Interest-Based Forwarding for Satisfying User Preferences in Vehicular Networks

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Abstract. Daily roadway commutes provide driving patterns in time and in space motivating the formation of mobile vehicular groups based on common backgrounds and interests. These groups can be used to reduce the propagation of irrelevant and redundant information and can be used also for group-based applications such as caravaning. This paper investigates the groups formation behavior under the dynamic topology of vehicular networks through different traces and synthetic scenarios. Next, to show the impact of group on content dissemination scheduling, a comparison of group-based scheduling with other relevant data dissemination scheduling schemes is conducted by simulations in terms of delivery ratio and latency. Simulation results show that groups can be used in order to share information in an intelligent way such that to reduce the propagation of irrelevant and redundant information. Additionally, this paper shows that group-based data dissemination can enhance the delivery ratio and latency compared to other relevant scheduling schemes.

1 Introduction

The advent of mobile technologies promotes the great use of mobile devices such as smartphones, PDAs and On-Board Units (OBUs). The growing ubiquity has been employed to characterize roadway commutes driving patterns. Also, it has motivated the formation of mobile vehicular communities, called Vehicular Social Networks (VSNs) [1] composed of commutes' devices temporarily grouped by their user's common backgrounds and interests.

Understanding the dynamics of the vehicular environment and their existing patterns is essential to strategically disseminate relevant information to users and propose mechanisms for network or service adaptation [2]. Vehicular networks are highly mobile and in a short period many changes may occur in the environment, such as the neighborhood can quickly change; communication networks may become available or unavailable, and user groups can appear or disappear. Content dissemination in these networks is a challenge mainly due to the opportunistic communication between vehicles and the weaknesses on wireless connectivity. Nodes interact when they meet geographically, thus, they have only

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a partial view of the network, making hard routing and dissemination decisions. Furthermore, wireless communication technologies present constraints making some solutions infeasible because they cause an excessive overhead for the network, e.g. the Epidemic protocol [3].

Groups formation can be useful for content dissemination in vehicular networks. In one hand, groups can be used to share information in an intelligent way such that to reduce the propagation of irrelevant and redundant information. In the other hand, several applications in vehicular networks such as caravaning, collaborative gaming, platooning, and so on [4,5] require connectivity between groups of vehicles in which users can communicate among them. Works on the literature define groups in such environment where vehicles communicate using the well-known centralized entities. For instance, in [6], authors developed a prototype for voice chat groups which enables drivers in the same location and time to communicate using voice messages. However, such a centralized communication mechanism may cause high latencies and also cannot work in ares poorly covered (e.g. rural areas). Other approaches define clustering algorithms where a clusterhead is elected in order to manage the group.

In this work, two definitions of group are used for the evaluation. First, a group is defined based on the notion of clique in the network graph. Each vehicle is in direct contact with all other nodes in the same group. Second, to compare group-based scheduling with other scheduling schemes, group is defined as a set of vehicles sharing common interest.

This paper evaluates first the viability and behavior of group formation in vehicular networks. This evaluation is performed under different traffic scenarios considering real traces and synthetic models. The group formation is evaluated in terms of vehicles density, group size and group lifetime. Analysis results show that under high traffic, vehicular groups can be used to enhance the performance of content dissemination. Next, simulations are conducted to compare group-based content dissemination scheduling with other relevant scheduling schemes in term of delivery ratio and latency. Results show that group-based dissemination scheduling can achieve better latency as well as delivery ratio comparing to other schemes. Finally, this paper addresses user satisfaction under vehicular social networks (VSNs) to promote the progress in the state-of-te-art of content dissemination in VSNs.

This paper proceeds as follows. Section 2 presents a review of related work aiming to show the unique position of this paper. The evaluation results of vehicular groups' formation under the dynamic behavior of vehicular networks are presented in Section 3. A comparison of group-based content dissemination scheduling with other relevant scheduling schemes is described in Section 4. Section 5 discusses the importance of user satisfaction in VSNs. Section 6 concludes the paper.

2 Related Works

In vehicular network, nodes move very quickly, reducing their contact duration (duration they are within the range of each other) and constraining data transmission. There are several attempts to measure the contact duration and other behaviors in vehicular networks, such as neighboring dynamics [7,8]. Precisely characterizing nodes or even commutes patterns can assist in data delivery, even though there is no guarantee that a route is available for data delivery. In face of these challenges, few approaches have followed a different perspective applying Delay Tolerant Network (DTN) protocols, such as Epidemic [9] and MaxProp [10], envisioning to improve data dissemination without characterizing network behavior. These protocols are, in general, based on broadcasting routing, assuming that a large number of copies of the same message can increase the probability of successful message delivery. Their main purpose is to optimize delivery delay, delivery ratio and minimize resource utilization. These solutions achieve valuable results. However, they are very resource consuming, leading to a rapid saturation of the mobile nodes buffer, as well as the network bandwidth.

Recently, group communication has been studied in the context of vehicular networks. Some of these works has been explored using the permanent connectivity of centralized server [1,6,11,12]. In [6], authors proposed a group-based voice communication that allows drivers to join chat groups defined a priori based on location and time at a centralized server. RoadSpeak uses the cellular network and cannot work otherwise. These works define groups based on common interests and users join these groups to share information. Unfortunately, these works rely on permanent availability of a central server, which manages interactions between drivers. Hence, even communications between drivers in the same vicinity need to pass through an intermediate (i.e. the central server), in which a direct communication link can be created. Furthermore, cellular network-based systems can easily overload the network and they cannot be used in poorly covered areas. Other works focus on group communications in vehicular networks based on clustering [13] where a clusterhead is chosen to manage the connection between the members of a group.

First, to understand the behavior of groups formed based on location and time, this work defines the group based on the notion of clique in the network graph. Each vehicle is in direct contact with all other nodes in the same group. Second, to show the impact of vehicular groups on content dissemination scheduling, this paper defines group as a set of vehicles defined as destination. This paper analyses the impact of group formation only on adhoc WIFI links between nodes (i.e. V2V communications).

3 Evaluation of Groups Formation in Vanets

Groups can be used to enhance content dissemination in vehicular networks. Groups can be used to share information in an intelligent way such that to reduce the propagation of irrelevant and redundant information. Further, several applications in vehicular networks such as caravaning, collaborative gaming, platooning, and so on require connectivity between groups of vehicles in which users can communicate among them. However, vehicular groups can suffer from short-lived links due to the highly mobile vehicles communications and the intermittent connectivity. Thus, in order to understand groups behavior in vehicular networks and conduct an informed design of content dissemination methods between vehicles, it is of great importance to evaluate the formation of vehicular groups in terms of density, frequency and lifetime. For this purpose, this evaluation is conducted under various real traces and synthetic traces. The Network Simulator NS-3 [14] and the traffic simulator SUMO [15] are both employed in order to set up Scenario1 as follows.

Scenario1 (on a short period - 180 seconds):
In order to present the network dynamics, simulations are limited to a short period. 20 vehicles are selected randomly and the transmission range is set to 250 meters. Each node sends periodically a discovery message (i.e. beacon message) which contains information about the node such as the identifier (ID) for neighboring discovery. When vehicles meet opportunistically, neighbors which present the nodes directly connected between them can form a group. This section defines the group as a set of nodes that are in the range of each other as shown in Fig. 1, it corresponds to the notion of clique in the network graph.

To study the traffic road impact on the stability of groups in vehicular networks, different traces and mobility patterns are considered using high and low traffic.

- Real vehicle traffic, based on two real traces (trace 1 and trace 2) under high and low traffic already generated from different cities [16]
- Random vehicle traffic, generated in real-world map extracted from a map of the OpenStreetMap tool [17], in which two mobility model (model 1 and model 2) using high and low traffic are produced by the traffic generator SUMO.

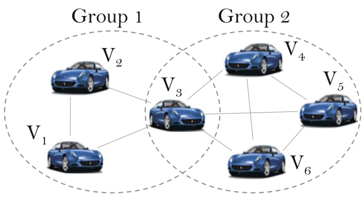
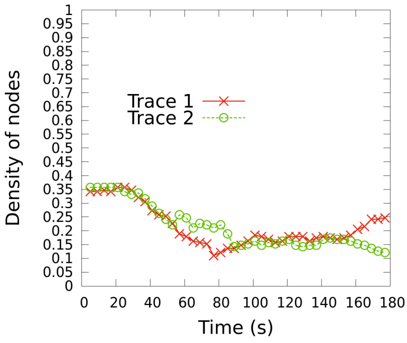


Fig. 1. Clique-based group

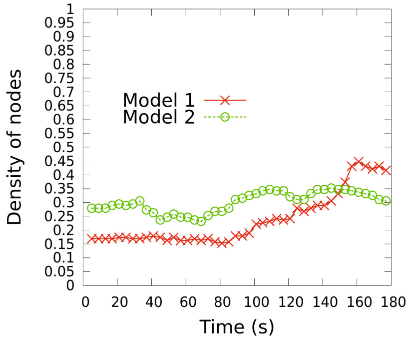
Scenario1 intends to analyze network density variation and show its impact on group formation, verifies the dynamic and viability of physical groups considering metrics as number of nodes per group, number of groups each node participates in, and group lifetime. The next subsections present the results.

3.1 Network Density Variation

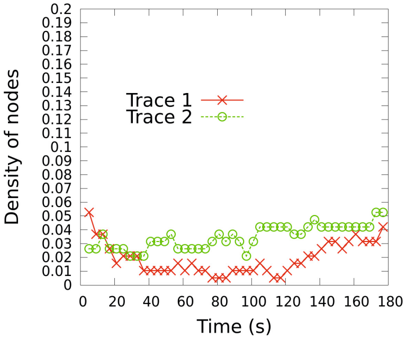
The normalized density is calculated as the proportion of actual connections to the maximum of potential connections. The variation of the density is shown in Fig. 2, and the average values are given in Table 1. The density of nodes tends to vary more under the random mobility than under real traces. The different graphs show that the density varies with time and show sometimes



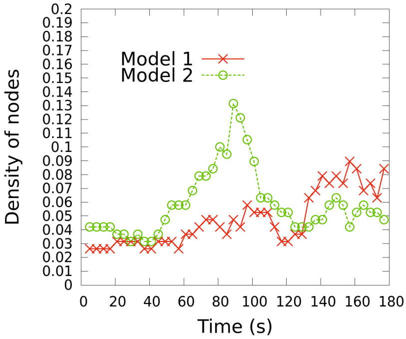
(a) Realistic high traffic



(b) Random high traffic



(c) Realistic low traffic



(d) Random low traffic

Fig. 2. Normalized density variation

Table 1. Average normalized density

Average normalized density		Low density	High density
Real vehicle traffic	Trace 1	0.019	0.21
	Trace 2	0.034	0.21
Random vehicle traffic	Model 1	0.047	0.23
	Model 2	0.058	0.3

peaks. This is explained by the fact that vehicles meet at intersections (i.e. the density increases) and then spread again all over the map (i.e. the density decreases). Average values of density are shown in Table 1.

3.2 Network Partition into Physical Groups

In order to assess if user groups based on their spatial dependence could assist to interactions between neighbor nodes on data dissemination, the network nodes are partitioned into several physical groups. A physical group is defined as a set

Table 2. Average percentage of nodes that are part of a group

Percentage of nodes that are part of group (%)		Low density	High density
Real vehicle traffic	Trace 1	31	85
	Trace 2	48	91
Random vehicle traffic	Model 1	50	91
	Model 2	57	91

of nodes in the range of each other. This subsection analyses the statistics about nodes belonging to the same groups. The identification of physical groups allows setting up efficient coordination schemes between the members of each group to reduce bandwidth waste.

Table 2 presents the percentage of nodes that belong to groups in low and high traffic. In high traffic, the results are similar in both cases (i.e. traces and synthetic models), where approximately 88% (respectively 91%) of nodes are part of at least one group in real traces (respectively synthetic mobility model). In low traffic the percentage of nodes that are part of at least one group is below 48% under real traces, and below 57% under random models. This explains, in low traffic, the network is fragmented, the communication between nodes being almost impossible to maintain it for a long time (i.e. a low density making connection between vehicles, present in the same location and at the same time, happens rarely). As for the high traffic, approximately 90% of the nodes are part of groups (i.e. vehicles in dense roads have more probability to encounter other vehicles such in intersection).

3.3 Number of Nodes Per Group

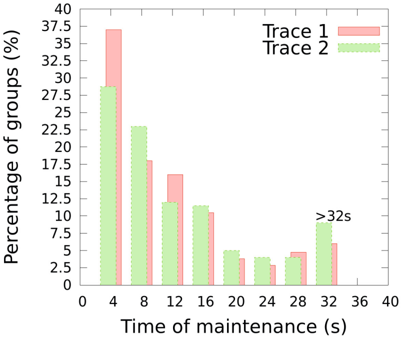
Table 3 presents the average values of the number of nodes per group. In high traffic, groups contain approximately 4 nodes for both real traces and random mobility. In low traffic, for both real and random traffic, the number of nodes in a group is fairly constant (almost time 2 and sometimes 3). Which means that a group is usually formed just between two vehicles that meet opportunistically.

Table 3. Average number of nodes per group

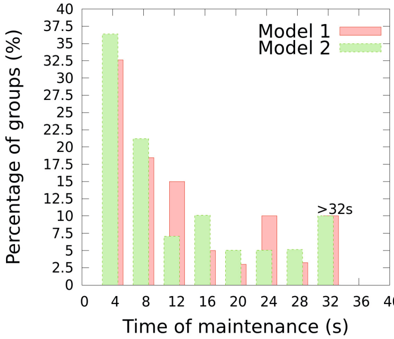
Average number of nodes per group		Low density	High density
Real vehicle traffic	Trace 1	2.04	3.87
	Trace 2	2.23	3.78
Random vehicle traffic	Model 1	2.13	3.96
	Model 2	2.28	4.28

3.4 Number of Groups Per Node

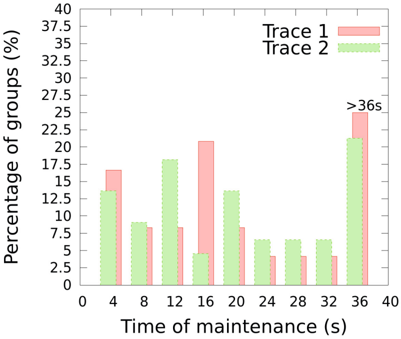
Tables 4 and 5 presents the average number of total formed groups and the average number of groups per node, respectively. In low traffic, most of the nodes are part of only one group at the same time. Moreover, the total number of groups is less than 6 under the random models and less than 4 with the traces. In the previous subsection, results show that there are approximately 2 nodes per group in low traffic. Therefore, in low traffic (e.g. rural roadways) it



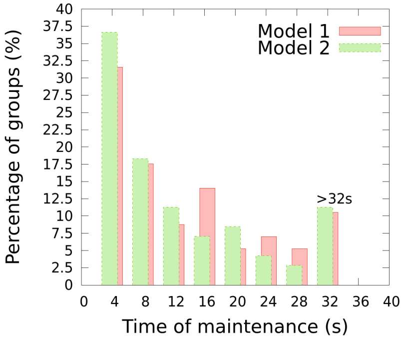
(a) Realistic high traffic



(b) Random high traffic



(c) Realistic low traffic



(d) Random low traffic

Fig. 3. Normalized density variation

is not efficient to create vehicular groups since most of the communications are between just two vehicles. Thus, a simple coordination between the two vehicles is sufficient.

In high traffic, as an average value, a node can be part of one or two groups in the same time. The results from the previous subsection show that a group contains 4 nodes. Thus, in the high traffic, a node can be in contact with 3 or with 6 nodes (i.e. a node is part of 2 groups and each group contains 4 nodes). If the node is part of 2 groups containing 4 nodes each, then it is in contact with 6 nodes. Additionally, there are more than 8 groups with random mobility and real traces. Hence, in high traffic, formation of groups can be useful to enhance content dissemination algorithms in vehicular networks if they are maintained for enough time.

3.5 Group Lifetime

The lifetime of a group gives an estimation of the maximal duration for data dissemination within the same group. Fig. 3 shows the groups lifetime for Scenario1.

Table 4. Average number of groups: Total

Average number of groups		Low density	High density
Real vehicle traffic	Trace 1	3	8
	Trace 2	4	9
Random vehicle traffic	Model 1	6	8
	Model 2	5	8

Table 5. Average number of groups per node

Average number of groups per node)		Low density	High density
Real vehicle traffic	Trace 1	1.02	1.56
	Trace 2	1.00	1.49
Random vehicle traffic	Model 1	1.27	1.66
	Model 2	1.15	1.92

Results show that in high traffic there are groups maintained for a long time comparing to the simulation time. Additionally, the figure shows that groups' lifetime using real traces and mobility model are close. In low density, Fig. 3 shows also that groups are maintained for a long time.

3.6 Discussion

The analysis on the vehicular groups point out two key issues for the next work:

In low traffic, results show that the network is highly fragmented. Indeed, almost half of the vehicles are not in contact with other vehicle (i.e. a vehicle is not part of any group). Further, almost all groups formed contains just 2 vehicles. Hence, in low traffic there is no necessity to create groups since a simple coordination between the two nodes is sufficient.

In high traffic, evaluation shows that groups are formed often and almost 90% of the nodes are part of at least one group. Moreover, groups contains usually 4 nodes (average). Some nodes are part of 2 groups in the same time, thus, these nodes can be used to aid the inter-groups communication. Additionally, several groups are maintained for enough time compared to the simulation time. Thus, the formation of groups can be used to share information in an intelligent way such that to reduce the propagation of irrelevant and redundant information. Also these results promote the development of group-based applications such as caravaning, collaborative gaming that require connectivity between group of vehicles.

4 Comparison of Group-Based Scheduling with Other Scheduling Schemes

Basically, users that form a group to interact between them share common interests. Thus, users with common interests join the same group [6], and then they can socialize and exchange information when they meet opportunistically. This section investigates the impact of group-based scheduling compared to other scheduling schemes representative from the literature, under different data dissemination algorithms as Epidemic and MaxProp.

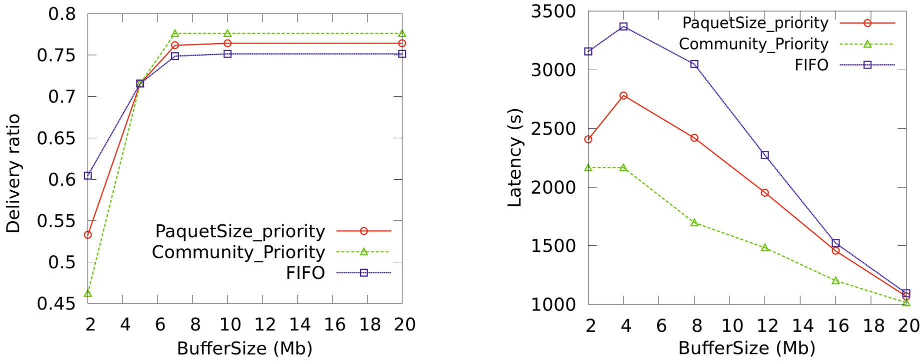
The main purpose of data dissemination algorithms in vehicular networks is to maximize the delivery ratio and minimize the latency between the source and destination. We compare the performance of Epidemic and MaxProp schemes under different packet forward scheduling. The most employed packet forward scheduling in the literature have been employed, as FIFO (First in First Out) and priority to the smallest packet. Therefore, this section analyses a hypothetical packet forward scheduling that gives priority to groups. For the analysis presented in this section, the ONE (Opportunistic Network Environment) [18] simulator is employed in order to set up Scenario2 as follows.

Scenario2 (on a long period - 12 hours):
An urban area of 4500m $\times$ 3500m has been chosen for these evaluations. The scenario considers 70 nodes equipped with a short-range wireless communication device, i.e. on board unit (OBU) or a smart-phone, to detect other users' devices and to communicate or share content. For the sake of simplicity, vehicles are divided into three different types: car, buses, and pedestrians in order to create different groups. Each type follows a specific mobility model appropriate for the node type. The different groups are set with features significantly closer to reality. The first type contains 40 cars that follow a synthetic mobility model [19] with a speed varying in the range of 10$\sim$50 km/h. The second type comprises 10 buses that follow a deterministic mobility model with an average speed of 10$\sim$37 km/h and stop periodically during 10$\sim$30 seconds of pause time. Finally, 20 pedestrians move randomly with an average speed of 1.8$\sim$5.4 km/h over the entire surface of the map. The node's transmission range is set to 250 m and the transmission speed is set to 2.5 Mbps. Simulations are conducted over various buffer sizes (2$\sim$20 Mb), and packet size (10$\sim$100 KB). Packets are generated randomly over random nodes each period of time in the range of $[25s, 35s]$. The TTL is set to 120 minutes.

For the group-based scheduling, each group has an identifier; pedestrians 0, cars 1, and buses 2. In the simulation, packets are assigned a priority, i.e. packets are generated with different identifier (i.e. 0, 1, or 2). When nodes encounter, using group-based scheduling, each node sends first the packets containing the same identifier as its group, then it continues sending other packets (i.e. prioritize packets that are assigned for nodes from the same group. Three scheduling schemes are compared: Packet size priority, FIFO, and groups priority. The following subsections investigate the influence of groups on data dissemination compared to other packet forward scheduling schemes. Investigations apply the delivery ratio and latency metrics for the evaluation. The delivery ratio is computed as the ratio of successfully delivered packets to the total number of packets at the end of the simulation.

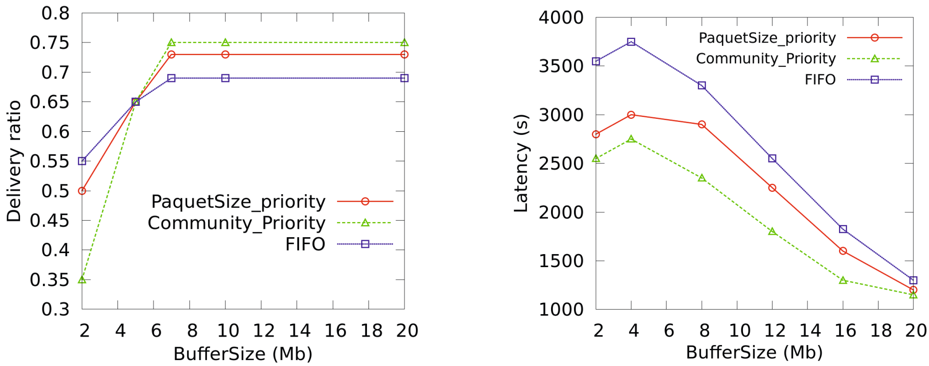
4.1 Results

Fig. 4 and Fig. 5 presents the delivery ratio and latency for the different scheduling schemes under the Epidemic routing and MaxProp routing, respectively.



(a) Delivery ratio **(b)** Latency

Fig. 4. Different scheduling schemes with Epidemic



(a) Delivery ratio **(b)** Latency

Fig. 5. Different scheduling schemes with Maxprop

Fig. 4a and Fig. 5a show that group-based priority shows an improvement over the other schemes when the buffer size is more than 5Mb, while for a low buffer capacity (less than 5Mb), group-based scheduling realizes less delivery ratio compared to other schemes. This technique allows prioritizing a group whose packets are ignored because of few contacts with the rest of the nodes. Additionally, with a large buffer capacity, the packet size priority is better than FIFO. This is because it allows the transmission of more packets during the short contact period between nodes. The most significant improvement is in terms of latency as shown in Fig. 4b and Fig. 5b. Using group priority, the packets arrive to destination faster compared to packet size priority and FIFO. As the buffer size increases, the latency decreases and the difference between the differences schemes decreases. This is because, with a small buffer capacity, a node has to send the appropriate packets in a limited contact duration before the packets are dropped due the limited buffer. Therefore, group-based scheduling schemes can improve the content dissemination and it has the same behavior under different routing protocol. Moreover, group-based dissemination enables users to share content that they are interesting first. Thus, it maximally satisfy users interests compared to other scheduling schemes that ignore the relations between users.

5 Towards Satisfying User Interests in VSN

Recently, vehicular social networks (VSNs) [1] have attracted tremendous interests in the context of opportunistic networks. Several works [2,8] have investigated social network in vehicular networks dissemination targeting to optimize both delivery ratio and fan-out delay. Such as the work in [2], authors proposed an opportunistic data forwarding scheme, named ZOOM, for fast routing. They integrate both contact-level and social-level in order to predict future contact and select the best relays. These works achieve valuable results. Unfortunately, most of them do not consider an important criterion: **user interests**. Even though these dissemination protocols can reach noticeable performance in terms of delivery ratio and delay, they might not be able to maximally satisfy users' preferences.

Those studies consider information as a black box, without handling the user's interest in the content. They consider a single type of object while there are different types of information such as traffic information and restaurant recommendation that need to be accommodated by a VSN.

VSNs constitute an environment where a large amounts of content are being generated every day. Users are seldom interested in all these content; they only want a small part of the information. Moreover, connections between vehicles in a VSN exist only during a very short period, allowing users to exchange a limited volume of data. Therefore, there is an increasing demand for efficient content dissemination in VSNs that takes user interests into consideration and that is designed to maximally satisfy user preferences. An efficient content dissemination protocol has to manage: which content objects to forward? how to schedule these objects? Additionally, there is a need for performance criterion (i.e. quantitative metric to compute how much users are satisfied) different from the classic metrics to evaluate dissemination protocols.

6 Conclusion

In this paper, we investigate the impact of traffic dynamics on temporary group creation in vehicular networks based on realistic traces and synthetic mobility models, to better understand groups behavior in vehicular networks. The analysis shows that in high traffic scenario groups can be formed with enough nodes and are maintained enough time allowing its members to communicate and share information between them. Thus, groups can be used in high traffic for groups-based applications or to enhance the content dissemination in vehicular networks. Next, we evaluate the impact of group-based scheduling on content dissemination under different routing protocols. Results show that the use of group provide, using enough buffer capacity, better results in term of latency and delivery ratio. Moreover, group-based content dissemination enables to maximize the satisfaction for users since it divide users sharing common interests in different groups. Finally, a new vision that targets on maximally satisfying user interests (specific for comfort applications) is discussed. Future works may lead us to propose an innovate protocol that exploits the formation of group based on common spatio-temporal and common interests between vehicles.

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