrastructure (UNII) been developed to support high mobility in IEEE 802.11 protocol. This emerging 802.11 standard for 5.9 GHz is generally referred to as Wireless Access in the Vehicular Environment (WAVE),
which provides Dedicated Short Range Communication (DSRC) for future vehicle-to-vehicle communications. The radio link of these communication systems has a range varying between a few meters and hundred meters (Eichler, 2007). Wireless LAN infrastructure is employed to build inter-vehicle communication based applications. WAVE networks consist of seven 10MHz wide channels, with Channel 178 being a control channel and the other 6 being service channels. The channel switching mechanism in IEEE 802.11h is adapted to perform the multi-channel operation. The physical (PHY) and Medium Access Control (MAC) layers of 5.9 GHz DSRC are based on IEEE 802.11a PHY, which uses an OFDM (Orthogonal Frequency Division Multiplexing) waveform and the IEEE 802.11 MAC respectively. However, the vehicular environment and the requirements for fast access introduce unique requirement on the MAC functionality. While IEEE 802.11 is intended for stationary or low mobility environment, communication in mobile WLAN (wireless local area network) must be able to transfer messages to and from vehicles at speed up to 120 miles per hour. Vehicular traffic scenarios pose greater challenges than the indoor WLAN applications, due to associated driving speed, varying vehicular traffic patterns and driving environments. The new standard is expected to establish requirements for packet error rate performance in these challenging environments. The IEEE is currently working on the IEEE 802.11p Wireless Access in Vehicular Environments (WAVE) standard. There are two types of inter-vehicle communication in WAVE. One is inter-vehicle communication using AP (Access Point). Access points may be provided or co-located at street corners, traffic lights, emergency phones, parking lots, rest areas, gas stations or other shops in service areas. This approach requires development of exclusive infrastructure and is cost expensive. The other is inter-vehicle communication supported by wireless ad-hoc network. In this mode, there is no distributed 802.11 beaconing mechanism. Only the basic carrier sense mechanisms are used, and the RTS (request to send)/CTS (clear to send) access is prohibited, with the purpose to facilitate fast access to vehicles. In ad-hoc network, each mobile vehicle detects other’s position and routing path.

The other potential candidate of vehicle-to-vehicle communication protocol is the IEEE 802.16e Wireless Metropolitan Area Network (WMAN) standard, operating in the 2-6 GHz frequency band. In Europe, a microwave frequency of 5.8 GHz is recommended. Two or four channels with 5MHz bandwidth each and a maximum Equivalent Isotropically Radiated Power (EIRP) of 3 db Watt are available (Baranowski, Lienard & Degauque, 1991).

In vehicle-to-vehicle communication, multipath fading is a major problem for short range mobile microwave links. Multipath fading is caused by reflected waves from the road, vehicles, traffic signs and buildings, which interfere with the direct signal. As a result, the received signal strength is position dependent and time varying. The interference of reflected waves can be destructive to the received radio power and lead to signal outages. Usually the reflected waves have less amplitude than direct wave in vehicle communications and the wave components can be absorbed, scattered or reflected. The received power is determined by the radiating characteristics of beacon and the vehicle antenna as well as statistically distributed reflectors. To study the link performance in multipath fading channels, both deterministic channel models and statistical channel models are developed in literature. A deterministic channel model was derived in (Pfeiffer & Schrei, 1994) for short range radio link,

\[
P_r = P_i G_t G_r \left( \frac{\lambda_0}{4\pi} \right) \frac{1}{n_i} | T |^2
\]

where the subscript \( t \) and \( r \) denote the transmitter and the receiver antenna, respectively. \( P \) indicates