An Overview of QoS Enhancements for Wireless Vehicular Networks

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Abstract

Vehicular ad hoc networks (VANETs) allow vehicles to form a self-organized network without the need for permanent infrastructure. Even though VANETs are mobile ad hoc networks (MANETs), because of the intrinsic characteristics of VANETs, several protocols designed for MANETs cannot be directly applied for VANETs. With high number of nodes and mobility, ensuring the Quality of Service (QoS) in VANET is a challenging task. QoS is essential to improve the communication efficiency in vehicular networks. Thus a study of QoS in VANET is useful as a fundamental for constructing an effective vehicular network. In this paper, we present a timeline of the development of the existing protocols for VANETs that try to support QoS. Moreover, we classify and characterize the existing QoS protocols for VANETs in a layered perspective. The review helps in understanding the strengths and weaknesses of the existing QoS protocols and also throws light on open issues that remain to be addressed.

Keywords: QoS, VANET, Inter-Vehicle Communications, MAC, Routing

1. Introduction

Nowadays, vehicles are more intelligent and soon to be equipped with communication devices that enable the possibility of exchanging information between them (Guo et al., 2014). This is possible as the vehicles form a network between them within a wide range. VANET provides a wireless communication between moving vehicles, using a dedicated short-range communication (DSRC). These types of communications allow vehicles to share different kinds of information, for example, safety information for the purpose of accident prevention, post-accident investigation or traffic jams (Al-Sultan, Al-Doori, Al-Bayatti, & Zedan, 2014).

VANET is a new form of wireless networks derived from Mobile Adhoc Networks or MANET. The features of VANET are typically similar to the operation technology of a mobile ad hoc network (MANET) in the sense that the self-organization, self-management, low bandwidth, and shared radio transmission conditions remain the same (Sharef, Alsaqour, & Ismail, 2014). However, it is differentiated from MANET as VANET has a specific characteristic in terms of mobility nodes. Nodes in VANET tends to have a certain high speed and tentative mobility.

Nevertheless, delivering a high level of performance provided towards users in VANET is quite a challenge. High levels of QoS in traditional networked environments can often be achieved through resource reservation and sufficient infrastructure, however, these cannot be guaranteed in dynamic, ad-hoc environments, such as those used in VANETs due the VANETs inherent lack of consistent infrastructure and rapidly changing topology (Zeadally, Hunt, Chen, Irwin, & Hassan, 2012). Thus, recent researches show efforts in minimizing the amount of time required to rebuild a broken connection. This can be done by implementing routing protocols that satisfy QoS requirements (Ramirez & Veiga, 2007; Niu, Yao, Ni, & Song, 2007b). Other possible approach is looking at the MAC layer solutions. One of the examples is by deploying a multi-channel MAC, as the IEEE 802.11 MAC protocol is not suitable for real-time traffic and QoS provision (Kakarla & Siva Sathya, 2012).

Attending to the emergence of VANET innovations, we survey the existing solutions on the purpose of enhancements in terms of QoS. Based on our analysis, there are some findings on challenges to respond the deployment of QoS in VANET that can be a consideration for future researches.

The remainder of this article is organized as follows. Section 2 is about a study on the state of the art of QoS enhancements in a layered perspective. The research directions are discussed on section 3. Finally, Section 4 will have concluding remarks.

2. Current Solutions

There are several existing solutions to improve QoS deployment on vehicular networks (Korkmaz et al., 2006) (Yan et al., 2011). The solutions are examined from a layered perspective, from the link layer to the network layer. From the link layer, the effort to be made is implementing MAC solutions. In the other hand, QoS routing solutions will be another approach to enhance QoS in the network layer's perspective.

2.1 Link Layer

MAC protocols that usually developed for VANET are where all vehicles share a common channel in the network. WAVE MAC uses contention-based access. (Wang, Leng, Zhang, & Fu, 2011) In order to deploy a QoS, high contentions and collisions must be overcome. The protocols proposed below use multi-channel MAC as the performance of single-channel MAC protocols degrades as density of vehicles increases.

In wireless channel access, the control must be surveyed in terms of the access of the medium. The transmission of data should be coordinated to avoid a large number of collisions. This can lead to the lost of data delivered, hence the QoS will not be ensured. MAC should control the access in a efficient and reliable way so that the high reliability and low latency is ensured.

For the summary, the major problems that a MAC protocol for VANETs has to solve are to:

1. Transmission Collisions
2. The Hidden Terminal Problem
3. Exposed Node Problem

In this case, the transmission collisions issue is the most encountered problem in providing QoS.

Based on this concerns, several MAC protocols are proposed to ensure a better delivery of information in a wireless network where the mobile nodes are vehicles.

2.1.1 Q-VCI MAC Scheme

The IEEE 802.11 MAC protocol might be not the best solution for real-time traffic and QoS provision. The solution is Multichannel MAC protocol. This protocol is proposed to enhance the saturation throughput of SCHs while ensuring the transmissions of safety messages. The approach aims to satisfy QoS requirements using a DSRC band with single interface in VANET. Channel access is prioritized by tuning DSRC configuration parameters. This multichannel MAC can adaptively change the contention window for different services and dynamically adjusting intervals of control channels and service channels working in multi-rate.

Fixed-duration Split-phase Channel Coordination in WAVE protocol makes a low throughput. This drawback of inflexibility has been questioned and improved. Channel accessing time is used by adjusting the duration of CCHI and further divided it into safety interval and Wave Service Announcement (WSA) interval, while the non-safety application is provided on SCHs after a successful WSA/ACK or RFS/ACK handshake during WSA interval. This enhancement results an increase of the throughput. Results are presented for optimized time intervals of control channel (CCH) and service channel (SCH), based on traffic condition.

The protocol uses various parameters like transmission range, transmission power and window size are varied adaptively depending on the network's density. Prioritization of traffic has been made as required by individual application for QoS provisioning in Vehicular environment. A short Contention Window is selected for highly prioritized data like critical safety information. This proposed MAC is able to help IEEE 1690.4 MAC support QoS services. However, it will perform poorly in densely populated scenarios due to contention and frequent collision of WSA/RFS messages. This also ignores channel failure and repair. (Wang et al., 2011)

2.1.2 Clustering-Based Multichannel MAC Protocol

Clustering is one of the solutions proposed in a multichannel MAC protocol. This aims to provide quick emergency message dissemination and bounded delay. The clustering-based multi-channel MAC protocol proposed is bundled with a QoS guarantee for safety and non-safety applications. Making the best use of the dedicated short range communications multichannel architecture, a cluster- based multichannel communications scheme is proposed to support not only public-safety message delivery but also a wide range of future multimedia (e.g., video/audio) and data (e.g., e-maps, road/vehicle traffic/weather information) applications

The safety messages are delivered in a timely manner using time-division multiple accesses broadcast and aggregated by the cluster-head vehicles and sent using a contention-based access protocol, while increasing throughput for non- real-time data. This clustering-based DSRC architecture that takes into account both reliability and delay. Safety messages that tend to be needed real-time used this type of communication scheme to reduce data congestion.

The Cluster Head (CH) takes on a managerial role and facilitates intra- cluster communication by providing a TDMA schedule to its cluster members; adjacent clusters are assigned different CDMA codes to avoid interference be- tween clusters. A contention-free TDMA-based MAC protocol is used within a cluster to provide deterministic delay. A contention-based protocol is used for communication between clusters. Additionally, multiple channels are used with high priority traffic. The safety messages are collected and forwarded by cluster- head and real-time packets between cluster-heads help to improve performance. These vehicular clusters disseminate GEOCAST message inside a VANET.

The clusters are defined based on their mobility. The protocol pools cars in close proximity and travelling in the same direction into groups called clusters. The seven WAVE channels are divided into four categories: an inter-cluster control (ICC) channel, an inter-cluster data (ICD) channel, a cluster-range control (CRC) channel and four cluster-range data (CRD) channels. Each cluster has a self-elected leader, called the cluster Head (CH), which controls the cluster and is also the source of synchronization. Every node is equipped with two transceivers that can operate simultaneously on seven separate and different channels while using CDMA codes. It is slow in overall channel reservation time. The cluster head uses one transceiver to collect and deliver emergency messages and control messages within its cluster, and uses another transceiver to exchange consolidated safety messages among cluster head. Slot Reservation and Back off Differentiation are the MAC mechanisms used.

This results a substantial reduction in probability of message delivery failure, when compared to traditional 802.11 MAC. This proposed scheme can efficiently support the non real-time traffics while guaranteeing the real-time delivery of the safety messages. Their model can derive the desirable contention-window size, which can best balance the tradeoff between the delay of safety messages and the successful rate of delivering safety messages.

However, due to the lack of efficient topology control mechanism, the cluster- based approach is more suitable for VANET with less topology variation (Su & Zhang, 2007).

2.1.3 MQOG

Multichannel QoS Cognitive MAC dedicated for vehicular networks or MQOG is one of the solutions for different traffic scenarios. This protocol can adapt to either urban and suburban traffic environment. This protocol makes a channel negotiation on a desirable control channel where the data is delivered on the other channel with no contention. Interference and multipath can be an issue in vehicular environments. Thus MQOG assesses the quality of channel before transmitting by employing a dynamic channel allocation and negotiation algorithm in order to get significant increase in channel reliability and throughput.

QoS of safety and non-safety frames are considered and the channel assignment problem was solved as well.

This protocol makes use of the ISM band and UNII-3 in case all available channels in DSRC were considered unreliable.

The proposed MAC ensures the faster reception of safety messages with smaller latency and less L2 retransmission rates. thsi protocol improves in terms of throughput. and packet delivery ratio (Ajaltouni, Pazzi, & Boukerche, 2012).

2.2 Network Layer

Using the term QoS to describe current protocols in this category is a trifle misleading. In an ideal sense, a QoS protocol should provide guarantees about the level of performance provided. This is often achieved through resource reservation and sufficient infrastructure. However, in an ad-hoc wireless network, this is a difficult task. With the exception of the potential for roadside units, there is no infrastructure to be relied upon for guaranteed bandwidth. The dynamic and cooperative nature of an ad-hoc network does not lend itself to resource reservation. What variables can we adjust in order to provide guarantees about service?

Most QoS routing strategies attempt to provide a robust route among vehicles. Factors such as link delay, node velocity and trajectory, node position, distance between nodes, and reliability of links all contribute to the stability of a particular route. Some performance guarantees can be made in vehicular routing, and we survey algorithms that can estimate the duration for which a route will remain connected, and minimize the amount of time required to rebuild the connection if it is broken.

2.2.1 Multi-Hop Routing Protocol for Urban VANETs

The IEEE 802.11 MAC protocol might be not the best solution for real-time traffic and QoS provision. The As in the vehicular networks there are high mobility and frequent link disconnection, delivering a packet using a robust multi-hop path is a challenge to respond this issue. MURU, a multi-hop routing protocol can find robust paths in urban VANETS in order to get high end-to-end packet delivery ratio with lower overhead. This protocol approach is by minimizing the probability of path breakage using mobility information of each vehicle in the network. TO select the most robust path, this protocol uses a metric called expected disconnection degree (EDD). MURU is scalable for VANETs as it is fully distributed and has fewer overheads. Plus, MURU does not require any pre-installed infrastructure

MURU significantly outperforms existing ad hoc routing protocols in terms of packet delivery ratio, packet delay and control overhead (Mo, Zhu, Makki, & Pissinou, 2006).

2.2.2 GVGrid

GVGrid is a QoS routing protocol for multi-hop VANETs. This routing protocol is deployed by constructing a route on demand from a source, which can be a fixed node to vehicles in a specified region. GVGrid aims to maintain a high quality route. A robust route by this mean is that a route for high quality communication and data transmission between V2I and V2V.

GVGrid exploits the geographical information for its consideration in routing. The geographical area is taken from the geographical information and divided into grids and forwards packets along the roads crossing different grids. Every vehicle knows in advance its geographical positions and direction through digital map, which is equipped with each vehicle. This routing is more scalable so that the deliverance of packets is more ensured, resulting the QoS communication

GVGrid could provide routes with longer lifetime. However, it assumes a dense network, which does not always hold true in VANETs (Sun, Yamaguchi, Yukimasa, & Kusumoto, 2006).

2.2.3 Prediction-Based Routing

Route breakage is always an issue in VANET due to the dynamic mobility of vehicles which play as nodes in this network. Prediction based routing (PBR) protocol is made for mobile gateway scenario and benefits the predictable mobility pattern of vehicles on highways. By using predictable mobility pattern of vehicles on highways, this protocol uses predicted route lifetimes to create new routes before the existing ones fail.

The frequent route failures result in a significant amount of time needed for repairing existing routes or reconstructing new routes. In spite of the dynamic mobility, the motion of vehicles on highways is quite predictable compared to other mobility patterns for wireless ad hoc networks, with location and velocity information readily available. This can be exploited to predict how long a route will last between a vehicle requiring Internet connectivity and the gateway that provides a route to the Internet. Successful prediction of route lifetimes can significantly reduce the number of route failures.

This protocol results significant reductions in route failures as it uses preemptive routing. Overhead of preemptive routing is kept in check due to the ability of PBR to predict route lifetimes (Namboodiri & Gao, 2007).

2.2.4 Delay and Reliability Constrained QoS Routing Algorithm

There is a proposal on a ink Delay and Reliability constrained QoS routing algorithm (DeReQ) for multimedia communications in VANETs. The traffic density is considered aside with the impact of the link duration for a new link reliability mathematical model to support this protocol. DeReq is an extension of AODV protocol that can achieve a satisfying performance

DeReQ algorithm aims to find a route that is compliant with delay requirements and reliable. It has link reliability and delay optimized routing algorithm. The algorithm can adaptively set the reliability bound for path selection by mapping reliability bound to a bounded integer

DeReQ algorithm can make a significant performance improvement alongside the AODV protocol, compared to the original AODV protocol, a QoS-extended AODV (AAC), and the location-based routing protocol (LBM). (Niu, Yao, Ni, & Song, 2007a)

2.3 Cross Layer Solutions

A cross-layer solution benefits the design between packet routing and medium access control (MAC) for a vehicular ad hoc network (VANET) in order to guarantee special quality of service (QoS) requirements. By combining the two layers or other layers in the network, the trust in deployment of QoS in this particular wireless network environment can arise.

2.3.1 Cross-Layer Design for Packet Routing in Vehicular Ad Hoc Networks

To guarantee QoS requirements, it is needed to have a ross-layer design between packet routing and medium access control (MAC) for a vehicular ad hoc network (VANET).

The solution benefits the advantages of a cluster-based forwarding mechanism to the MAC. Collisions can be decreased and the packet forwarding is more con- trolled. MAC protocol helps the deployment as it provides cluster and neighbor node information to the routing algorithm.

This proposed cross-layer protocol has a good performance. The protocol performs better than the 802.11 MAC. This mechanism can achieve the required packet delay for an information propagation area.

The mechanism used for spatial reuse is not involved in this new cross-layer concept. This issue and other advantages might be found by enlarging the design in the future. Other advantages might be found by enlarging the design by other layers like the physical layer. (Wiegel, Gunter, & Großmann, 2007).

2.3.2 Cross Layer Design of Fragmentation and Priority Scheduling in Vehicular ad hoc Networks

A cross layer scheme of fragmentation and priority scheduling is proposed here to respond the lack support of QoS differentiation and degraded channel utilization in IEEE 802.11 DCF protocol.

The approach focuses on time varying property of the wireless channel and networks load condition. This cross layer scheme estimate the cannel condition in the MAC layer. When a channel is busy or idle, the adaptive contention window channel is set. To support the performance, an adaptive fragmentation algorithm is used to provide robust when the orders of magnitude varies.

This cross layer scheme can provide a timely delivery guarantees to different classed of real time date traffic and increase the throughput. The simulation results show that the performance of the cross layer scheme was compared with that of the ieee802.11e protocol

Nevertheless, this algorithm can be improved further on by considering additional available information, such as routing protocol in VANETs (Liu, Sheng, Lv, Li, & Ma, 2008)

3. Challenges and Open Issues

In the future, as connectivity on the road is used for many applications, static gateways can be used to supplement mobile gateways, making up for the lack of density in certain areas and at certain times. WLAN technologies other than IEEE 802.11b with a higher communication range would also prove useful to offset reduced density on state highways and rural roads, which generally do not have enough vehicle density. A higher range would also reduce the route lengths, which reduces route failures. The tradeoff of increasing range is decreasing capacity due to the radio interference among nodes. This issue needs to be researched further, especially looking at power control to vary the range depending on vehicle density. Furthermore, pricing models for the scenario can be used to ensure the viability of the scenario for all concerned. Overall, there are still opportunities in resolving open issues of QoS protocols. A high level of QoS is needed considering that multimedia applications are the most wanted items in a mobile communication.

4. Conclusion

Based on the analysis done regarding the QoS deployment in vehicular net- works, we can derive that there are some research directions to be considered as future works. One of the aims QoS deployment is to support voice, video applications, and other multimedia communications that need a good delivery of information. However, QoS deployment in wireless networks especially in an environment where the nodes move dynamically is a challenge as the network topology changes frequently. Also, the wireless channel capacity is limited in VANET. Another issues are the multi-hop communications path problem and link variability.

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