Preface

Transportation systems are evolving towards Intelligent Transportation Systems (ITS) and the dependence on road transport in our daily lives has grown massively in recent years, in line with the problems arising from its use: permanent congestion on highways and urban centres, energy waste, CO_2 emissions with consequent impact on public health and high rates of accidents on the road networks. Recent research shows that the incorporation of information and communication technologies within vehicles and transportation infrastructure will revolutionize the way we travel today. The enabling technologies are intended to realize the frameworks that will spur an array of applications and use cases in the domain of road safety, traffic efficiency and driver's assistance. These applications will allow dissemination and gathering of useful information among vehicles and between transportation infrastructure and vehicles in pursuance of assisting drivers to travel safely and comfortably. However, dependable, reliable and real-time communication between vehicles and transport infrastructure are still critical challenges and need to be tackled for the success of these applications.

Understanding the importance of dependable and real-time communication in ITS domain, this book presents contents and significant results that provide the essential methodologies and algorithms for designing and implementing deterministic mechanisms for vehicular networks. The contents of the book are very consistent starting from the overview of basic concepts to the more technical aspects of dependable and real-time communication for vehicular networks along with the simulations, test beds and applications presentation. One of the distinctive aspects of this book is the presentation of work considering the real-time and dependable communication for vehicular networks. This book can contribute to enhance the knowledge of readers especially researchers, engineers and students working in this field. The gradual and interlinked organization of the chapters will enable readers to rapidly grasp the concepts related to dependable and real-time vehicular communication from physical and Medium Access Control layer to the application layers.

A concise overview of each chapter can be presented as follows. Chapter 1 presents the introduction, motivation and application of ITS. Basic architecture along with the communicating entities and functional elements constituting the European ITS Communications is presented. Furthermore, the two main protocol architectures for vehicular communication systems, one developed by the Institute of Electrical and Electronics Engineers (IEEE) and the other by the European Telecommunications Standard Institute (ETSI), are illustrated and compared. The chapter is concluded by providing an insight on the dependable and real-time communication in the scope of vehicular communications. IEEE has paid special consideration to the development of visible light communication (VLC) by introducing the IEEE 802.15.7 standard, which defines the PHY and MAC layer services for visible light personal area networks (VPANs). Although the implementation and use of VLC is still in early stages, there are research teams working in this area to find out solutions to achieve high data rates and reliable links using visible light communication. Therefore, Chap. 2 is fully devoted to visible light communications for cooperative ITS. The chapter presents the achievements of the experimental research in the scope of VLC prototyping for ITS. Special attention is devoted to the development of a VLC prototype based on IEEE 802.15. 7 standard, using low-cost embedded systems as the target platforms.

Strict real-time behaviour and safety guarantees are typically difficult to attain in vehicular ad hoc networks, but they are even harder to attain in high-speed mobility scenarios, where the response time of distributed algorithms may not be compatible with the dynamics of the system. In addition, in some operational scenarios, the IEEE 802.11p MAC may no longer be deterministic, possibly leading to unsafe situations. This calls for a reliable communication infrastructure with real-time, secure and safety properties, which is mandatory to support the detection of safety events and the dissemination of safety warnings. Therefore, Chap. 3 presents a proposal of a deterministic MAC protocol, the vehicular flexible time-triggered (V-FTT), which adopts a master multi-slave time division multiple access (TDMA), in which the road-side units act as masters to schedule the transmissions of the on-board units. The presented work analyses the proposed V-FTT protocol by quantifying an infrastructure deployment in motorways, particularly defining the usual coverage range for each RSU and the spacing between RSUs. A comprehensive survey on MAC protocols for vehicular networks, and especially targeting infrastructure TDMA-based deterministic protocols, has been presented in Chap. 4. In addition, the chapter presents a proposal for scheduling safety messages in the scope of wireless vehicular communications based on the V-FTT protocol.

Chapter 5 presents a comprehensive study on the efficiency of MAC protocols based on IEEE 802.11p/WAVE standard to timely deliver safety messages. Several aspects of an infrastructure-based MAC protocol, detail characteristics needed for safety-critical messages and bounded delay MAC protocols within specific scenarios, have been covered. Besides the V2I or I2V communication, there are situations where there is a need of relying exclusively on V2V-based communications to disseminate safety messages. Therefore, the chapter also presents an approach for cases where the infrastructure may not be accessible, or even not feasible to have total RSU coverage. Moving forward, Chap. 6 presents a direction-aware cluster-based multi-channel MAC protocol for vehicular ad hoc networks (VANETs) in which vehicles travelling in the opposite direction may result in a short communication period. How the cluster is made, and how the cluster head is elected based on the eligibility function that considers the number of connected neighbours, average speed deviation and the average distance between neighbours and itself, is elaborated. The chapter introduces direction-based clustering and multi-channel medium access control (DA-CMAC) protocol which aims to reduce access and merging collisions in the channel, by grouping the time slots into two sets based on the direction of movement.

Chapter 7 presents work on the predictable vehicular networks to provide reliability and predictability. The chapter shows how the MAC protocol for wireless mobile ad hoc networks can recover from timing failures and message collision and yet provide a predictable schedule in a time division fashion without the need for external reference. In addition, how mobile ad hoc networks and vehicular networks can organize themselves for emulating virtual nodes as well as emulating replicated state machines using group communication is presented. Vehicular networks are often facing the scalability problems due to high-speed mobility scenarios and under high dense vehicular environments. This results in high end-to-end delay and high packet drop rates; thus compromising the reliability of vehicular communications. Considering these challenging issues, Chap. 8 presents a fault-tolerant architecture to improve the dependability of infrastructure-based vehicular networks. The presence of road-side units (RSUs) and a backhauling network adds a degree of determinism that is useful to enforce real-time and dependability, both by providing global knowledge and supporting the operation of collision-free deterministic MAC protocols.

Chapter 9 explores and presents the development of the proactive handover mechanisms required to provide seamless connectivity and dependable communication in VANET environments. The chapter also presents classification of various handover mechanisms and proposes a new model of the handover process based on cumulative probability. In addition, results from simulation and analytical models have been presented, and a prototype is being deployed to further explore the issues associated with handover process. Chapter 10 presents work on the consideration of realistic road conditions for vehicular networks and elaborates a mathematical model that considers microscopic parameters. The model is able to capture the impact of road constraints such as traffic lights and road incidents on the traffic flow. It has been shown how the microscopic and macroscopic characteristics of vehicles moving on the roads are utilized for the improvement of vehicular connectivity dynamics. eCall is an initiative by EU with the purpose to bring rapid emergency assistance to an accident location. Hence, Chap. 11 shows how eCall is implemented via an Android phone using the cellular network and the IEEE 802.11p (ITS-G5) as communication medium. The main aim of the proposed system is to speed up the integration and implementation of eCall and accident detection mechanisms in legacy vehicles. In addition, this work provides a cost-effective and portable solution of eCall implementation. Experimental results related to accident and rollover detection are illustrated and discussed.

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