



Quality of Service Guarantees in Vehicular Networks Using Cluster

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Abstract

Background: *Quality of Service (QoS) provision for vehicular networks (VANET) is an important issue to consider for packet transmission. Efficient routing algorithms are essential to guarantee reliable communication in Vehicular Adhoc Networks (VANETs). In an effort to provide QoS in VANET, the IEEE 802.11p physical layer (regarded as VANET MAC protocol) experiences a large amount of packet loss rate as a result of packet collisions. However, the fundamental channel access mechanism of WAVE, Enhanced Distributed Channel Access (EDCA), is not able to provide guaranteed QoS due to the unpredictable random access. Somehow its performance can be improved by using Time Division Multiple Access (TDMA) techniques. Aims: This paper proposes a new approach for multi-constrained QoS routing in vehicular network by adopting TDMA clustering approach. Method: In this approach design, some QoS parameters such as delay, packet loss, packet delivery ratio among others are used in addition to the stability metric for finding and establishing a stable route to destination. Results: The paper also contributes by the highlighting the state of the art of finding and providing QoS guarantees for real-time applications.*

Keywords: *Quality of Service (QoS), guarantees, routing, vehicular networks, cluster, TDMA*

1. Introduction

Data exchanging on the roads from connected vehicles in ITS systems is becoming more and more interesting, as the number of vehicles equipped with computing technologies dramatically increases. This provides the traffic management centers with detailed, real-time information on traffic flow, speeds, and other vehicle conditions. However, the advancements of wireless technologies in VANET has recently been motivated by several research projects conducted globally. The rationale behind these projects is to address the issues of road safety as well as vehicular communication networks. More so, the extreme safety and non-safety applications of vehicle have motivated the research and development of Intelligent Transport system (ITS).

Vehicular Ad hoc Networks (VANET) play an important role in future car-to-car communication systems. It is a technology that uses moving vehicles as nodes in a network to create a mobile network. Vehicular networks aim at enabling the driving-environment awareness, improving the transportation safety system applications and QoS provision in such networking environment are the cornerstone of the next-generation Intelligent Transportation Systems (ITS) such as traffic alert dissemination, file sharing and dynamic route planning (Eichler, 2007; Kenney, 2011; Zeadally, Hunt, Chen, Irwin, & Hassan, 2012). VANETs recently received a significant attention, and the introduction of real-time applications in such environments has increase research activities in the area of quality of service (QoS) support. However, the unique features of VANETs, namely High speed mobility patterns of mobile vehicles and their routing pose numerous challenges, and hence require cost-effective solutions for any QoS provisioning mechanism.

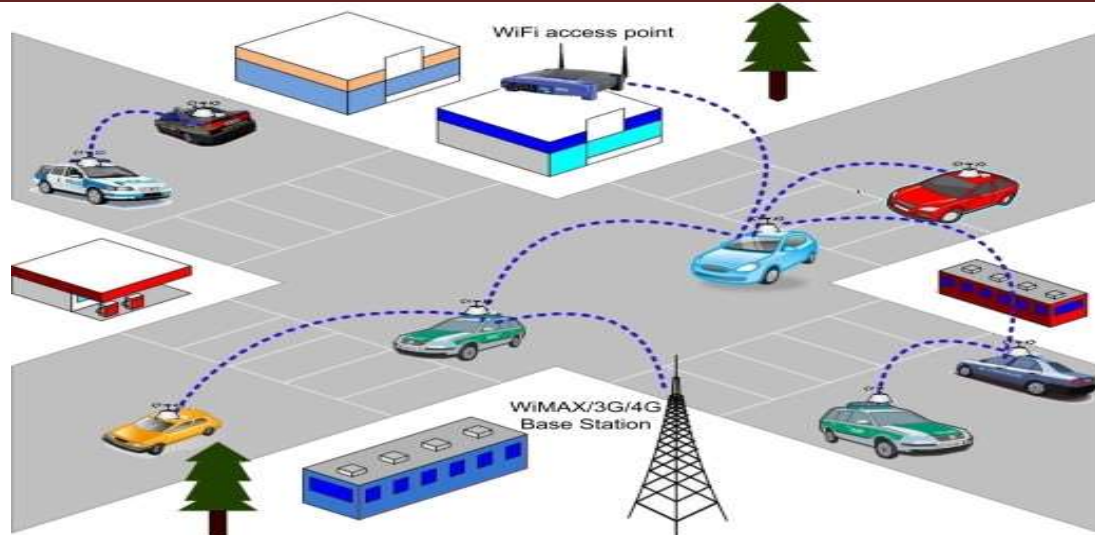


Figure 1: VANET Communication

VANETs are based on short-range wireless communication (e.g., IEEE 802.11) between vehicles (Ghosh, Paranthaman, Mapp, Gemikonakli, & Loo, 2015). In 2003, the Federal Communications Commission (FCC) has allocated 75 MHz in the 5.9 GHz band for licensed Dedicated Short Range Communication (DSRC) aimed at enhancing bandwidth and reducing latency and offers a strong baseline for the V2V and V2I communication (Kenney, 2011). The physical layer of the IEEE 802.11p is similar to the IEEE 802.11a standard. The total bandwidth allocation of 75 MHz supports seven separate channels consists of one control channel (CCH) and six service channels (SCHs). These may also enable the future delivery of rich multimedia contents to vehicles at short- to medium-range via either V2V or V2R links in VANETs.

Numerous challenges must be overcome to realize the practical benefits of ad hoc networking. These include effective routing, medium (or channel) access, mobility management, power management, security, and, of principal interest here, quality of service (QoS) issues, mainly pertaining to delay and bandwidth management (Lianggui Liu & Feng, 2007; Lo, Lin, & Gao, 2013). The actual QoS constraints that ought to be met are delay, bit error rate, bandwidth, route duration etc, in addition to VANET specific requirements like route stability and route reliability. Providing end-to-end QoS support guarantee for traffic data in VANET is even more challenging (Feng, Li, Jiang, & Zhang, 2014; Lei Liu et al., 2018; Mu'azu & Fageeri, 2017), because in a high speed mobility context. Thus, multiple nodes contend for a common channel which make many data packets to be lost and the failure notifications together with the overhead due to route repairs increase significantly. In an effort to reduce the number of re-transmission of packets, several research works that were initially designed for mobile ad-hoc networks (MANET) are modified to suit VANET.

To support QoS in vehicular environment, a service guarantees can be characterized by a set of measurable pre-specified service requirements such as minimum bandwidth, maximum delay, maximum delay variance and packet loss rate (different applications can have very diverse QoS requirements). Thus, providing QoS guarantees to various applications is an important objective in designing the next-generation wireless vehicular networks (Malik, Qadir, Ahmad, Alvin Yau, & Ullah, 2015). Some applications, such as power plant control, require reliable transmission and the control command need to be timely delivered. In such application, no packet loss is of course inevitable during packet transmission. This kind of guarantees is referred to as deterministic or hard guarantees. However, a multimedia application does not demand such stringent QoS requirements. They tolerate and compromise with a small degree of QoS violation. This kind of QoS guarantees is referred to as statistical or soft guarantees. Therefore, this paper considers only the soft guarantees. To achieve such guarantees for not only timely delivery of real-time safety message information, the paper employed multichannel communication architecture to support a wide range of multimedia applications,

2. Related Works

In spite of the substantial advancement in physical layer technologies, the present wireless LAN still are unable to provide the same level of maintained bandwidth as compared to their wired networks. Simultaneous data transmission in a single channel wireless network between neighbouring nodes is not allowed due to contention for the shared medium (Hu & Cao, 2017; Liang, Gao, & Zhang, 2017). Subsequently, data transmission in multi-channel network is made available on different channels; therefore no collision will be occurred by such simultaneous transmissions. Thereby significantly improving the throughput of wireless networks since the use of multiple channels can reduce interference influence (Dragonas, Oikonomou, & Stavrakakis, 2017). However, channel assignment and routing are the central design issues multi-channel wireless Mesh Network architecture. Figure 1 shows the architecture for transporting multiuser traffic over time-slotted fading channels. A cellular wireless network is assumed, and the downlink is considered, where a base station transmits data over N parallel, independent channels to K mobile user terminals, each of which requires certain QoS guarantees.

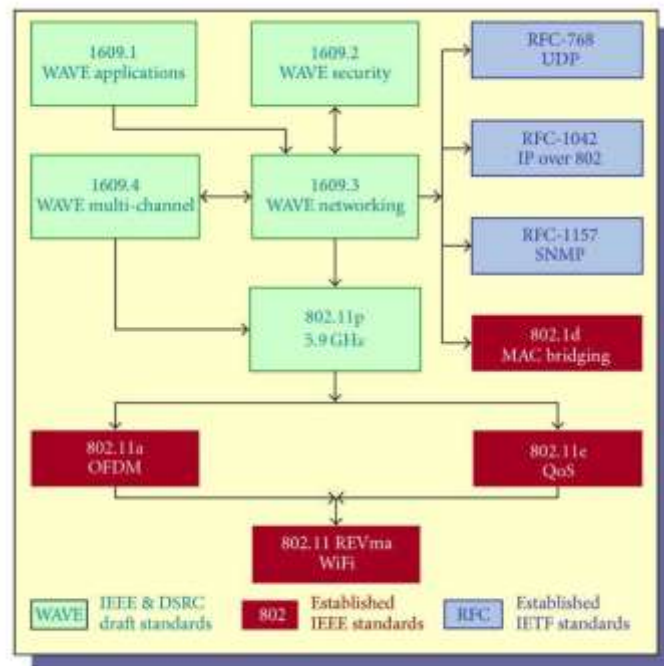


Figure 2: Multiple Channels Architecture for QoS Guarantee (Source: YL Morgan, 2010)

A number of accesses as well as transmissions by multiple users concurrently could certainly corrupt the transmitted data. Consequently, vehicles within IVC networks need to have a mechanism to gain access to the channel in an organized approach. This mechanism in (Fan & Biswas, 2007) however, makes it possible for vehicles to successfully broadcast their own real-time safety related imperative information with minimum delay to other vehicles and without any data packet loss or data corruption. The number increases if there is no such mechanism to coordinate the data packet transmission. Channel access schemes in a dynamic environment are being provided by the MAC protocol on how to avoid data packet collision. Therefore, the MAC protocols are divided in line with the mechanism for data collision avoidance. These include the Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), and Code Division Multiple Access (CDMA) protocols



(Guo & Balon, n.d.). To prevent data collision, a channel in TDMA protocol is separated into time slots whereby each individual user is allocated to a certain time slots. Either of these MAC protocols (TDMA or FDMA) requires time synchronization that's complicated to attain within a network where the nodes have a high dynamic mobility. This thesis assumed the synchronization to be done using GPS. As required importance, the MAC protocol should be efficiently and reliability fulfil the synchronization requirements.

However, the QoS implemented in MAC layer is crucial and is an important aspect. It guarantees a high prospect of access that experience low delay particularly when higher priority messages want to have access to the channel. The bandwidth reservation problem is considered in such environment. A route discovery algorithm is proposed, which is able to find a route with a given bandwidth (represented by number of slots) based on the stability value. Incidentally, this research work modified some famous reactive routing protocols (Ad-hoc On-Demand Distance Vector (AODV) and incorporate location request of LORA-CFB) to suits VANET environment for proper implementation of the proposed scheme.

3 Issues Related to Guaranteed QoS Routing for VANETs

The goal of QoS routing is to select a feasible path if one exists, and to select an optimal path that can satisfy multiple constraints and use the network resources effectively if there are multiple paths.

The notion of QoS, as mentioned before, is a guarantee by the network to satisfy a set of predetermined service performance constraints for the user in terms of the end-to-end delay statistics, available bandwidth, probability of packet loss, and so on. The cost of transport and total network throughput may be included as parameters for guaranteeing QoS. Obviously, enough network resources must be available during the service invocation to honor the guarantee. The first essential task is to find a suitable path through the network, or route, between the source and destination(s) that will have the necessary resources available to meet the QoS constraints for the desired service. The task of resource (request, identification, and) reservation is the other indispensable ingredient of QoS. By QoS routing, we mean both these tasks together.

It is obvious and important to make the real-time safety traffic applications effective with timely delivery and less delay especially for vehicular network. Despite the high speed of the mobile nodes and frequent topology changes, it is important to find out a better solution to the network technology. Data traffic with a wide emergency application requirements in VANET tend to demand for new and proper control and management mechanisms for of communication networks (Hu & Cao, 2017). The term QoS, just as its name implies, describes the measure of service used to express the level of performance provided to users (Niu, Yao, Ni, & Song, 2007). The main aim of QoS guarantees is to achieve a more deterministic network behavior, by doing so the information carried by the network can be better delivered and network resources can be better utilized.

The most important issue in QoS capable communication networks is to specify what the requirements are and to quantify them accurately. In (Mu'azu, Jung, Lawal, & Shah, 2014), transmitted traffic through communication networks is characterized by four primary parameters: packets loss, delay, jitter, and bandwidth. According to these parameters, different kinds of traffic can be classified. Most of the real-time applications can be classified as delay sensitive traffic sources and applications such as file transfer and web browsing can be classified as loss-sensitive traffic sources. For some applications, security might also be thought as a decision parameter. Most of the time, multiple metrics model both networks and applications more accurately. But the problem of finding a stable path subject to multiple metrics is difficult and in many cases is considered as NP-complete. It cannot be solved in a real-time scale, which is very crucial for the many of applications in general and for delay-sensitive applications in particular (Boukerche, Rezende, & Pazzi, 2009).

The cost metric used in route computations can be one of the following or compositions of them.

- Additive metrics:

$$m_p = \sum_{i=1}^{L_K} m(l_i) \quad (1)$$



m_p represents the number of metrics m considered in a path p , whereas the l_i defines a link in the path (p) and the total number of L_k s the total number of the available links in path (p). Examples of such additive class are delay and jitter.

- Concave Metrics:

$$m_p = \frac{\min}{\max (m(l_i))} \quad (2)$$

Example of such class includes bandwidth.

- Multiplicative metrics

$$m_p = \prod_{i=1}^{L_k} m(l_i) \quad (3)$$

These requirements are typically in the form of bandwidth or end-to-end delay guarantees, so that identifying a path capable of meeting them implies some knowledge of the availability of resources throughout the network. It's concerned with the problem of how to select a path for a flow such that the flow's QoS requirements such as bandwidth or delay are likely to be met. In order to make judicious choices in path selection metric, it is imperative that we have some knowledge of the global network QoS state, e.g., the traffic load distribution in the network. In the design of any QoS routing scheme, we must therefore address the following two key questions: 1) how to obtain some knowledge of the global network state and 2) given this knowledge, how to select a path for a flow. Solutions to these questions affect the performance and cost tradeoffs in QoS routing as well as scalability in VANET.

4 Proposed QoS Guarantees Routing Scenario

The scenario considered in this research work consists of moving vehicles in a city area connected via highway to show the impact on the performance of the routing algorithm. The grid area of the city differs from each other with the number of moving with an average speed. Vehicles rely on multi-hop ad hoc fashion to deliver the data packages especially when they are not in proximity with each other. In the proposed scenario, the exchange of information is among the vehicle as there are no road side units (RSU). The density of the network is an important factor in communication in VANETs. In order to perform multi-hop communication in timely fashion, the network of vehicle should have a certain amount of density. The minimum level of density required for communication is dependent on the wireless communication range, and varies in different environments. This research concentrates on the problem of transmission of real-time traffic information for Vehicle to Vehicle communications in a dense environment without deploying roadside infrastructure as illustrated in Figure 3.

For this reason, the number of rebroadcast is restricted to help minimize the number of packet collisions due to smaller flooding of the packets in the network. The clustering approach considers mobility aspect of vehicle to increases the route stability, and reduces the amount of routing control overhead. This could be feasible because vehicles moving in the same direction shall express the same speeds and moving patterns which relatively leads to stable network topology.

Nonetheless, the neighborhood relationships for the moving vehicles those are close in proximity indicating the impact of transmission range on it mobility which is denoted by $r(N)$.

Let d_{ij} denote the distance between vehicle i and vehicle j in K -hop neighbor. Vehicle i and j are considered neighbors when they can directly communicate with each other. That is if vehicle j can receive a data packet from vehicle i . The transmission rate of each vehicle equals R bits/seconds. Vehicle i can successfully transmit a packet to vehicle j only if vehicle i is a neighbor of j . A K -hop cluster is a cluster in which the cluster head vehicle is the K -hop neighbor of all cluster member vehicles. As such, the maximum distance in hops between the cluster head vehicle and cluster member vehicles is K .

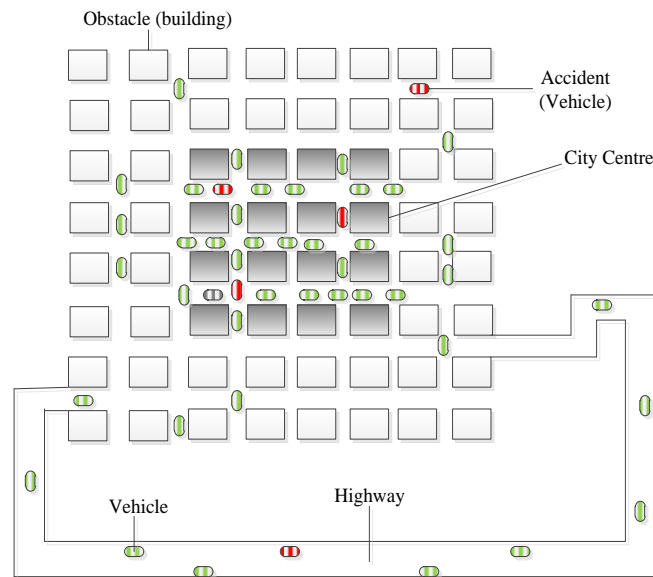


Figure 3: VANET Scenario Considered

It is assumed the traffic model for the network in the proposed model, that the aggregate packet arrival rate at a mobile vehicle is packets/sec, which includes packets generated by the mobile vehicle itself as well as packets arrived from neighbor vehicles for forwarding and it is given by equation 4

$$\beta = n * \beta_i \quad (4)$$

where β_i = packet arrival rate of mobile node i MN itself

n = number of its neighboring nodes.

The approach proposed by (H Su, Technology, & 2007, n.d.), also uses a distributed TDMA in combination with a contention-based scheme. They use a clustering algorithm (Mu'azu, Jung, Lawal, & Shah, 2014) to place vehicles into different clusters, where each cluster has a vehicle as the cluster head. Within each cluster, TDMA is used, for collection and delivery of safety messages in the cluster, which are consolidated in the cluster head. Two clusters communicate through their cluster heads, using a contention-based protocol. Thus, two vehicles cannot communicate directly with each other, if they are from different clusters, even though they are within each other's communication range. This will add extra delay, for delivery of routine safety data.

4.1 Cluster Based Routing

Usually, a node in a hierarchical network has two basic roles: cluster head and cluster member; and an additional role: cluster gateway. The role of a cluster head or master represents for routing, management and aggregation. A cluster gateway can belong to more than one cluster and this role normally only represents for routing data between clusters. Besides, all other nodes are all in the role of cluster members. However, hierarchical routing and path maintenance were a secondary concern. The idea is to construct clusters of nodes that within one-hop of some central node, consequently, all nodes are within two-hops of each other.

Cluster size is controlled through radio transmission power—assumed to be a fixed and uniform value. The clusters are used to control access to the transmission medium and reserve bandwidth for QoS constrained communications. The algorithm for organizing the clusters is not based on any quantitative performance criteria. A distributed algorithm based on lowest node identifiers deterministically partitions a network into two-hop clusters. The challenge of hierarchical routing techniques is the election of cluster head and cluster gateways.

Many researchers are of the view that network clustering, and dynamic hierarchical routing is too complex and cumbersome to be effective in ad-hoc networks. However, as new techniques have evolved, and the efficacy of hybrid routing strategies that can capture the benefits of both proactive and reactive routing become more apparent, the literature on the topic has become increasingly rich.

The proposed algorithm in (Gerla & Tzu-Chieh Tsai, 1995) is similar to our approach in that both suggest a clustering approach where TDMA is chosen as the access protocol for the nodes within a cluster. Furthermore, they suggest lowest ID algorithm for clustering where vehicles periodically broadcast their neighboring information. It is assumed in this thesis that the time slot within a cluster to be allocated using TDMA downstream broadcast method similar to (Hang Su & Chen, 2006) as explained in our previous paper (Mu’azu & Fageeri, 2017). As it is seen in Figure 4, the initial stage involves the election of the cluster head (CH) and formation of cluster regions. The setup state is followed by the steady data transmission state, which is subdivided into data acquisition and data dissemination stages.

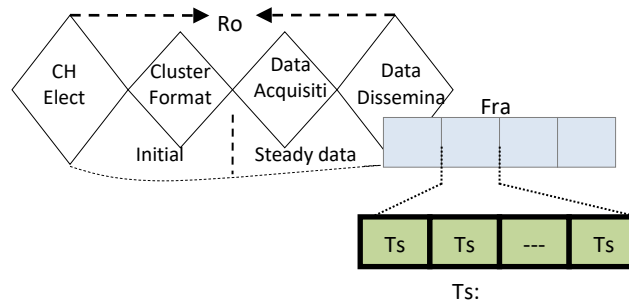


Figure 4: Cluster-based routing stages with TDMA

There exist two different phases of cluster based TDMA to provide network stability as well as access channel utilization, the intra-cluster and inter-cluster communications are shown in Figure 5. When intra-cluster nodes transmit data packet to their cluster members, they usually cause mutual interference: so do when inter-cluster nodes transfer data to adjacent clusters, they also cause interference.

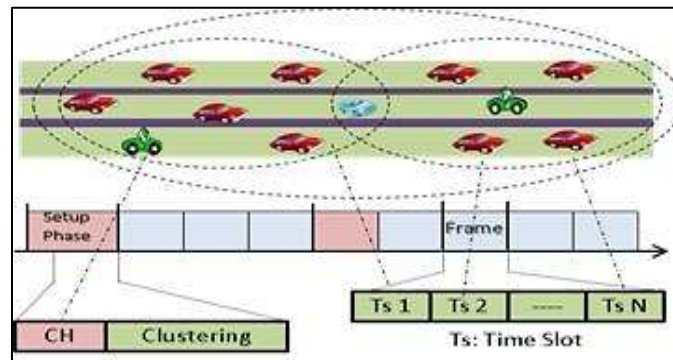


Figure 5: TDMA Time Slots Allocation

Within the TDMA setting as shown in Figure 4, only one channel can be used to correspond among the nodes at a particular interval of time. The TDMA frame consists of a control phase along with a data phase (Ağgün, Çıbuk, & Ur-Rehman, 2020; Singh & Mann, 2017). Each node within the network includes a designated control time slot, so it uses to deliver its control information. It is used to realize the timely delivery of safety traffic information with QoS requirements.

Further, the size of each packet is assumed to be at a constant rate with equals L bits in length and assuming no queuing delay. This ensures the transmission of one packet takes one slot time for quality of service guarantees. The QoS information is being updated in the neighborhood availability information according to Table 1 for the timely transmission of real-time traffic information.

4.2 TDMA-Based QoS Routing

To create wide scale vehicular ad-hoc networks, changes need to be made to the media access control (MAC) layer. The aim of MAC layer is to allow access to shared medium, which is the wireless channel. If no method is

used to coordinate the transmission of data, than a large number of collisions would occur and the data sent would be lost. In order to avoid packet loss in critical situation and to support real-time multimedia service in VANET, it is necessary for a network to provide connection oriented scheme so that the resource can be computed and reserved. This proposed scheme uses TDMA for transmission of real-time safety traffic information within a cluster. In the following discussion, such scheme is described for in the proposed network model.

VANET environment provide transmission of the real-time safety traffics information and also the non-real-time safety traffics. Safety related applications of vehicular communication possess extensive reliability as well as delay bound needs. Providing each vehicle time slot to transmit safety messages without disturbing other vehicles is of importance. TDMA stands out as the concept that can easily be used to allocate a unique time slots to every vehicle within the cluster. More so, the cluster head will manage the TDMA slots assignment.

The protocol proposed by (Ma & Steenkiste, n.d.) is similar to this research work for improving QoS routing within a cluster. Whenever a source node S needs to preserve a QoS route to forward data towards a destination node D, it shall transmits a QREQ message which consists of the number of slots (available bandwidth), bw; needed for that expected QoS path. These slots at the moment are labeled as allocated within the communicating nodes. Within this situation, node D unicasts a QREP reply message to node S as shown below:

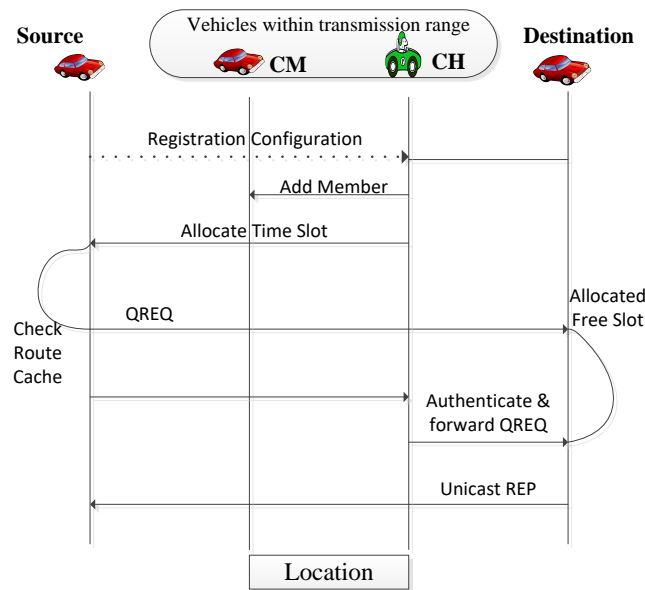


Figure 6: TDMA-Based QoS Routing Scenario

The source vehicle communicates with its cluster head in case it doesn't know the location or the route with QoS to the desired destination vehicle. Then the cluster head can now forward the QREQ to the desired appropriate vehicle within its members or to the adjacent clusters. This particular data is actually traverses across the nodes within the allocated route as being discussed in details in (Ma & Steenkiste, n.d.). The route discovery process gives an overview of the routing process, but the route discovery process is expatiated in the (Mu'azu et al., 2014). Within the proposed scheme, every vehicle is connected under two (2) potential conditions; either cluster head (CH), or cluster member (CM).

Providing each vehicle time slot to transmit safety messages without disturbing other vehicles is of importance. TDMA stands out as the concept that can easily be used to allocate a unique time slots to every vehicle within the cluster. More so, the cluster head will manage the TDMA slots assignment. After the cluster formation, the route discovery process starts by finding a route between the source and the CH; and later between the CH and other destinations within the cluster or in adjacent clusters using the same mechanism. Typically, the QoS is derived in terms of delay bound, packet delivery ratio and packet loss rate for a given bandwidth



allocation. Therefore, the proposed algorithms depend on three stages: neighborhood availability information, QREQ request and data forwarding strategy.

The Neighborhood Availability Information is executed in every node by utilizing two local information tables keeping track of all incoming and outgoing connections. The Node Q_table preserves information (which includes the available bandwidth, link stability and source to destination addresses and mobility) according to the vehicle's relative state. More so, the Node Q_table handles the neighborhood availability information which is also managed according to the MAC layer beacon to measure the stability of the path that exists between two nodes. In addition, it contains an estimated duration of a link that could exist between the paths. It also determines the connection within communication range of mobile vehicles during the simulation period (i,j) with at least one k-hop path.

Routing paths in VANET environment is not static due to the rapid topology changes. Therefore, it is frequently updated in accordance with the link transition state links R(X) (i.e links movement from one transmission intensity to another). To maintain the frequent track of transition, the total number of transitions of a link is compared over a certain period . Therefore, the frequency (f) of the transitions is given as:

$$f = \frac{X_T}{\Delta T} \tag{5}$$

X_T is the number of transitions at a time interval ΔT . It is very difficult to estimate the statistical time interval, so ΔT is assumed to be inversely proportional to the average speed of the vehicles (π) and directly proportional to the vehicles number (N) and expressed as:

$$\Delta T = k \cdot \frac{N}{\pi} \tag{6}$$

During the route discovery, the cluster head collects the number of transmission (n) intensity values at time interval ΔT . With these values, the received signal intensities are check to confirm that all are greater than or equal to the minimum threshold (τ_{min}) value at the particular ΔT (i.e. $X_T \leq X_{Tmax}$). On the other hand, the network link is said to be unstable, if the maximum threshold (τ_{max}) for the numbers of link transitions at ΔT is less than transmission intensity value (i.e. $X_T > X_{Tmax}$). the contents of the Node Q_table and how it could be update.

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5. Conclusion

Providing each vehicle time slot to transmit safety messages without disturbing other vehicles is of importance. TDMA stands out as the concept that can easily be used to allocate a unique time slots to every vehicle within the cluster. In this paper a new approach for multi-constrained QoS routing in vehicular network by adopting TDMA clustering approach. In this approach design, some QoS parameters are used in addition to the stability metric for finding and establishing a stable route to destination. In future work, the implementation of the prosed a cluster algorithm for vehicular network would be considered.

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