Performance Evaluation of DREAM Protocol for Inter-vehicle Communication

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***Abstract*—VANETs are emerging as new network environments for developing future automotive applications. Numerous research issues have recently been identified and should be tackled before real implementations of pervasive vehicular applications and services. The design and the implementation of efficient and scalable routing protocols constitute one main issue. In this paper, we study and evaluate the performance of a geographical protocol in VANETs using real vehicle mobility scenarios. Performance metrics such as the control load and the average latency are evaluated using ns2.**

Keywords-Inter-vehicle communication, geographic routing, simulation evaluation, Real-vehicule mobility.

I. INTRODUCTION (HEADING 1)

With the growth and expansion of wireless communication technologies, considerable research efforts have occurred in the area of inter-vehicle communications in order to carry out safety applications. Two communication modes can be distinguished: the Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications. The first mode requires the use of roadside sensors for vehicles to gather information such as traffic signal violation warning. In the second mode, vehicles can communicate directly with each others without passing by the road infrastructure. The objective is to increase the vehicle safety by relaying required information from vehicle to vehicle. For example, a vehicle detecting an icy road could inform other vehicles like those traveling in the opposite direction and those traveling in the same lane [30].

To allow V2V communication, vehicles must form some kind of network, called Vehicle Ad hoc NETwork (VANET). VANET is a Mobile Ad-hoc NETwork (MANET) that has vehicles as network nodes. A VANET is a decentralized and self-organizing network composed of high speed moving vehicles [5]. Several applications may use VANET to establish communication between vehicles. For example, information about potential congested areas can be relayed from a vehicle to another, in order to inform the drivers of eventual accidents or possible traffic jams. Thus, drivers could be notified that they are proceeding toward a location where an accident has occurred. Moreover, the system would be able to compute alternate routes if such information is used as an input into a vehicle navigation system in order to avoid congested area.

The dynamic nature and directional mobility of the vehicles and the unreliable wireless channel, delivering messages to one or all vehicles represent a challenge. Moreover, because of the absence of the infrastructure and the higher mobility of the vehicles, relying messages between vehicles require finding and maintaining information about routes which constitutes an issue that should be addressed. As stated in [1], geographic routing protocols are more convenient for dynamic networks due to their good performance.

In this paper, a performance evaluation of a geographical protocol, DREAM (Distance Routing Effect Algorithm for Mobility), in VANETS using vehicle mobility based on real road map is presented. The remainder of this paper is organized as follows. Section 2 presents related work. In section 3, we present a brief overview of DREAM protocol. Section 4 presents the simulation methodology and describes reported results. Conclusions and future work are presented in section 5.

II. RELATED WORK

In recent years, various approaches have been proposed to address the problem of multi-hop routing in MANETs. These routing approaches can be classified in two main classes: table-driven or topologic-based approaches and geographic or location-based approaches [1,2]. Topologic-based approaches use information about links, similar to static networks, to forward packets between the nodes of the network. Examples of protocols using following these approaches are DSDV [3], AODV [7], ZRP [9], and CBRP [10].

Position-based approaches have been proposed to address some drawbacks of topologic-based techniques by using information about physical or geographical positions of nodes that can be obtained by positioning services such as GPS (Global Positioning System) [1,32]. In these approaches, at each node, the routing decision is based only on the position of the destination node and the position of the forwarding node's neighbors, but not on a routing table as in topologic-based approaches. Examples of protocols using these techniques are MFR (Most Forward within Radius) [13], GFG (Greedy-Face-Greedy) [17], Grid [19], and DREAM [22]. However, to know the current position of a specific node, location-based systems in which each node registers physical positions of other nodes is required. Examples are Quorum system [26] and GLS (Grid Location Service) [27]. More sophisticated approaches [32] can be used to develop location-based systems. More depth study of these protocols can be found in [1,2].

V2V routing protocols should be robust, reliable and minimize the latency and the network load. For example, in [11] the routing protocols AODV, DSR, FSR and TORA, are compared and analyzed using a realistic urban road traffic scenarios. The reported results have shown that AODV and DSR outperform FSR and TORA for all studied performance metrics. A comparative simulation study of AODV and GPSR protocols was presented in [8] and reported results have shown serious performance problems of these protocols in VANETs. Two improvements have been investigated to increase their performance when deployed in VANETs. In a recent study [31], DREAM was evaluated for large scale mobile ad hoc networks using the realistic mobility model, RealMobgen. The reported results show that average latency is less sensitive as the network size increases. In this paper, a performance evaluation of the DREAM protocol for geographic routing in VANETs is presented.

III. DREAM PROTOCOL OVERVIEW

DREAM protocol [1,2,22,23] is a restricted flooding communication protocol used in unstructured architectures. Each node may maintain a location table about the position of all nodes of the network and frequently floods a location packet, called control packet, to update the position information maintained by its neighbors. Each location packet submitted by a node *A* to other nodes to update their location tables contains *A*'s coordinates along with its speed and the time the location packet was transmitted. DREAM uses the principle of distance effect in which the location tables update frequency is determined by the distance of the registered nodes. In other words, the closer to another node, the more updates sent to this node. The frequency of sending a control packet is adjusted based on the moving speed of the source node *S* [29].

When the source node *S* wishes to send a message to a destination node *D*, it starts by looking for its location table and retrieves information about its geographical position. If the direction of *D* is valid, *S* sends the message to the all one hop neighbors in the forwarding zone determined by that direction. If no location information is available for *D*, then a recovery procedure must be executed by flooding partially or entirely the network in order to reach *D*. When a node *A* receives the message, it checks first if it is the node destination. If this is the case, it sends an acknowledgement to the source node. Otherwise, *A* repeats the same process by sending it to all one hop neighbors that are in the direction of *D*. Each of these nodes, in turn, repeats this process, if possible, until *D* is reached.

To determine the forwarding zone in the direction of the node *D*, the source node S calculates the expected zone which contains *D*. Figure 1 shows an example of expected zone, i.e., the circle around the position of *D*. The radius r of this zone is set to $(t_1 - t_0)v_{\max}$, where t_0 is the timestamp of the position information that *S* has about *D*, t_1 is the current time, and $v_{\max}$ is the local known speed that the node *D* may travel in ad hoc network. After determining the expected zone, the node *S* defines its forwarding zone which is the region enclosed by an angle whose vertex is at *S* and whose sides are tangent to the expected zone calculated for *D* and then sends the packet, destined for *D*, to all its neighbors in the forwarding zone [23].

In DREAM, exchanging nodes' coordinates instead of exchanging complete link state or distance vector information helps reducing the occupied bandwidth. Moreover, since DREAM uses the distance effect principle described above, it can perform well in dynamic mobile ad hoc networks. This paper first conducts a performance evaluation of DREAM and reports simulation results to shed more light on its performance for inter-vehicle communication.

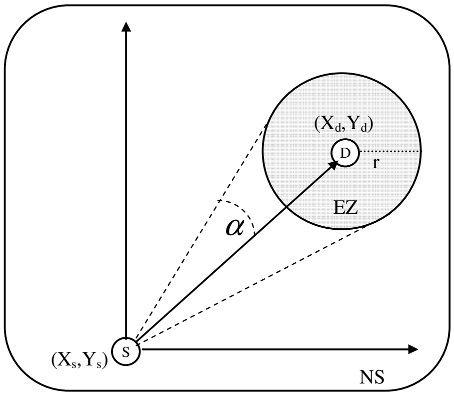

Figure 1. Expected zone (EZ) within a network space (NS)

IV. EVALUATION METHODOLOGY

In this section, DREAM evaluation study is performed by means of the code developed in [23] using ns2 (version 32). In the rest of this section, parameters related to the DREAM protocol, to mobility scenarios, and to traffic that imitates the applications are presented. Performance metrics together with simulation results are also reported.

A. Mobility scenarios and traffic parameters

Performance studies of ad hoc network protocols depend mainly on the chosen mobility model [24,25] to obtain accurate simulation results. In order to evaluate the performance of the protocol DREAM, realistic vehicular mobility models or scenarios are necessary. A mobility model is the pattern that defines vehicles motions within the simulated area during a simulation time, which reflects, as close as possible, the real behavior of vehicular traffic. For this purpose, we have used MOVE (MObility model generator for Vehicular networks) [15] and TRaNS (Traffic and Network Simulation Environment) [14] to create a movement pattern for a small part of a city. These tools are built on top of SUMO, an open source micro-traffic simulator [4]. The generated mobility trace file contains information of realistic vehicles movements.

In this study, the scenario generated is a grid topology with a block size of 200mx200m as depicted in Figure 2. The number of vehicles was fixed at 50. This scenario generated randomly and contains six roads, nine intersections, and twelve crossover points at the border. Fifteen vehicles move along the grid of horizontal and vertical streets on the map. Each line representing a single-lane road and vehicular movement occurs on the directions shown by arrows. At a crossover, vehicles choose to turn left or right with equal probability, 0.5. At an intersection of a horizontal and a vertical street, each vehicle chooses to keep moving in the same direction with probability 1/2 and to turn left or right with probability 1/4.

It is worth to noticing that several realistic mobility models have been proposed for MANETs and VANETs as well [16]. The most known one is Random Waypoint mobility [34] proposed mainly for the evaluation of MANETs. Other models are artificial mobility and real-world mobility models which can be considered as a major step towards generating realistic vehicle traces. More depth analysis and details of these models can be found in [25] for MANETs and in [16,6] for VANETs.

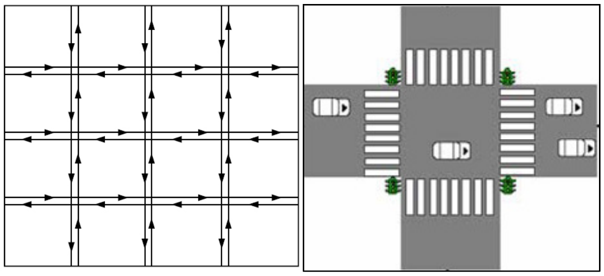
(a) (b)

Figure 2. (a) Mobility scenario, (b) The structure of each intersection

Several simulation scenarios by varying the number of traffic sources are generated from light to heavy traffic (1, 5, 10, 15, 20, 25 nodes). The CBR (Constant Bit Rate) traffic generator was attached to each node source to generate packets 64 bytes each and at a deterministic rate (4 packets/s) to all other nodes. All nodes use 802.11MAC operating at 2Mbps. The transmission range is 250m. Similar to [23], a peer-to-peer traffic pattern was used instead of random traffic in which traffic is randomly spreads among all nodes.

B. *Simulation results*

The following performance metrics described in [23] are evaluated to study the scalability of the DREAM protocol:

- Data packet delivery ratio: defines the ratio of the number of data packets delivered to the destination nodes divided by the number of data packets transmitted by all source nodes.
- Average end-to-end delay or average latency: is calculated from the first data packet to arrive at the destination node. It includes buffering, queuing, retransmission and propagation delays.
- Control packet overhead: is defined as the number of control packets transmitted for each data packets delivered. The evaluation of this metric can help capturing the power overhead requirements of the protocol.
- Data load: is defined as the number of data packet transmissions per data packets delivered. The evaluation of this metric can help capturing the bandwidth overhead requirements of the protocol.

Different simulation scenarios have been conducted and results are reported to analyze the relationship between these performance metrics and the number of traffic sources in one hand and the vehicles' speed in another hand. At the beginning (i.e., data start time) of each simulation instance, each source node starts to generate data packets according to the traffic model described above. Nodes start sending data packets from 50 up to 100 seconds simulation time. Ten simulation trials for each of scenarios are performed and results are reported for each performance metrics. All results show the effects of varying the number of constant bit rate (CBR) sources and vehicles' speed on considered performance metrics.

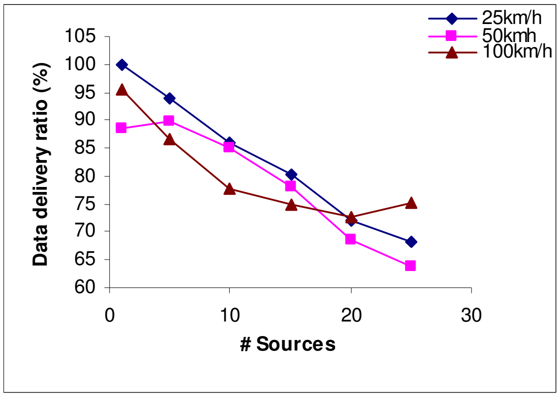

Figure 3. Data packet delivery ratio vs. number of sources

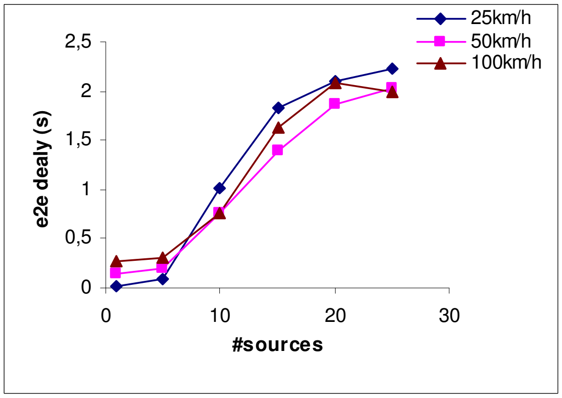

Figure 4. Average latency vs. . number of sources

Results depicted in Figure 3 show the fraction of data packets that are successfully delivered during the simulations time versus the number of traffic sources. As the number of traffic sources increases, the data packet delivery ratio decreases because the network becomes more congested with heavy traffic causing more packets to drop. In another words, when the number of CBR sources increases, there is an increase in the number of packets contending for a common wireless channel, which leads to more collisions and packet drops. As shown in this figure, the drop is more sensitive to traffic load than vehicles' speed.

Figure 4 illustrates the variation of the average latency by varying CBR sources. When increasing the number of traffic sources beyond 5, the average latency increases constantly because increasing the number of source nodes the network becomes more congested with heavy traffic and so buffers become full causing more flits to wait in the buffers. We can also see in figure 4 that the average e2e delay is less sensitive when nodes speed increases. We can see in Figure 5 that the data load increases as the number of CBR sources increases. As the number of traffic sources increases, more data packets will be sent. However, the protocol is less sensitive to vehicles' speed, i.e., data packet overhead remains constant as vehicles speed increases due to flooding behavior of the protocol.

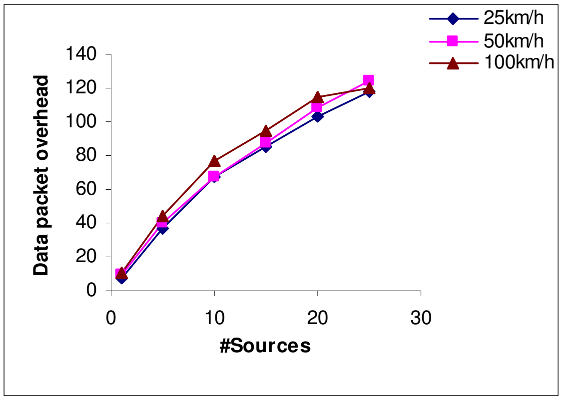

Figure 5. Data packet overheads vs. . number of sources

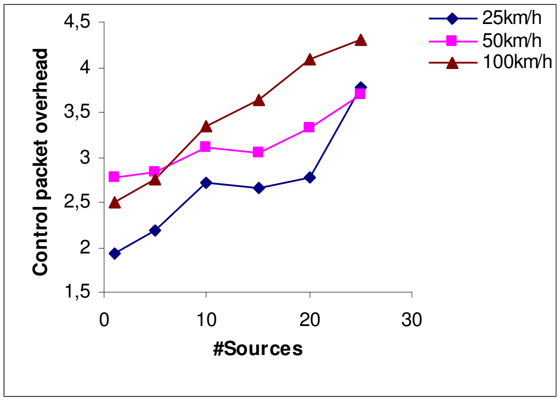

Figure 6. Control packet overhead vs. . number of sources

Figure 6 illustrates the control packet overhead by varying the number of CBR sources. As seen in this figure, the control packet overhead increases as the number of source nodes increases because of the number of packets sent to exchange location information. This figure shows that the control packet overhead is more sensitive to nodes speed increases which increase route breakages. This can be explained by the big number of control packets generated by each node to inform the other nodes about its position, since each node maintains position information about all other nodes of the network. DREAM also returns an ACK packet for each data packet that is delivered from the forwarding zone which increases the control packet overhead.

V. CONCLUSIONS AND FUTURE WORK

This paper presents a simulation study of DREAM protocol for inter-vehicle communications using a real mobility model. The results show that the protocol is more sensitive to traffic load than vehicles' speed which is more convenient for dynamic mobile ad hoc networks like VANETs. Simulation comparison with other protocols (e.g., LAR, AODV, and GPSR) is an ongoing work. Future work will address the development of pervasive applications and context-aware driver assistant systems as well as cooperative driving techniques for traffic control.

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