IJCSC International Journal of Computer Science & Communication Vol. 1, No. 2, July-December 2010, pp. 399-403

Data Scheduling in VANETs : A Review

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ABSTRACT

Vehicular Ad-Hoc Networks (VANETs), a special kind of Mobile Ad-Hoc Networks (MANETs), where wireless-equipped (road) vehicles form a network without any additional infrastructure. Due to the fast growing number of vehicles and saturation of the transportation infrastructure traffic congestion, accidents and transportation delays become unavoidable. Several measures are implemented in order to solve these problems and construction of more and better roads and highways and to develop safety applications like accident notification, traffic congestion warning and traffic congestion avoidance that lead to a significant reduction of critical traffic events. These applications utilize a variety of data obtained from the host vehicle, the road and surrounding vehicles. The information must be transmitted immediately with high reliability and low delay. In this paper, we survey data scheduling approaches available to schedule the necessary data considering vehicle to vehicle, infrastructure to vehicle or vehicle to infrastructure communication.

Keywords: DSRC, VANETs, RSU, Data Dissemination, Routing, Scheduling

1. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) are emerging as the preferred network design for intelligent transportation systems. VANETs are based on short-range wireless communication (e.g., IEEE 802.11) between vehicles [1]. The Federal Communications Commission (FCC) has allocated 75 MHz in the 5.9 GHz band for licensed Dedicated Short Range Communication (DSRC) [2] aimed at enhancing bandwidth and reducing latency for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. Unlike infrastructure-based networks (e.g., cellular networks), VANETs are constructed on-the-fly and do not require any investment besides the wireless network interfaces that will be a standard feature in the next generation of vehicles. Furthermore, VANETs enable a new class of applications that require time-critical responses (less than 50 ms) or very high data transfer rates (6-54 Mbps). VANETs have unique characteristics as: very high mobility, theoretically infinite extension, absence of a centralized control, and intermittent connectivity through the sparse infrastructure. These characteristics give rise to challenges [21] in information exchange and data scheduling.

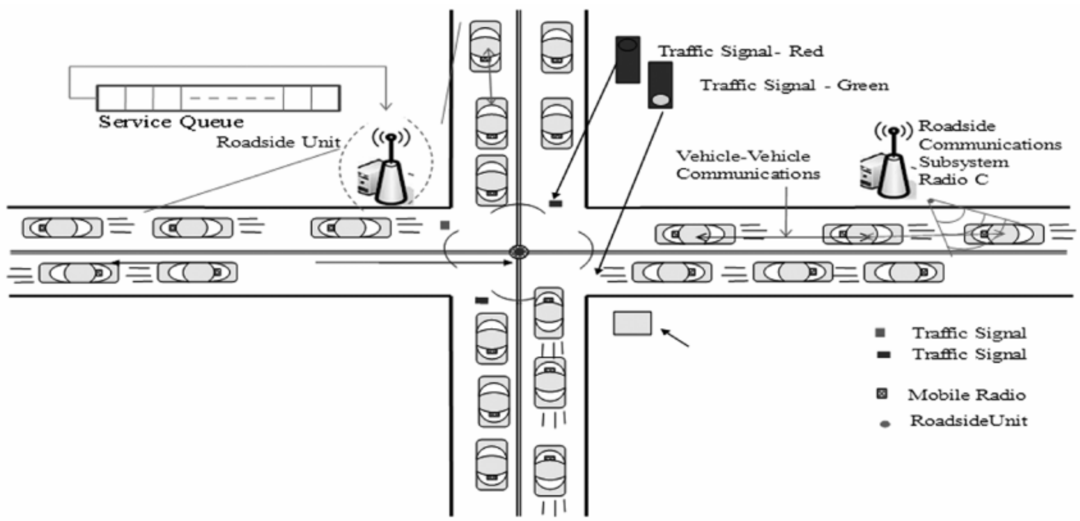

Fig. 1: Vehicular Ad Hoc Networks

Providing reliable delivery of broadcast messages in a VANET introduces several key technical challenges. In next sections, we focus on data dissemination techniques, routing protocols applicable to the vehicular networks, data scheduling algorithms and the related work. The rest of this paper is organized as follows: data dissemination techniques are discussed in section II. In section III, a survey on routing protocols in VANETs is presented. Scheduling algorithms are discussed in section IV and section V covers the related work. Section VI concludes the paper and recommends some future works.

2. DATA DISSEMINATION TECHNIQUES

Data broadcast is an attractive solution for large scale data dissemination. In contrast to unicast, where a data item must be transmitted many times to answer multiple requests, broadcast has the potential to satisfy all outstanding requests for the same data item with a single response. In general, there are two major data broadcast approaches [4, 5, 9, 19]: push-based and pull-based. In push-based broadcast, the roadside unit (RSU) broadcasts the whole or part of the database periodically according to a static broadcast program, which is based on historical data access statistics or a set of pre-defined request profiles. All vehicles listen passively to the broadcast channel to retrieve data items of interest without sending any request. Usually, push-based algorithms bear the advantage of achieving optimal or near optimal solutions by using some prior knowledge such as data access patterns to design broadcast programs. It is believed that broadcast-based applications have the potential of bootstrapping vehicular ad-hoc networks. The goal of the data broadcast or push communication model is to exchange information which may have parameter or data like speed, position and direction of the vehicle on regular basis among a set of vehicles which may also be moving in order to enable each individual vehicle to view and access traffic conditions. There are two main mechanisms to achieve this goal [4]. In the flooding mechanism, each vehicle periodically broadcasts its own data or information. Whenever another vehicle receives a broadcast message, it stores and immediately forwards it by rebroadcasting. This mechanism is not scalable because in high traffic density a large number of messages will flood over the network. In dissemination, each vehicle broadcast information of itself as well the information of all the vehicles available with it. Each vehicle receives information broadcasted by another vehicle, updates accordingly and defers forwarding the information to the next broadcast period, at which time it broadcasts its uploaded information. This mechanism overcomes the disadvantage of flooding and therefore scalable, since the number of broadcast messages is limited because network is not flooded by them.

In pull-based broadcast, commonly known as on-demand broadcast, the RSU disseminates data items in response to explicit requests submitted by vehicles. Compared to its push-based counterpart, pull based is more scalable to large size databases. Moreover, the absence of assumption on data access patterns makes it more adaptable to dynamic workload environments. However there are various parameters in vehicular networks which need to be kept in mind so as to implement either of the approach. In the research literature, many methods of data delivery are presented and, we can distinguish the following data dissemination approaches: (1) Opportunistic: Under most highway scenarios VANETs tend to be disconnected. To overcome the limitation imposed by lack of connectivity, opportunistic communication is proposed using cars as data mules. Information is pulled from other vehicles or the infrastructure as a target vehicle encounters them [1, 3]; (2) Vehicle-Assisted: It adopts the idea of carry and forward, where a moving vehicle carries the packet until a new vehicle moves into its vicinity and forwards the packet. A vehicle carries information with it and delivers it either to the infrastructure or to other vehicles when it encounters them. This process involves mobility in addition to wireless transmissions in order to disseminate the information [4]; (3) Co-operative: Vehicles can download partial units of some content and then share them afterwards to obtain the complete content. This method is particularly suitable for content dissemination (where the amount of information is rather important in terms of le size) and it was adopted to develop dissemination protocol based on rate-less codes.

3. ROUTING

A routing protocol plays a vital role in scheduling of data in communication. Since the operational principles of MANETs and VANETs resembles therefore most of the routing algorithms which were applicable to MANETs has been studied and modified as the difference is in high speed mobility and the nature of unpredictability of their movements. Since each node has a limited transmission range, messages often have to be forwarded by other nodes in a VANET. The routing protocols can broadly be categorized into two classes:

1. Topology–Based Routing;
2. Position-Based Routing or Geographic Routing.

Topology-Based Routing uses the data/information about links that exist in the network to perform packet forwarding whereas the Geographic routing or position-based routing uses the information of the neighbouring location to perform packet forwarding. Taxonomy of various routing protocols in VANETs has been shown in figure 2. below.

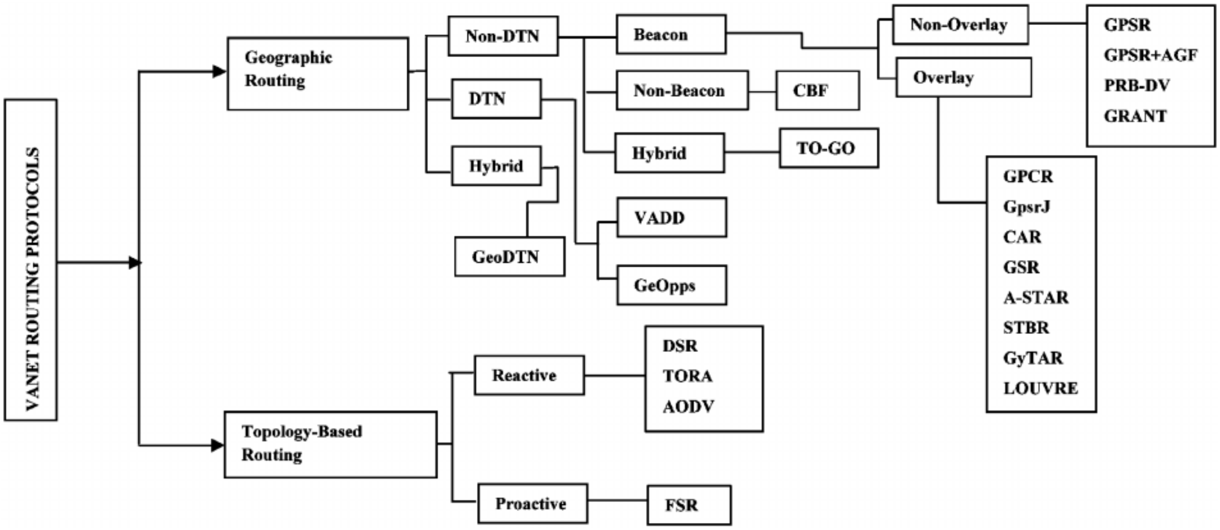

Fig. 2: Routing Protocols in VANETs

Topology-based routing protocols use the information about the links that exists in the network to perform packet forwarding. On the other hand, location-based routing the forwarding decisions is based on a nodes location. They can be sub-divided into proactive and reactive approaches.

Proactive algorithms employ classical routing strategies such as distance-vector routing (e.g. DSDV) or link-state routing (e.g. OLSR and TBRPF). Proactive algorithms maintain routing information about the available paths in the network even if these paths are not currently used. The main drawback of this approach is that the maintenance of unused paths may occupy a significant part of the available bandwidth if the network topology changes frequently. In response to the maintenance problem, reactive routing protocols were developed. Reactive routing protocols maintain only the routes that are currently in use, thereby reducing the burden on the network when only a small subset of the available routes is in use. In location-based routing, forwarding decisions are based on the location of the forwarding node in relation to the location of the source and destination nodes. Location-based routing protocols consist of location services and geographic forwarding. Geographic forwarding takes advantage of a topological assumption that works well for wireless ad hoc networks: nodes that are physically close are likely to be close in the network topology also. Each node learns its own geographic position using a mechanism such as GPS, and periodically announces its presence, position, and velocity to its neighbors. Thus each node maintains a table of its current neighbor's identities and geographic positions.

4. SCHEDULING

Vehicles moves at a high speed and they stay in the area of roadside units only for a short period of time. Therefore scheduling of data is very crucial so as to serve as much requests as possible, reducing delay of downloading etc. Scheduling is an important issue for data access in vehicular environment. Any scheduling algorithm is verified considering some performance metrics. We list some parameter metrics which has been kept to test any scheduling algorithm in the literature; fairness, reliability, responsiveness, time constraint, data size, service ratio and data quality. Based on the above performance metrics, the following are the few scheduling algorithms [3, 9, 10, 16, 18] which are available in VANETs (1) First Come First Serve (FCFS): FCFS is the simplest scheduling algorithm. Request with the earliest arrival rate will be served first. (2) Longest Wait Time (LWT): Works in broadcast environment, and capable of deadline handling. (3) Most Requests First (MRF): MRF also works in the broadcast environment. (4) Longest Total Stretch First (LTSF): Reduces waiting time and based on a metric stretch defined as the ratio of the response time of a request to its service time. (5) First Deadline First (FDF): In FDF, the request with the most urgency will be served first. FDF neglects the service time spent on data items. (6) Smallest Data Size First (SDF): Request asking the data with the smallest size will be served first. SDF neglects the urgency of the messages. (7) MQIF-Maximum Quality Increment First: Serves first the messages which would bring the maximum quality of service (namely reliability) increment. First calculate the expected increment in TRM and then estimate the expected increment in SRM **(**Time Reliability Metric and Space Reliability Metric**)** assuming allocation the current cycle to a message. Afterwards, the two increments are combined. (8) LSF-Least Selected First: Least Selected First (LSF) scheduling, tries to schedule into the schedule window as many messages as possible. The general idea is that if a message had the least opportunity to be served before, it will be given the highest priority this time. (9)

D*S Scheduling Algorithm: Considers both the Deadline (D) as well as data size (S), to serve the request. The requests are served by giving a service value to the request as its service priority weight,

5. RELATED WORK

Ott and Kutscher's seminal paper proposing Drive-thru Internet [1] was the first to perform a detailed experimental analysis of opportunistic Internet access in vehicles. Gass et al. [2], worked on opportunistic communication and termed *in-motion networking*, confirmed the feasibility of using opportunistic connections to vehicles under a variety of different conditions. D. Hadaller et al. [3] focused on the problem of providing vehicular Internet access using roadside 802.11 access points. The biggest limitation of their work was that they only evaluated a single scenario: one vehicle, one vehicle speed, one environment, one wireless card, and only downlink data transfers. Zhao et al. [4] introduced variations of VADD that chooses the next forwarding node after the next forwarding path has been determined. Jiang et al. [10] and Rajan et al. [13] investigated only periodic push-based broadcast, which is fundamentally different from on-demand broadcast in system architecture. Jaap et al. [6] evaluated AODV, DSR, FSR, and TORA in city traffic scenarios. The simulation shows that AODV has the best performance and lowest control overhead. It is followed by FSR, DSR, and then TORA. DSR suffers from a very high delay because source routes change continuously due to high mobility. Its route overhead is comparable to FSR yet higher than AODV since DSR keeps route information within the packet header. The common characteristic among all four routing protocols is that performance degrades as network densities increase, indicating their scalability problem.

In [7] authors conducted an evaluation study of Geographic Source Routing, AODV, and DSR in a small part of a map of Berlin. The authors simulated the movement of 955 vehicles by the traffic flow simulator. Results indicate that AODV performs better than DSR for the same reason mentioned above because large packet overhead creates a significant bandwidth overload and mobility causes frequent route breakage. However, both of the topology-based reactive routing protocols do not perform as well as GSR. In [8] compared various routing protocols which include AODV, PGB, and GPSR. The propagation model used is probabilistic Shadowing Model that considers the non-uniform non-circular behaviour of radio waves due to blockage. Results indicate that AODV + PGB perform better than AODV and GPSR in all node densities because of constant broadcast overhead. Comparing AODV and GPSR alone, as density of vehicles increases in both city and highway scenarios, the packet delivery ratio of AODV decreases and becomes worse than that of GPSR; and the overhead of AODV increases and becomes higher than that of GPSR.

Wong studied several scheduling algorithms such as first-come-first-serve (FCFS), longest wait time (LWT), most requests first (MRF) in the broadcasting environments [9]. Later, many broadcast scheduling algorithms have been proposed to reduce the waiting time and energy consumption [13]. Acharya et al. [11] addressed the broadcast scheduling problem in heterogeneous environments, where data items have different sizes. The solution is based on a new metric called Stretch, [9] defined as the ratio of the response time of a request to its service time. Based on stretch, they proposed a scheduling algorithm, called longest total stretch first (LTSF) to optimize the stretch and achieve a balance between the worst case and the average case. However, a straightforward implementation of LTSF is not practical for a large system, as at each broadcast time, the server has to recalculate the total stretch for every data item with pending requests in order to decide which data to broadcast next. The work in [12] introduced the concept of Quality Contracts (QCs) which combines the two incomparable performance metrics: response time or Quality of Service (QoS), and staleness or Quality of Data (QoD). The author proposed an adaptive algorithm to maximize the total profit and is based on point-to-point communication and does not take advantage of broadcasting. All these works mainly focus on responsiveness such as average/worst- case waiting time or fairness without considering the time constraints of the user requests. However, in vehicular networks, time constraint of the request has to be considered. In [10, 13, 14, 18] authors studied the scheduling problem in real-time broadcasting environment and took time constraint into account. The authors in [14] investigated online scheduling algorithms for time critical on-demand data broadcast. The authors only tried to improve the service ratio for download broadcasting. The authors in [17] proposed priority based for highway safety messaging using 802.11e. The authors in [1] gave the first understanding of the impact of the vehicle's speed, transmission rate, 802.11 bit-rate, and packet size on throughput and delay of vehicle-roadside communication and illustrated a basic picture of how running vehicles contact with roadside hot spots through a "drive-thru" data access. The authors in [15] proposed D*S to consider both deadline and data size when making scheduling decisions. To make use of wireless broadcasting, the authors gave another scheduling scheme called D*S/N to serve multiple requests with a single broadcast. The authors also identified the effects of upload requests on data quality, and proposed a Two-step scheduling scheme to provide a balance between serving download and upload requests. The work by [16] suggests improving scheduling by improving the service ratio. The requests are not dropped even if not served. In various earlier works deadline constraints of the requests were not considered. However, some works took into account deadline for some requests and found that the requests shall be dropped completely if vehicles move out from the RSU area.

6. CONCLUSION

In this paper, we first gave a description of vehicular ad hoc networks, classification in three categories: V2V, V2I and I2V. Section II describes the specific characteristics. We classified data dissemination techniques, routing protocols and scheduling algorithms in VANETs. Section VI describes the related work and the problems of vehicle-roadside data access. Although the works are numerous, there are still open issues which are challenging. We presented works related to data scheduling by various researchers and academicians. However, we want to clarify that the list of open problems identified here is not exhaustive. We hope, at least, that this study contributes to feed the debate and open the window of new research directions.

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