Content Dissemination in Vehicular Social Networks: Taxonomy and User Satisfaction

Farouk Mezghani, Riadh Dhaou, Michele Nogueira, and André-Luc Beylot

ABSTRACT

Social networking applications have gained huge popularity. With the widespread use of smart devices (e.g., on-board units, smartphones), these social networks are increasingly going mobile. As a result, a new trend of networking has emerged, referred to as vehicular social networking (VSN), which combines the wireless communications between vehicles with their social relationships. In a broader view, VSNs are social networks formed on roadways by users who have social relationships, interactions, and common interests. The exploitation of vehicular users' social properties provides better networking and social support to innovative applications and services. This article overviews recent achievements in VSN by providing an organized view of existing approaches. Its contribution lies in a taxonomy for content dissemination approaches in the context of VSN. Also, a framework is outlined to tackle a major new challenge: supporting user satisfaction. Finally, this article emphasizes open research and future trends.

INTRODUCTION

Social networks have gained significant attention in the research and industrial communities. With the rapid evolution of the Internet, online social networks (OSNs) such as Facebook appeared as the first form of social networking, but have been limited to online activity. With the advent of wireless mobile devices (e.g., smartphones, onboard units — OBUs) that have the capability to detect proximity to other users, and communicate and share data with them, various types of networks are emerging as new paradigms to exploit social properties of mobile nodes such as vehicular social networks (VSNs), mobile social networks (MSNs), and delay-tolerant networks (DTNs).

VSNs [1] enable drivers and passengers who usually travel every day between home, office, and points of interest to socialize and exchange information with other commuters on the road. These commuters may perceive the traffic situation and share the driving experience (e.g., road hazards and traffic jams) in order to enhance traffic management. Furthermore, they can support the exchange of useful information for commuter entertainment (e.g., gas prices and video news). Due to the resource constraints of mobile devices and communication networks, content dissemination in VSNs presents several challenges. For example, due to the high dynamism of the network, it is hard to understand the social properties of the nodes and how to take advantage of users' behavior to improve the performance of the network in terms of content dissemination [2]. Communication links between vehicles might remain active only for short periods of time because of the high mobility of vehicles.

In the last decade, researchers have begun to address these issues. However, the literature on VSN lacks work that can present the state-of-the-art challenges in content dissemination. Furthermore, the literature lacks work pointing out the main characteristics of existing approaches for content dissemination and outlining open issues. Hence, this article:
- Reviews recent achievements related to content dissemination in VSNs
- Provides an organizing view of existing approaches by clearly pointing out their advantages and constraints
- Facilitates deep study of advances in the state of the art

Furthermore, it has been observed that interesting approaches exploit classic metrics such as delivery delay and delivery ratio to support the content dissemination schemes. Although those solutions represent improved results, another important feature has been left behind: *user satisfaction*, a quantitative metric that computes how well users are satisfied. It calculates, through a function of users' interests, the benefit (gain) of users in receiving the content. In VSN content dissemination is interest-driven; hence, it is necessary to provide a scheme that maximally satisfies users' interests (i.e., maximize the total data utility by sending the appropriate content objects that match user interests). This work presents a framework to measure and maximize the satisfaction of users' interests.

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The contributions of this article are first to provide the reader a comprehensive view of content dissemination in VSNs, paying particular attention to the different ongoing solutions, pointing out their limits and advantages. It allows emphasis to be placed on open research issues that the research community is called to address. Second, for tackling one of the main challenges, the lack of user satisfaction, a framework that targets maximally satisfying users' interests is proposed.

This article proceeds as follows. We provide a background on VSNs. Then a taxonomy for the VSN content dissemination approaches is presented. Next, we present a framework as a proof for the need to consider the user satisfaction feature in content dissemination schemes. Finally, we draw important directions for future studies.

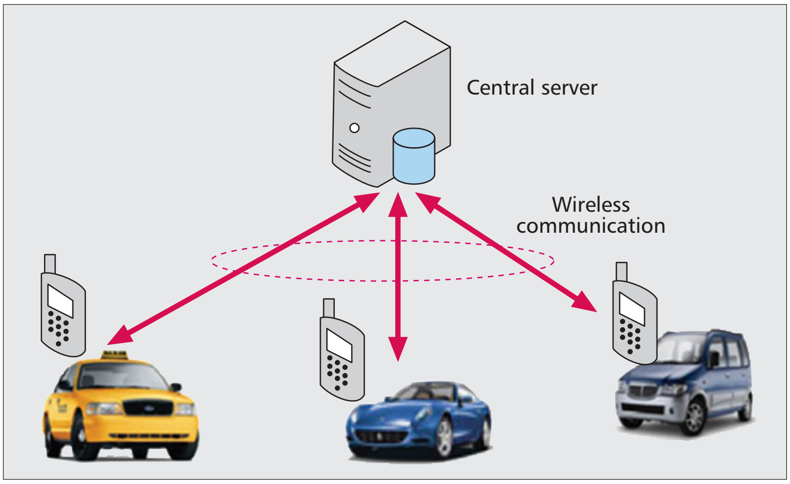

Figure 1. Centralized VSN.

BACKGROUND

DIFFERENCE BETWEEN VSNS AND MSNS

An MSN is defined as a social network formed by mobile handsets carried by humans. When these participants are moving in vehicles (drivers, passengers), they form a so-called VSN. Furthermore, in VSNs other equipment such as OBUs can be used on board vehicles.

From the social networking point of view, social relationships between users in MSNs are considered stronger than the ones in VSNs. Indeed, in MSNs, users have a very high probability of meeting each day and for enough time to exchange a lot of information (e.g., colleagues at a university, employees at work). On the other hand, VSN users do not have the same probability to meet even if they share the same destination. This is because of the highly dynamic topology and high speed of vehicles.

From a communication point of view, vehicles always move at high speed (except at intersections) in very large areas, while in MSNs, users are usually walking in a confined area (e.g., within a campus). Thus, contact frequency between the same users is very different between VSNs and MSNs. Additionally, contact duration between users is much longer in MSNs than in VSNs. Indeed, it is on the order of minutes for MSNs instead of seconds in VSNs. For instance, considering a communication range of 200 m (direct WiFi or IEEE 802.11p), the minimal contact duration for moving humans is equal to 2 min 22 s. For moving vehicles this duration is about 15 s when speed is equal to 50 km/h [3, 4]. The limitation of duration shows how difficult exchanging data is in a vehicular environment, especially for contents of large size. Even so, in MSNs users connect for enough time; they can exchange many objects, even of large size. Furthermore, regarding the communication constraints, only MSN users have energy constraints since VSN users can benefit from the power resources in vehicles.

These differences show the complexity of VSNs in relation to MSNs. Therefore, content dissemination protocols proposed and used in MSNs are either incompatible or not efficient for VSNs.

VEHICULAR SOCIAL NETWORKS

The main components of a VSN can be defined as follows:
- Participants
- Mobile device
- Network infrastructure

In vehicular networks, not only can drivers participate, VSNs, but also passengers in the vehicles. Each user can be either a content provider or a consumer. Mobile devices can be integrated in the vehicles (e.g., OBUs) or carried by users (e.g., smartphones), enabling the detection of proximity to other users' devices, and communicating and sharing content. Network infrastructure, such as cellular networks and RSUs (roadside units), is usually used in VSNs for centralized applications.

According to the way users are able to access and deliver data objects, VSNs can be broadly classified into three types of architecture: centralized, decentralized, and hybrid. The centralized architecture of VSNs, as shown in Fig. 1, works under the assumption that users must continuously access a centralized server, which coordinates and manages their interactions with other users, even when the vehicles are physically close. In such an architecture, there is no direct interaction between vehicles. Vehicles interact directly with the infrastructure of support, mainly RSUs; this communication is referred to as vehicular-to-infrastructure (V2I) communication. Vehicles communicate indirectly by means of the RSUs.

The social relations and personal profile of each user may be deemed to be relatively stable (i.e., preserved in the central server) unless the VSN users update their profiles and interests or their friendship ties over time.

A decentralized VSN, as shown in Fig. 2, includes social networks only enabled by opportunistic vehicle-to-vehicle (V2V) contact. This concept leads to benefits from both physical and virtual communication. Content dissemination in infrastructureless VSNs is a challenging task since it requires users to collaborate without the aid of a central entity. When different nodes on the road, sharing common interests, are in proximity, they can establish a temporary community

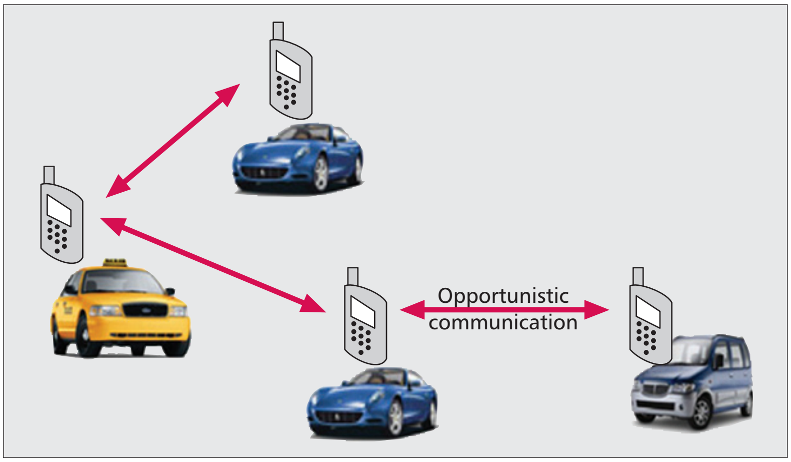

Figure 2. Decentralized VSN.

by self-organization and share data objects. Then the community can be broken up once they complete the dissemination process.

A hybrid architecture comprises both V2I and V2V communications. RSUs that are specifically designed for vehicular networks are not deployed often due to the excessive cost of their deployment. Thus, nowadays, several vehicular network applications are based on cellular networks due to the lack of RSUs. Beyond on-road safety, many services that are user-oriented are emerging for vehicular communications systems. In particular, social networking can be useful and helpful for vehicle traffic efficiency and infotainment. Two major types of VSN applications are considered:

- *Traffic management*
- *Entertainment*

Traffic management applications such as WAZE [5] and NaviTweet [6] provide user information about traffic collected in real time such as traffic jams and approaching police. Entertainment applications may be useful for drivers and passengers, especially on a long trip. For example, a voice-based application [7] enables drivers sharing common interests and driving in the same roads to interact using voice messages.

Content Dissemination in Vehicular Social Networks

This section highlights the evolution of content dissemination approaches in VSNs. Figure 3 presents the proposed classification. It consists of three main categories:

- Information processing
- Content delivery
- Performance

From the perspective of information processing, which represents the way VSN dissemination approaches treat the information, VSN dissemination is classified into three parts. Information relevance is ignored (i.e., considered as a black box), estimated, or taken from users' (personal) preferences. From the content delivery perspective, VSN dissemination schemes are categorized as utility-based or blind-based. And from the perspective of performance, VSN content dissemination approaches follow three main features: delivery delay, delivery ratio, and used bandwidth. The following subsections detail each category providing the state-of-the-art VSN content dissemination approaches.

Note that an approach is not exclusive to a single category.

Information Processing

In the first category, the classification is based on the way VSN dissemination approaches treat the different content objects. It can be classified into three types: information as a black box, estimating the information relevance for the user, or employing user preferences.

Information as a Black Box — Most previous empirical work [8–10] in the literature does not consider the subject of different content in VSNs. Information relevance for users is ignored, characterized only by its general features such as size and lifetime. Therefore, when delivering content, all vehicles are considered as targets. VSN applications are designed for commuters' comfort and entertainment; thus, nowadays users prefer to get few contents matching more with their interests and bringing more benefits than receiving several contents in which they are hardly interested. It is important to emphasize that dissemination in VSNs is characterized by information content. Different contents may correspond to different user interests.

Estimating Information Relevance — In [11], the authors propose a new technique to estimate the relevance of data for the drivers. Their solution identifies and classifies the information type to the vehicle in order to estimate the information relevance, then deciding whether to inform the driver or share the information further. The advantage of approaches that estimate information relevance is avoiding the exchange of users' interests. The main concern behind these approaches is that information relevance is related to the direction of the vehicle and the type of information, and not to the vehicular user's personal interests (i.e., the probability of a vehicle encountering an event increases as the relevance of this event increases). Estimating the information relevance makes no sense for some types of information, such as music, which is related to the users' personal interests.

Considering User Preferences — A third class of work assumes that content is related to the personal profile of the user [12, 13]. Each user defines her/his personal interests in order to receive content in which s/he is interested.

This method is best to match the users' interests. The only disadvantage is that there is a need to exchange preferences before data delivery.

Content Delivery

Content delivery is a challenging issue in VSNs due to the dynamic topology and intermittent connectivity. The second group of the presented taxonomy aggregates content dissemination approaches addressing these issues. Content dissemination algorithms are classified in two general types: *blind delivery* and *utility-based* delivery.

Blind Delivery — Several content dissemination algorithms are broadcast-based, such as the work in [8, 9]. The underlying principle is to use social communications to enhance the network resources. Blind-delivery-based dissemination can be effective for network resources, but may not be effective for users.

For example, in blind-delivery-based approaches, social relationships are used in order to accelerate the dissemination process, finding the appropriate forwarding nodes/links to increase the delivery efficiency and reduce the delay. Moreover, it can limit the bandwidth utilization by minimizing the number of nodes responsible for forwarding. Interaction between nodes is done in only one step, which consists of exchanging the data (i.e., there is no neighbor discovery or interests exchange). In [8], the authors propose a scheme for fast forwarding. This scheme uses the social relation ties between vehicles to choose the most appropriate data relays. Blind delivery can be efficient in terms of network resources, but might not be efficient for commuters. The main drawback of blind delivery approaches is the ignorance of users' preferences. In reality, social relationships are achieved between nodes that share common interests. Therefore, another important criterion that should be considered in the dissemination process is the users' interests.

Utility-based Delivery — In recent works [6, 12, 14], the authors present the problem of dissemination in VSNs from a different perspective. Even though content dissemination algorithms can deliver content rapidly to as many users as possible, many of these forwarded objects might not be useful for users, and they are ignored. For example when receiving an object, usually the user, according to the topic, decides to use or ignore the object. Social interactions are used to share content between users with common interests; thus, it is likely that the user shares the information in which s/he is interested. The probability of sharing information of less interest is low. This method may allow users to receive data in which they are interested while reducing the reception of uninteresting objects. For example, in [1] the authors proposed a VSN approach that enables commuters on the same road at the same time to communicate through voice messages about a specific topic. This proposal only considers one type of service, while different types of services need to be accommodated by VSNs. Therefore, there is a need for a multiservice dissemination scheme that efficiently explores users' interests.

Performance

The third group of the presented taxonomy comprehends VSN dissemination approaches that improve content dissemination performance based on a feature. Those approaches are classified into three groups, according to the employed performance metrics *delivery delay*, *delivery ratio*, and *bandwidth usage*.

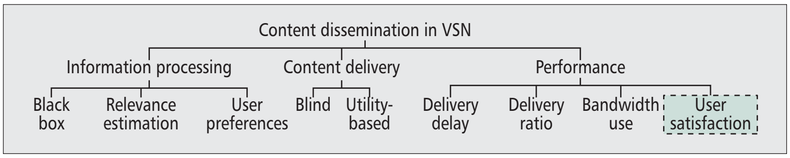

Figure 3. Taxonomy for content dissemination in VSNs.

Delivery Delay — This refers to the delay for a message to be received at the destination. The delivery delay is the major constraint for some applications, such as safety, traffic, and information, that has a short lifetime. The distributed information has a short time to live, and thus should be delivered to the destinations before it expires. For example, the work in [8] proposes a scheme based on social ties between vehicles for fast forwarding. However, delay-tolerant applications such as entertainment applications have fewer constraints on the delivery delay. For instance, information about a gas station or music has an unlimited or long lifetime; therefore, a short delivery delay is appreciated but not mandatory.

Delivery Ratio — This represents the ratio of data objects successfully delivered to destinations. The main concern behind this approach is that it considers all vehicles as destinations. For example, in [9] the authors propose a VSN scheme for mobile advertising that targets improving the coverage and intensity of advertising. However, in VSN entertainment applications, destinations refer to the nodes that are interested in a given data object. In this case, information is successfully delivered to nodes that are interested in it. Objects delivered to other nodes are ignored.

Bandwidth Usage — This refers to the use of network resources [10]. The use of bandwidth represents a major constraint: dissemination algorithms need to efficiently use network resources, not overload the system. Especially in a dense network, an excessive exchange of data and/or signaling may overload the network.

Discussion

The observation of the proposed taxonomy leads to different features that can improve content dissemination approaches. We have observed that existing works lack another important feature that evaluates the satisfaction of users. To meet this need, this article proposes adding a new feature, labeled *user satisfaction*, in the performance group shown in Fig. 3. The main goal is to maximize the total data utility by sending the appropriate content objects that match user interests. Indeed, users have different interests; thus, an efficient dissemination algorithm has to reduce the reception of useless objects. Moreover, a user has heterogeneous preferences; for example, a vehicle may be interested in traffic information more than a gas station notification. Therefore, the dissemination protocol should be based on an efficient method that can increase the satisfaction of users by delivering the appropriate objects. This feature may not be important in safety applications because these

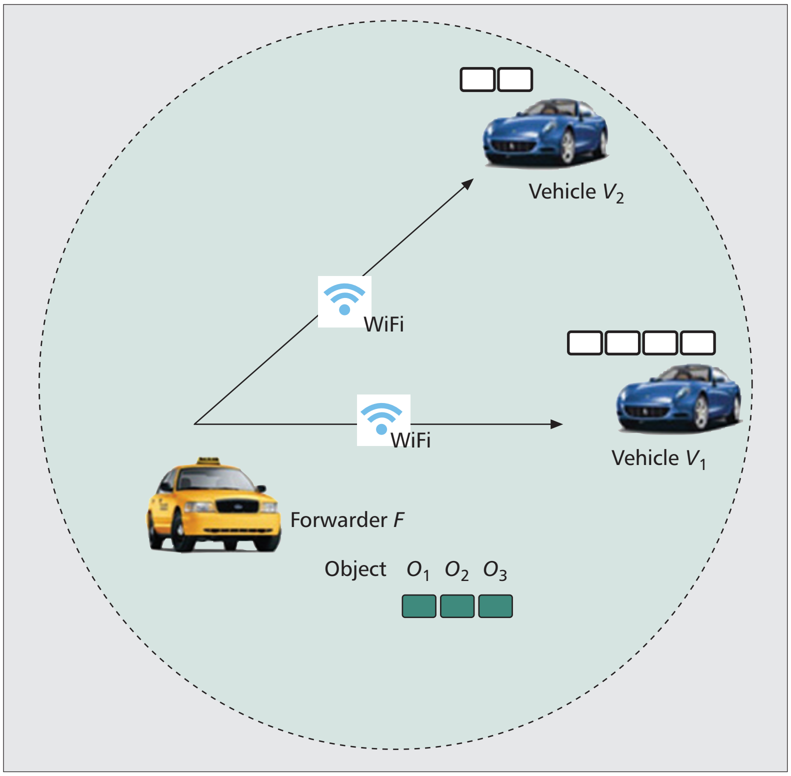

Figure 4. Simple scenario with different object interests and contact durations.

Forwarder F	Contact duration	O_1	O_2	O_3
V_1	$4T$	7	2	4
V_2	$2T$	5	9	9
sum I_{V_i,O_j}		12	11	13
		sum $I_{V_i} = 36$		

Table 1. Example of simple scenario.

applications aim to increase the security for the drivers and do not aim to increase their satisfaction.

User Satisfaction Framework

VSNs constitute an environment where a large amount of heterogeneous contents are being generated every day. Users are seldom interested in all these contents; they only want specific useful information. Nowadays, with the growing popularity of personalizing applications, customers prefer to get content based on their personal interests. Moreover, connections between vehicles in a VSN occur 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 considers the heterogeneous preferences of users and targets maximally satisfying user interests.

In order to tackle this challenge, we propose a framework based on two main goals: first, the user preferences should be taken into consideration to deliver objects interesting to them; second, heterogeneous user preferences should be taken into account to distribute the appropriate objects accordingly in short periods of time.

Consider the example shown in Fig. 4, where a forwarder F owns three objects (O_1, O_2, O_3) and meets neighboring vehicles, V_1 and V_2. Each user V_i ($i \in \{1, 2\}$) has interest $I_{V_i, O_j} \in [0..10]$ for object O_j ($j \in \{1, 2, 3\}$), as shown in Table 1. Assume that the contact duration is only long enough for vehicles V_1 and V_2 to receive 4 and 2 objects, respectively.

We define the metric of *user satisfaction*, $U_{satisfaction}$, to determine how well users' interests are satisfied. It computes the utility gained (benefit) of the users after receiving the different content objects from F.

When vehicles meet opportunistically, an efficient content dissemination strategy addresses which objects to forward and how to schedule these objects to maximally satisfy user interests. Based on classical dissemination approaches, the forwarder F disseminates objects randomly. However, this dissemination strategy cannot maximize satisfaction. If we take into account heterogeneous user preferences, users can distribute objects efficiently to attain better satisfaction for neighboring users. In particular, based on local interests, F distributes the objects in the following order: [O_3, O_1, O_2], since the satisfaction that can be obtained is 13, 12, and 11, respectively. In this case, the global satisfaction, which represents the gained cumulative satisfaction, obtained after the broadcast of all the objects of the forwarder F is 0.75 ((13 + 12 + 2)/36).

Additionally, considering other parameters such as *contact duration* between vehicles can enhance this forwarding strategy and ensure a high level of user satisfaction. The link between F and V_1 is maintained for enough time (V_1 can receive all 3 objects as opposed to V_2, which can only receive 2 objects). Then, since object O_2 is more important to V_2 than object O_1, F can send the objects in the following order [O_3, O_2, O_1]. Thus, the global achieved satisfaction is: 0.86 ((13 + 11 + 7)/36).

Even though content dissemination approaches enable content to be delivered quickly to many users, they might not guarantee the satisfaction of users; hence, as this example shows, the need for a *user satisfaction* metric. This metric considers user preferences and allows the appropriate objects to be distributed efficiently.

Simulations are conducted to evaluate a scenario of 100 equipped vehicles with a transmission range of 200 m. One thousand objects, with a time to live set to 1 h, are generated in the beginning of simulations and distributed randomly over 10 users as initial data sources. For each user, a list of interests are associated using a uniform distribution. Simulations compare the following schemes:

- **Epidemic**: Each forwarder randomly schedules its set of data.
- **Local interest**: The forwarder sorts its data by their importance to the receivers (i.e., considering only the neighbors' interests).

- **Interest- and contact-duration-based**: Content objects' scheduling is based on both duration of nodes' contact and user interests.

Figure 5 shows the user satisfaction rate produced in the network over time. When all objects lifetime have expired (i.e., at $t = 60$ min), interest- and contact-duration-based satisfied 0.94 of user interests, while local interest and epidemic satisfied 0.845 and 0.747, respectively.

Challenges, Open Issues, and Future Directions

VSNs are a very recent research domain, and many challenges remain yet to be addressed. This section presents some future research directions in this field.

Selfish Users

Unlike the classic selfish behavior considered in different works, in the context of VSNs, two types of selfishness are considered: individual and social user selfishness. Individual selfishness refers to a node that is always looking out for its own interests. In contrast, from the social perspective, a selfish user is usually willing to cooperate with other users with whom s/he has social relationships or belonging to the same community.

Caching Methods

Car manufacturers tend to produce vehicles equipped with OBUs with no memory constraints (i.e., OBUs with large capacity). However, the arrival on the market of these new technologies may take some time. Consequently, nowadays, vehicle users are still using smartphones (with limited buffer size) since there are few cars that are equipped with OBUs. Therefore, given the large volume of data being generated in everyday life, the provision for a content dissemination scheme for soliciting and caching the appropriate set of contents is an effective way to enhance data forwarding in VSNs.

Driver Safety

The number of traffic accidents and traffic violations is increasing due to the use of in-vehicle devices. Therefore, it is necessary to provide a mechanism that minimizes the interaction of the driver with the onboard devices in order to manually share information. The work in [15] has proposed an architecture that enables the vehicle to automatically share information detected autonomously by the sensors in the vehicles.

Driver or Vehicle Behavior

Vehicles are classified, according to their mobility behavior, into three important types:

- *Taxis*: They have random trajectories with low probability to of similar behavior in everyday life.
- *Normal cars*: On weekdays, a normal car usually repeats its paths in the same period to the same destination such as school, work, and so on. On the contrary, during weekends, other destinations, usually chosen for entertainment, are frequently visited.

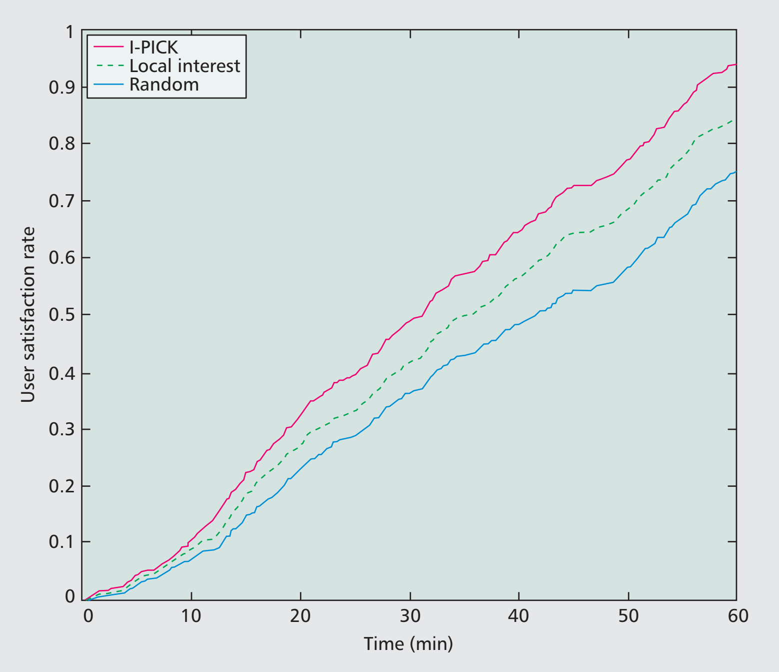

Figure 5. Cumulative satisfaction over time.

- *Buses*: They have a behavior easy to predict since they have a fixed route and schedule. Studies on dissemination algorithms are usually based on the same vehicle type such as buses. Therefore, it is necessary to investigate a general dissemination protocol for VSNs compatible with all types of vehicles.

Conclusion

VSN is emerging as a new hot topic of research in the academic and industrial communities. In VSNs, the concept of social relationships among vehicles can be used to improve the efficiency and effectiveness of content dissemination to meet the requirements of applications and services. This article presents recent achievements in VSNs. It contributes by presenting a taxonomy of existing content dissemination approaches, assisting researchers to advance in the state of the art. In VSNs, a large number of users participate and cooperate to share and access different data. Under this context, this article also presents a framework showing that a user satisfaction feature could be explored to build more efficient content dissemination protocols. Finally, the article discusses open issues and future research directions.

References

[1] S. Smaldone *et al.*, "RoadSpeak: Enabling Voice Chat on Roadways Using Vehicular Social Networks," *1st Wksp. Social Network Sys.*, 2008, pp. 43–48.

[2] F. D. Cunha *et al.*, "Is it Possible to Find Social Properties in Vehicular Networks?," *19th IEEE Symp. Computers and Commun.*, 2014, pp. 1–6.

[3] P. Ranjan and K. K. Ahirwar, "Comparative Study of VANET and MANET Routing Protocols," *Proc. Int'l. Conf. Advanced Computing and Commun. Technologies*, 2011, pp. 978–81.

[4] M. Gerla, C. Wu, G. Pau, and X. Zhu, "Content Distribution in VANETs," *Vehicular Commun.*, vol. 1, no. 1, Jan. 2014, pp. 3–12.

[5] "WAZE: Waze Navigation Service," https://www.waze.com/, last access: Nov. 2014.
[6] W. Sha *et al.*, "Social Vehicle Navigation: Integrating Shared Driving Experience into Vehicle Navigation," *14th Int'l. Wksp. Mobile Computing Sys. and Applications,* 2013, p. 16.
[7] L. Han *et al.*, "Ad-Hoc Voice-Based Group Communication," *Proc. IEEE Int'l. Conf. Pervasive Computing and Communications*, 2010, pp. 190–98.
[8] H. Zhu *et al.*, "ZOOM: Scaling the Mobility for Fast Opportunistic Forwarding in Vehicular Networks," *Proc. IEEE INFOCOM*, 2013, pp. 2832–40.
[9] J. Qin *et al.*, "POST: Exploiting Dynamic Sociality for Mobile Advertising in Vehicular Networks," *Proc. IEEE INFOCOM*, 2014, pp. 1761–69.
[10] R. Fei, K. Yang, and X. Cheng, "A Cooperative Social and Vehicular Network and its Dynamic Bandwidth Allocation Algorithm," *INFOCOM Wksps.*, 2011, pp. 63–67.
[11] N. Cenerario, T. Delot, and S. Ilarri, "A Content-Based Dissemination Protocol for VANETs : Exploiting the Encounter Probability," *IEEE Trans. Intelligent Transportation Systems*, vol. 12, no. 3, 2011, pp. 771–82.
[12] Y. Zhang, J. Zhao, and G. Cao, "Roadcast: A Popularity Aware Content Sharing Scheme in VANETs," *Proc. IEEE ICDCS*, 2009, pp. 223–30.
[13] R. S. Schwartz *et al.*, "On the Applicability of Fair and Adaptive Data Dissemination in Traffic Information Systems," *Ad Hoc Networks,* vol. 13, Feb. 2014, pp. 428–43.
[14] D. Popovici *et al.*, "A Framework for Mobile and Context-Aware Applications Applied to Vehicular Social Networks," *Social Network Analysis and Mining*, vol. 3, no. 3, 2013, pp. 329–40.
[15] I. Lequerica, M. G. Longaron, and P. M. Ruiz, "Drive and Share: Efficient Provisioning of Social Networks in Vehicular Scenarios," *IEEE Commun. Mag.*, 2010, pp. 90–97.

Biographies

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