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A Review on Congestion Control in MAC Layer of VANET

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Abstract: Vehicular Ad hoc Networks (VANET) play an important role in future car-to-car communication systems and related applications like Self-Organizing Traffic Information Systems (SOTIS), which are based on broadcast/geocast transmission schemes. Congestion control for VANETs has not been studied thoroughly so far – but this feature will be extremely necessary for VANET applications and network performance. Due to the high mobility and the resulting highly dynamic network topology, congestion control will need to be performed in a decentralized and self-organized way, locally in each VANET node. This paper presents a novel concept for utility-based congestion control and packet forwarding in VANETs. The control algorithm uses an application-specific utility function and encodes the quantitative utility information in each transmitted data packet in a transparent way for all users within a local environment. A decentralized algorithm then calculates the "average utility value" of each individual node based on the utility of its data packets and assigns a share of the available data rate proportional to the relative priority.

Keywords: VANET, MANET, Congestion Control.

I. INTRODUCTION

Vehicular Ad hoc Networks (VANets) are employed by Intelligent Transport Systems (ITSs) to operate wireless communications in the vehicular environments. VANets are designed to provide a reliable and safe environment for users by reducing the road accidents, traffic jams, and fuel consumptions, and so on. The VANets' users can be informed of hazardous situations by vehicular communications and exchanging the information about surrounding environments [1], [2]. VANets are a type of Mobile Ad hoc Networks (MANets). The vehicles in VANets are similar to the mobile nodes in the MANets. Although VANets inherit most of the characteristics of MANets, VANets have some unique characteristics such as high mobility, high rate of topology changes, and high density of the network, and so on. Thus, VANets have different characteristics in comparison with MANets [7].

Congestion occurs in the channels when these channels are saturated by the nodes competing to acquire the channels. Indeed, by increasing the vehicle density, the number of channel collisions increases occurrence of congestion in the network. The occurrence of congestion increases the delay and packet loss (especially for safety messages) leading to mitigation of the VANets' performance [8]. To guarantee the reliability and safety of the vehicular communications, and to improve the performance of VANets, Quality of Service (QoS) should be supported. Controlling congestion is an effective way that should be employed to support the QoS [2], [4]. By controlling the congestion, the delay and packet loss and consequently the performance of VANet can be improved that help have a safer and more reliable environment for VANets' users [12]. Due to the special characteristics of VANets, the congestion control strategies are different compared to the congestion control strategies proposed for MANets [12].

The congestion can be controlled in VANets in different ways such as by tuning the transmission rate, tuning the transmission power, determining the contention window size and Arbitration Inter-Frame Spacing (AIFS), and prioritizing and scheduling the messages [13]. However, congestion control strategies in VANets face some problems including high transmission delay, unfair resource usage, inefficient bandwidth usage, communication overhead, and computing overheads, and so on [10], [13]. Therefore, new strategies, considering these problems, should bedeveloped to control the congestion in VANets, especially in critical situations where the safety messages should be transferred without any significant delay and packet loss.

II. COMMUNICATION PATTERN IN VANETS

In VANets, each vehicle may have different roles including sender, receiver and router to conduct vehicular communications in the network. Vehicular Communication (VC) is divided to three major groups: 1) Inter-Vehicle Communication (IVC), 2) Roadside-Vehicle Communication (RVC), and 3) Hybrid Vehicle Communication (HVC).

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IVCs are the communications between vehicles that are completely free of infrastructures. This group of communications needs OBUs for carrying out the communications. IVCs are classified into Single-hop IVCs (SIVCs) and Multi-hop IVCs (MIVCs) communications. SIVCs support the applications requiring the short range communications like the lane merging application. In the other hand, the MIVCs are used by the applications requiring the long range communications like the traffic monitoring applications. RVCs develop the communication between OBUs and RSUs. RVCs are composed of Sparse RVC (SRVC) and Ubiquitous RVC (URVC). SRVCs provide communication services in hotspots, while URVCs provide the high speed communications for all the nodes. For full coverage in all roads (in large countries), the URVCs may require extra equipment. Finally, HVCs are used for making communication between vehicles and roadside infrastructures for extending the coverage area of RVCs. Also, when the vehicles do not resident in the range of roadside infrastructure, HVCs can use other intermediate vehicles as the mobile relay nodes. Therefore, HVCs increase the transmission range of RVCs. In the other hand, HVCs cannot guarantee the connectivity in low vehicle density environments. Figure 1. demonstrates the communication patterns in VANets.

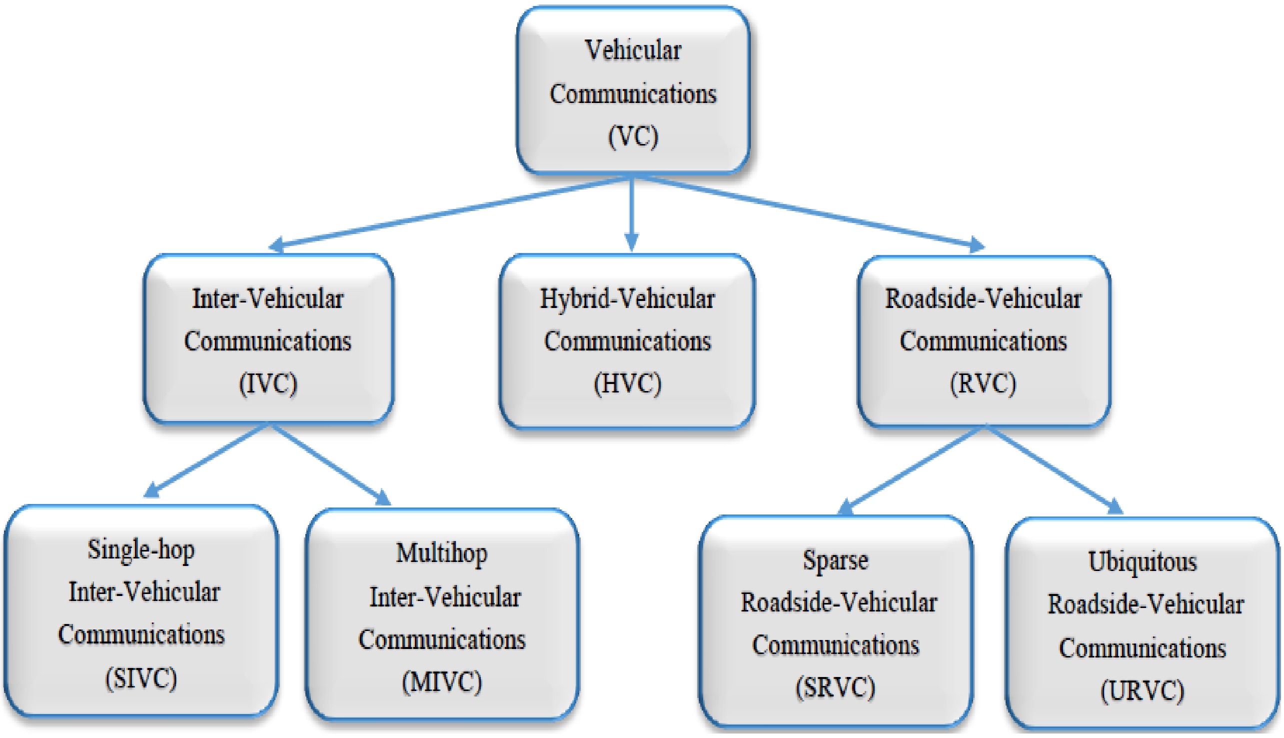

Figure 1. Communication Pattern in VANET.

III. CONGESTION CONTROL

Generally, in each network, there are some resources that are shared between the users of the network competing to acquire those resources. Adjusting the data rate used by each user is essential to control the network load and prevent the channel overload. When the packets arrive to a router node and the router cannot forward them, the router drops the new packets, whereas these packets consumed a significant amount of resources for arriving to this node. One of the main reasons, which results in dropping the packets by the router nodes, is the congestion. Indeed, when the capacity of the network is less than the networks load, the packets are dropped due to the congestion occurrence in the networks. The throughput of the network significantly reduces due to the network congestion. Therefore, congestion control should be performed to prevent the congestion occurrence and increase the successful delivery of data in the networks. In addition, controlling the congestion enhance the bandwidth utilization, responsiveness, and fairness usage of network resources.
Transmission Control Protocol (TCP) employs the slow-start algorithm as the main part of the congestion control process in the networks. In the slow-start algorithm, the congestion window size is initially set to 1, 2, or 10. When an acknowledgment is received, the congestion window size is doubled. Once a packet is lost or the congestion window size exceeds the predefined slow-start threshold, TCP considers that the congestion occurred in the network. In this situation, TCP increases the congestion window size by one unit in each Round-Trip Time (RTT) to reduce the channel loads and control the congestion.

Various congestion control strategies accomplish based on TCP to avoid the congestion occurrence in the networks. TCP-Tahoe is a congestion control strategy referred by many congestion control strategies. Using the TCP-Tahoe strategy, the congestion is detected by determining the timer for acknowledgments. In the TCP-Tahoe strategy, when congestion occurs in the network, the slow-start threshold is set to half of the current congestion window size and the slow-start algorithm is reset to the initial state. In TCP-Reno strategy, however, when three duplicate acknowledgements are received, the congestion window size is set to the half of the current value, and the slow-start threshold is set to the current value of congestion window size.

The packet losses are considered to detect the channel overloading in the traditional TCP congestion control strategies. However, when the bandwidth is available, the packets losses may still occur due to the random bit corruption, channel error, and route failure. Also, using the packet losses is not a sufficient for determining the level of contention in the channels. Therefore, in addition to packet losses, other parameters of network conditions should be considered for controlling the congestion in the networks.

Although TCP congestion control strategies efficiently carry out on the Internet, these strategies are not efficient for MANets due to the unique characteristics of these networks. Indeed, the standard TCP faces many issues in MANets due to unique characteristics of these networks, different environments, different protocols, and different architecture. The unique characteristics of MANets include the shared wireless channels, node mobility, and multi-hop wireless communications and so on. Due to the node mobility in MANets, the frequently routes break or change lead to increasing the packet loss or delay for delivering the packets. In the Internet, congestion occurs in a single router node, while, in MANets, the congestion occurs in an area because of employing the shared medium in these networks. Moreover, TCP congestion control strategies consider that all packet losses are caused by congestion, while, in wireless mobile networks, the packet can be lost due to the congestion occurrence, channel errors, and route failures. Therefore, TCP congestion control strategies are not efficient in mobile ad hoc networks and result in a performance reduction.

The EDCA mechanism is used in the IEEE 1609 WAVE protocol for determining the priorities for different types of messages generated in VANets. In EDCA, the high priorities are assigned to the safety messages to occupy the channel and transfer with less delay compared to the other low priority messages. Indeed, EDCA determines a smaller contention window size and AIFS for high priority safety messages to acquire the channels quickly.

The congestion detection part employs some information from the application layer to detect the congestion occurrence in the network. In addition, the congestion can be detected by sensing the channel in the physical layer and measuring some parameters like channel usage level. The congestion control can be conducted in different ways in different network layers. The application layer can contribute to congestion control by tuning the message generation rates of different applications, and reducing the traffic loads as well as congestion in the networks. The network layer can control the congestion by smart routing algorithms that efficiently rebroadcast the messages and mitigate the congestion. The prioritizing and scheduling messages at MAC layer can significantly help control the congestion in VANets. Moreover, the control and service channels can employ to transfer the prioritized safety and non-safety messages, respectively.

In VANets, congestion control strategies can be classified based on the means and parameters employed for controlling the congestion. Thus, the congestion control strategies can be classified into the rate-based, power-based, CSMA/CA-based, prioritizing and scheduling-based, and hybrid strategies. The rate-based strategies adjust the transmission rate based on the channels conditions to reduce the collisions in the channels. The power-based strategies dynamically tune the transmission power (range) to control the channels loads. The CSMA/CA-based strategies control the congestion by adjusting parameters of CSMA/CA protocol such as the contention window size and/or AIFS. In prioritizing and scheduling-based strategies, the priorities are defined for the message, and then the prioritized messages are scheduled to transfer in the control and service channels. Finally, in the hybrid strategies, all or some of the means or parameters used in previous categories are employed to avoid or control congestion occurrence in the connect network [13].

IV. CONCLUSION

Considering the significant impact of the transmission range and rate on the channel conditions, these two parameters are used to control the channel loads as well as congestion. The high transmission range can increase the number of vehicles receiving the messages, especially the safety messages. However, the collision rate increases by increasing the transmission range. A high transmission rate also increases the performance of VANets' applications due to updating the information. However, the channels are overloaded by increasing the transmission rate. Therefore, the optimal values for these parameters should be obtained to avoid channels saturation. Obtaining the optimal values of transmission range and rate in reasonable time is a complex process in VANets due to the special characteristics of these networks. Moreover, the high density of vehicles leads to increasing the beaconing rate in the control channels and consequently the control channel is congested. For increasing the reliability of emergency messages, the messages should be prioritized, and the control and service channel queues should be scheduled. Therefore, the prioritizing and scheduling of the messages are performed to control the congestion in VANets.

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