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Intelligent Vehicular Networks and Communications

Fundamentals, Architectures and Solutions

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Contents

Preface

The evolution of vehicular networks has advanced significantly with the introduction of intelligent transportation systems (ITS) dating back to the 1990s, and it keeps evolving with technological innovations. The solutions involved in this multifaceted problem area range from planning to safety implementations, and it is one of the long-term goals of smart city transportation planning and development. Recently, as vehicular communications have been identified as a key technology for enhancing road safety and transport efficiency, governments have started to allocate fixed portions of their communication spectrum to intelligent transport systems.

The diversity of services and communications has introduced new challenges in the design of both network architecture and protocols. Thus, a significant research effort has been put in the definition of complete network architectures, new standard protocol stacks, new routing solutions, and redesigning existing media access control (MAC) [1].

Vehicular communications are mainly classified into vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. V2V communications are between vehicles and V2I is vehicle to roadside unit (RSU) communication. An intelligent vehicular network is a network of vehicles that interact with one another and with infrastructure to transmit and receive data. As vehicular networks are expected to become somewhat ubiquitous by 2016, security elements of these types of networks would also come into the picture. It is clear that false or unauthorized data communication or attacks leading to denial of service within such a vehicular area network (VAN) could cause devastating results, compromising the driver's judgment and/or safety [2].

The rapid development and availability of mobile computing systems and environments have created a highly heterogeneous vehicular network. As a consequence, the provision of seamless connectivity across different wireless networking technologies is very complex, especially in terms of quality of service, routing, and security. Thus, it is expected that the next generation of ITS will reflect a more holistic approach to network solutions [3].

Localization in vehicular networks is critical, especially when used in safety applications. These applications require more reliable and highly accurate localization values to be effective. Generally a satellite-based positioning system such as GPS is used in each vehicle, but these systems are not accurate and are not always available. Reliable and more accurate ubiquitous localization techniques are to be used by vehicles in critical safety and emergency applications and will likely be provided by a combination of different techniques and data fusion [3].

Vehicular communications have been allocated the 5.9-GHz spectrum bandwidth for dedicated short-range communication (DSRC). Still, having a large number of vehicular wireless nodes communicating in a limited space may quickly exhaust the available spectrum. Due to stringent QoS requirements on the DSRC spectrum, it is not possible for all applications to depend only on the licenced DSRC spectrum. To solve the problem of possible spectrum resource starvation in vehicular networks, cognitive radio (CR) has been considered as a potential solution to exploit licenced but unused frequency bands [4]. However, spectrum sensing in vehicular environments is a challenging task due to mobility, shadowing, and other factors.

Big Data endows the novel technique of probability to collect, manage, and analyze vast quantities of data, which indeed offers a smart and intelligent transportation system. This technique enables vehicular networks to store large quantities of real-time data for further analysis [5]. But there are various challenges for empowering Big Data in the vehicular network, such as the need for centralized access to image and video traffic data storage at various locations. In addition, the sole purpose of Big Data is to optimize utilization of massive data storage of vehicle monitoring data for as long as possible to supply information for intelligent transport of vehicles.

For this enormous choice and collection of data, adaptive models have to be built to help transportation companies decide on the best routes to optimize the time of delivery, safety, cost, and fuel consumption. Using Big Data, this collected data can be analyzed, and by quantifying traffic behavior in bad weather, transport companies can make decisions on alternative routes, which allows them to optimize various factors for better fuel efficiency [6]. The need is to develop predictive models and use the data for realistic benefits to the company. Big Data analytics for vehicular ad-hoc networks (VANETs) can be used to improve road safety, optimize routes for drivers, and improve fuel efficiency.

This book is intended for researchers and students who are in the field of vehicular communications, providing detailed insights into fundamentals, architectures, and solutions for ITS. This book includes nine chapters, each further broken down into numbered sections.

Chapter 1 deals with the background of vehicular communications—its evolution models and methods, the standardization of vehicular communication, and technologies in transportation communications. The first section outlines a concern for road safety that has increased across the globe over the past few years due to the reporting of large numbers of traffic accidents. It also points out that road traffic efficiency and marketing policy are areas that could harness the benefits of intelligent transport systems. The next section discusses the evolution of transport systems, starting as a result of massive highway construction in the 1950s, coupled with the advancement of IT in the 1980s. In brief, transportation models generally can be classified into microscopic, mesoscopic, macroscopic, and metascopic models. The third section deals with the advancement in wireless technologies which has brought about various standards in vehicular communications such as ISO, ETSI, IEEE, and so on. The final section highlights the technologies in vehicular communications, categorizing them into existing and possible vehicular communication technologies.

Chapter 2 introduces ITS, which emerged as a result of the growth and advancement in IT for sensors/actuators, artificial vision, control systems, data storage management, and so on. The first part discusses the aims of IT in terms of fostering safety, efficiency, and economy for owners/drivers. The second section details the application and implementation of a comparative study on various ITS projects around the globe. Finally, this chapter discusses the computational technologies and sensing methodologies in ITS—which is the integral part of Chapter 3, Vehicular Network Model.

Chapter 3 targets a brief presentation of the design goals and challenges in a vehicular network model. The first section deals with cluster models in the ITS network: active, beacon, and other clustering models. The second section explains vehicle platooning, a technique where the highway traffic is organized into groups of close-following vehicles referred to as a platoon or convoy. Section 3 discusses the vehicular cloud in ITS: a detailed study and analysis of the vehicular cloud, where vehicles can share computation, storage, and bandwidth resources amongst themselves. Various other items, such as privacy issues related to vehicular networks from the ITS perspective, are also discussed. Section 4 investigates the integration between wireless sensor networks and vehicular networks. Section 5 deals with the Internet of vehicles (IoV), which is actually an integration of three networks: an inter-vehicle network, an intra-vehicle network, and a vehicular mobile Internet. This chapter concludes with a discussion of the working model of vehicular networks, outlining some of the research challenges that still need to be addressed to enable the ubiquitous deployment and widespread adoption of scalable, reliable, robust, and secure ITS architectures, protocols, technologies, and services.

Chapter 4 concentrates on analysis and evaluation of proposed system models, providing deep insight into vehicular communications measures such scalability, latency, and reliability of the particular network. This chapter discusses the feasibility of using alternative technologies for the vehicular network model. The chapter begins with a detailed description of data dissemination models, and continues with a discussion of the mobility management and architectures in vehicular network. The chapter includes a thoroughly investigated case study on mobility management of an IPv6-based vehicular network. The chapter also looked at different type of routing mechanisms and protocols used in vehicular networks.

Chapter 6 explores the essence of cooperative cognitive vehicular networks, and deals with spectral efficiency, spectral scarcity, and high mobility in the same. Additionally, various techniques and strategies of spectral sensing in CR of vehicular communication have been explored, along with case studies. The architectural viewpoint of the cognitive vehicular network is also illustrated. Finally, the chapter ends up with a discussion on various research issues and challenges.

Chapter 7 discusses the practical and experimental peripheries of vehicular communications. Section 1 deals with context awareness in vehicular networks while section 2 focuses on cloud application in transport networks, in design and architectural views. A trust-based information dissemination framework for vehicular networks is investigated in section 3. Knowledge-based intelligent Transportation Systems are the subjects of Section 4. The last two sections discuss hybrid sensor and vehicular networks and intravehicular communications, respectively. Overall, this chapter explores the working principles of controller area network (CAN) protocol and the working function of the onboard unit (OBU), both of which are integral to establishing communication between vehicle or infrastructure nodes. The working principles of roadside unit (RSU) and other infrastructure nodes are also examined.

Chapter 8 explores the possibility of applying Big Data analytics principles in vehicular networks. The chapter discusses technologies of big data for vehicular networks, data validation, Vehicular Carriers for Big Data. In this chapter, we discuss the role of descriptive analytics and predictive analysis, to exploit the historical data and to predict future trends and occurrence in vehicular networks. Various tools that are applicable for Big Data analysis in vehicular networks are discussed. Further, issues and challenges related to real time Big Data analysis in a vehicular network are illustrated. In conclusion, this chapter determines how market policies translate into facilities for both scientific understanding and improving the forecasting, planning, policy-making, and evaluation of vehicular networks.

Chapter 9 discusses the next generation and future trends of ITS, particularly the standardization. It focuses on autonomous vehicles and their effect on ITS. Further, this chapter discusses various research issues and challenges related to ITS and possible solutions where applicable to real world scenarios.

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