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Comparative analysis of Cluster based MAC protocols in VANET

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Abstract: The limited bandwidth, fast changing topology, and non-uniform distribution of vehicles in the VANET environment create a challenge in the process of fair channel allocation to the vehicles. The various efficient MAC protocols are suggested in the literature that worked for enhancing the flow of data traffic and minimize the delay in data delivery by handling the issue of channel access. Among these protocols, the cluster-based MAC protocols discussed in the literature claim that they become more appropriate for the vehicular environment due to clustering characteristics. Cluster based structure helps to make better coordination among vehicles and support to provide fair channel access. The design of MAC protocols is also influenced by the two types of messages in the VANET environment, i.e., safety and non-safety messages. Safety messages are shared to warn drivers for expected hazards, whereas non-safety messages for general and commercial purposes. The prime concern of research contributions to MAC protocols in VANET is focused on reliable, fast delivery of safety messages. In this section, a summary of important cluster-based MAC protocols is provided one by one to explore the importance of the clustering technique over MAC protocols.

Keywords: MAC; Protocols; VANET; Clustering;

I. Introduction

The role of MAC protocols becomes vital in the minimization of packet collisions and packet drop ratio due to limited channel bandwidth allocation for vehicular communications. With such a motive, the TDMA cluster-based MAC algorithm, briefly named as TC-MAC. TC-MAC focuses on the interchange of non-safety messages without influencing the process of reliable exchanging of safety messages [1]. For their work, the more appropriate traffic flow algorithm is used for cluster formation. The CH maintain collision free intra-cluster data communication using TDMA. The non-overlapping TDMA frames are aligned in each service channel. Each TDMA frame is divided into 0 to N slots of the same size [2]. The N number of vehicles occupies these N slots. Further, each time slot on the control channel is partitioned into k mini slot to disseminate required updated status information [3]. The suggested TC-MAC protocol is a lightweight communication protocol and used for single hop intra-cluster communication. The result of TC-MAC is better than DSRC in successfully delivering non-safety messages without affecting the delivery of safety messages.

II. Types of Protocols in VANET

There are some critical factors which may affect the transmission capabilities of

channel like vehicles mobility, limited bandwidth, and frequent link disconnection in VANET environment. To keep such factors in mind, Ning et al. have proposed a hybrid cluster-based MAC protocol (HCMAC). The authors assumed that all vehicles in the network have the same transmission capability [4]. They introduced a Motility factor metric for clustering operation whose higher value increases the chance for a vehicle to become a cluster head. In this suggested scheme, inter and intra-cluster communication are supported by CSMA and TDMA/CSMA protocols, respectively [5]. The channel allocation either with TDMA/CSMA or CSMA protocol led to reducing transmission delay. The transmission delay of safety messages is here considered as a key metric for evaluation of performance [6]. The proposed mechanism shows improved throughput and reduced transmission delay for safety messages in comparison to two popular algorithms CMMP, D-BCM.

Reliable data delivery is strictly required in almost every application of VANET. The applications concerned on clustering protocol at the MAC layer follow the scheduling of transmission links for reliable data delivery. Authors suggested a distributed cluster-based (DCB) transmission scheduling scheme that consider a mathematical optimization model for getting higher throughput and reduce delay in reliable data delivery. The existing DHCV clustering technique is considered in their suggested model. In their proposal, the CH plays the role of transmission coordinator that continuously intimate about the scheduling information to CM. The traffic flow is maximized through proper scheduling among CH and CMs. The suggested transmission scheduling scheme gives better throughput as compared to CSMA/CA and VDA scheme under varying vehicle densities.

Unlike TC-MAC scheme, the Raghavendra et al. have suggested adaptive mobility and range based clustering (AMRBC) on the MAC layer. The objective of the scheme is to provide stable clustering and instant channel access for the safety messages. Here, the unbiased channel allocation among vehicles gives each vehicle comfort that they can exchange their beacons within the control channel interval. Each CH vehicle inside a cluster uses two service channels: one is used for communicating with their cluster member while other is for communicating with CH vehicle of other clusters. They have proposed an additional cluster partitioning and combining algorithm to maintain the number of vehicles in a cluster for optimized functioning. For the urban scenario, the simulation result shows a minimum delay in the transmission of safety messages as compared to existing DMMAC. This delay goes to under 1msec at a density of 25–100 vehicles.

Unlike AMRBC based MAC and TC-MAC protocol, novel cluster-based MAC protocol known as CB-MAC. CB-MAC protocol focuses on improving the reliability in the transmission of both safety and non-safety messages under the vehicular environment. The control packet format at the MAC layer is modified in such a way that it can make a better communication process in a cluster-based vehicular network structure. In the protocol, the CH vehicle broadcast safety messages to CH/CM, whereas CH perform unicast transmission for non-safety messages to its cluster member or neighbour CH. The effective acknowledgment procedure used in the protocol to ensure reliable data transmission. The performance of the proposed protocol is compared with traditional MAC protocol, and it indicates

a significant improvement in overall performance.

In sequence, a collision free MAC protocol to address the issues of inter and intra-cluster data transmission. The proposed scheme is a multichannel MAC scheme where different channels used by adjacent clusters to stop interference. CH vehicle of every cluster takes the responsibility of assigning time slots to their members as per their demand. In a considered scenario, out of 25 frames, three frames are used for exchanging the control packet and other frames for data transmission. The time slot allocation to gateway nodes is done based on the connection subdomain to avoid a collision. The result shows that the performance of the proposed scheme is much better than the EDCA algorithm in terms of successful transmission probability.

To ensure the efficient delivery of safety messages within the bounded time limit and overcome the other issues of the IEEE 802.11p protocol, A location and mobility aware clustering based TDMA (LMA-CT) MAC protocol. LMA-CT MAC protocol used two transceivers, one for service channel (SCH) and other for the control channel (CCH) to avoid channel switching overhead. Here, TDMA based disjoint slot on CCH and SCH is allocated to vehicles according to the direction of moving vehicles to avoid merge collisions. Mobility and location information of a vehicle in a cluster helps CH to identify the gateway nodes at the front and rear end to avoid the hidden terminal problem. One reserved slot is assigned to RSU, a member of all clusters within its range, to establish communication with neighbour vehicles. The performance of the proposed scheme is evaluated in both urban and highway scenarios. The result of the LMA-CT MAC protocol is much improved than TC-MAC and the IEEE 802.11p scheme at the MAC layer in terms of PDR, throughput and end-to-end delay.

Protocol	**Objective of clustering**	**Packet delivery ratio**	**End-to-end delay**	**Throughput**
TC-MAC	Minimize the collision and packet droping	ND	ND	ND
HCMAC	Reduced the transmission delay and achieving high throughput	ND	Minimize at high number of vehicles	Medium
DCB	Make the data transmission more scalable and reliable	ND	Medium	Medium
AMRBC	Minimize the safety message delay	High	Low	High at large number of vehicles
CCFM-MAC	To achieve high packet delivery ratio and high throughput	Higher at an average speed of	Low at high number of vehicles	Higher at average number of vehicles

Protocol	Objective of clustering	Packet delivery ratio	End-to-end delay	Throughput
		vehicles		
CB-MAC	Efficient utilization of bandwidth	Medium of the safety messages	Low of safety messages	High at average number of vehicles
LMA-CT	Ensuring the efficient delivery of safety message	High	Low	High as number of vehicles increases

III. Conclusion

The above suggested cluster-based MAC protocols in literature used different models/techniques to provide fair channel access among vehicles for safety and non-safety applications. The overall purpose of all above discussed protocols in view of channel access is to improve reliability in data delivery with minimum delay through avoidance of transmission collision problem. In the cluster-based structure, CH plays an important role in making coordination among vehicles. The vehicle coordination helps CH to make proper channel access scheduling for their members. The requirement of application for fast channel access abruptly increases the packet delivery ratio. The scheme discussed focused on safety messages, whereas for non-safety messages and for a hybrid type of messages. The detailed comparison of these protocols is provided in Table 1 in terms of the objective of clustering, PDR, end-to-end delay, throughput, scenario, and other useful information.

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