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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport System (ITS).

Introduction

By introducing wireless communications between vehicles and between vehicles and road infrastructure or other fellow road users such as pedestrians and bicyclists, the road environment will become safer and potentially more environmentally friendly. Many different cooperative intelligent transport systems (ITS) applications have been suggested for the vehicular environment, both for road traffic safety and efficiency. Depending on application area, the resulting communication requirements are quite diverse. Different wireless access technologies have different features and different benefits and all cooperative ITS applications suggested for the vehicular environment cannot be solved with one single technology due to resource constraints and diverse requirements. Vehicular *ad hoc* networks (VANETs) based on, e.g. IEEE 802.11p [i.2], will be used for road traffic safety applications, [i.1], [i.2]. However, other wireless carriers such as cellular technology (e.g. 3G, LTE) will also be used to support different cooperative ITS applications in general.

The major difference between VANETs and cellular technology is that there is no central controller in the former. The central controller usually has perfect knowledge about the nodes within range and it can distribute and optimize the available resources. However, in cellular technology there is a central controller in the form of a base station present, otherwise communication is not possible. VANETs do not need coverage by base stations - instead if there is someone to communicate with, communication will take place directly in between any two nodes within range of each other. The *ad hoc* structure is advantageous, since it does not require coverage by base stations, but without a central control mechanism, problems with scalability may arise. Due to the lack of a central coordinator, all nodes typically transmit on a common frequency channel. This frequency channel, called the control channel, is known *a priori* to all nodes. For road traffic safety applications, this channel is where the most important data will be transmitted. To facilitate additional cooperative ITS applications with higher bandwidth requirements, two or more service channels are also available. However, the control channel is the core of a VANET.

Many emerging road traffic safety applications will be based purely on broadcast communication, [i.3], i.e. one-to-many. Due to the broadcast communication, the assurance of sufficient reliability is limited. A sender does not know if the transmitted data has arrived at the intended receiver because no acknowledgments of successful reception are possible in broadcast mode (receivers cannot send an acknowledgment to the sender since the number of intended receivers is not known and this may flood the network). One way to increase the reliability in broadcast mode is instead to repeat the same message several times.

Ultimately, cooperative ITS applications for enhancing road traffic safety should be designed taking the characteristics of a VANET into account. These characteristics can be summarized by: a decentralized network topology, a common control channel and broadcast as the preferable communication mode. The utilization of the control channel should be carefully designed so it can be used to its maximum. The medium access control (MAC) protocol schedules access to the shared control channel. A MAC protocol suitable for road traffic safety applications in VANETs should be decentralized such that it functions without a central controller, it should support broadcast such that channel access is fair and predictable for all participating nodes and it should aim to minimize interference between transmitters to maximize scalability. Further, as road traffic safety typically involves interaction with vehicles located in the vicinity of each other, the MAC method should maximize the packet reception probability for the closest neighbouring nodes.

ETSI has standardized a VANET protocol based on a profile of IEEE 802.11p [i.2], called ITS-G5 [i.1], which uses the MAC method carrier sense multiple access (CSMA). CSMA has some of the desired properties, i.e. it is decentralized and aims at minimizing interference between any transmitters. However, it does not necessarily maximize the packet reception probability for the closest neighbouring nodes or provide fair and predictable channel access for broadcast. The present document therefore scrutinize time slotted MAC protocols, to determine if these can utilize the common control channel more efficiently than the current proposed MAC from IEEE 802.11p [i.2].

1 Scope

The present document describes the use of time slotted MAC algorithms in VANETs. Two specific MAC methods, self-organizing time division multiple access (STDMA) and mobile slotted Aloha (MS-Aloha), are described in detail, not excluding other time slotted approaches. Time slotted approaches are suitable for road traffic safety applications as the maximum delay is predictable and channel access can be made fair among all participating nodes even during broadcast. However, time slotted approaches do require synchronization between nodes to build a common framing structure for transmissions, something that is not needed for non-time slotted approaches, e.g. CSMA as used by ITS G5 [i.1]. In the literature of time slotted MAC protocols for VANETs, synchronization is provided by a global navigation satellite system (GNSS) such as the global positioning system (GPS) or Galileo. The present document also describes the GNSS synchronization issue as well as proposals for dealing with synchronization when the GNSS signal is absent or weak, which can occur in urban environments and tunnels. Further, time slotted approaches use fixed-length time slots for transmissions, implying that packet lengths are fixed. However, as the physical (PHY) layer suggested for VANETs offers several transfer rates, this means that different packet sizes can be obtained in the fixed time slots. The analysis of the most preferable configuration in this context constitutes the second technical topic covered by the present document. Finally the present document also deals with the coexistence between CSMA and time slotted MAC approaches nodes. The backward compatibility and coexistence are of crucial importance since the first generation of VANETs will use CSMA technology. This represents the third and final topic of the present document.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI ES 202 663: "Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.2] IEEE 802.11p: 2010: "IEEE Standard of Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements; Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications; Amendment 6: Wireless Access in Vehicular Environments".

[i.3] ETSI TR 102 638: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions".