A Vehicular Network for Social Services Using Data Dissemination

Rasool Esmailifar1*, Nadia H. Khiadani2, Faramarz Hendessi1 and Sayed Mostafa Safavi Hemami2

1 Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran
2 Department of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran

ABSTRACT

Roads, streets and the heavy traffic emerged in metropolises are places where people spend a considerable amount of time. These are locations where there is lack of presence of the social-inspired networks and services and also the new opportunities that could be offered to the people are clearly evident. Undoubtedly, the absence of a proper infrastructure is one of the major barriers to create and deliver social application for vehicular scenarios. In this study, we focus on the idea of establishing a dynamic vehicular network to manage the social groups and the information of social applications. In order to achieve this goal, this paper presents a three layer network architecture with a middleware at its core. The middleware manages social groups and handles pivotal functions of information management and dissemination. The design principles and patterns used enable our strategy to disseminate the information quickly and extensively using different communication schemes. Through this approach, we evaluate this infrastructure based on groups with common spatio-temporal properties and analyzing the constant speed mobility in our data dissemination scheme.

KEYWORDS

Social networking, Network service middleware, Data dissemination, Vehicular ad-hoc networks (VANET)

1. INTRODUCTION

The increasing access to the digital technology, internet services, social networks, and applications in all aspects of our everyday life has caused people to look for live, exciting, and interactive services in urban infrastructures and road systems. On the other hand, the increasing use of vehicles and the heavy traffic emerged in metropolises have both turned the cars to an integral part of everyday life.[1]; hence, many people expect cars to be a link to the outside world and increase their pleasure and driving experience.

In this regard, several proposals have been presented to establish a social vehicular network in a local area. But the required communication infrastructure of these networks has been less investigated. For example, Schroeter, et al. [2] have reviewed the possible proposals and recommended some of applications and services for this purpose. For example, they have described that drivers could be allowed to rate the behavior of other drivers. These crowd-sourced ratings will be used to compensate for the drivers’ behavior to receive tags for friendly driving, good parking, courteous way-giving, etc., which in turn will be displayed to other drivers. They also mentioned that in-car system could understand social cues/context in order to figure out the drivers or passengers impression and express their feeling to the other vehicles. This expression and view of the surrounding environments will impact on the drivers’ behavior and prevent aggression, selfish driving and anti-social behavior. These example and the others, e.g. [3-7] are only a small part of the proposals that are presented in this area.

According to the proposals, a lot of information such as the profiles of the users, feelings, views or comments regarding surrounding issues should be shared collectively between interested users. However, over the past years, the existing in-car information systems have not significantly changed. They mainly involve [8-12]:

- exchanging communication texts generally including writing/reading, such as SMS, emails, or more recently tweets and social media status updates,
- making voice calls,
- creating an entertaining environment inside cars,
• navigating and commanding vehicle system, and more recently,
• exploring shared interests.

A common drawback of all these systems and solutions is restriction to limited groups or peer to peer communication. Thus, these systems are not suitable to be used for the above-mentioned social networks. In fact, little is done about offering an infrastructure that is suitable for a local social vehicular network to consider its challenges and new opportunities.

In the required infrastructure, the effective and interesting information should be managed well. This information should be even delivered to the users that are not accessible through the routing methods. However, the lack of a fixed infrastructure, the need to propose a dynamic structure for managing this information and different preferences of the users turn this issue to a challenging task. In addition, along with increasing the shared information in this social network, optimizing the exchange of information evolves into another challenging task. Furthermore, most of the exchanged information should be delivered at the right time and location to be useful. Given the large volume of relevant and irrelevant information exchanged by the vehicles, one of the other challenging tasks is how to evaluate the usefulness of the information, e.g., user interests, social service policies, etc., received by each vehicle. In this paper, we focus on establishing a vehicular network infrastructure for social services.

In order to create a communication platform between cars, many studies have been performed on Vehicular Ad-hoc Networks (VANETs) in recent years. Vehicles and roadside units could be connected in vehicular communications and from this perspective, VANETs communication can be divided into Inter-Vehicle Communications (IVC) and Roadside-to-Vehicle Communications (RVC) which requires roadside unit equipment [13]. Unlike RVC, IVC is more flexible and is independent of the road infrastructure. This feature make IVC a more attractive option for vehicle-related applications.

Moreover, VANET communication is performed on the basis of the IEEE 802.11p radio technology [14] and from this perspective, the information exchange can be divided into two categories of data directive and data dissemination. Data directive is for the exchange of information based on routing through one hop or multi-hop transmission [15]. On the other hand, data dissemination is an information distribution technique that uses source coding to deal with issues, such as channels fading [16].

In this paper, we propose a three-layered architecture to solve these issues. This architecture presents a middleware to form and manage the social groups and also provides the essential functions. This middleware considers a dynamic vehicular group to overcome the lack of a fixed structure and to reduce the network overload. Our strategy enables our architecture to disseminate the information in the surrounding area more quickly and provides this information to the unreachable vehicles using data dissemination scheme. This middleware also considers the utility of the exchanged information for the social services and using this method, downgrade the redundant social information.

The efficiency of our solution is investigated using a simulation based approach. The constant speed mobility has been also analyzed in our data dissemination scheme. The simulation evaluates our desired efficiency and scalability parameters and applies realistic mobility traces for a convoy of vehicles. Later on in this paper, we inspect the simulation setup and the results in detail.

The rest of this paper is organized as follows. In section 2, we present our scenario with a set of requirements. In section 3, we demonstrate the network architecture and basic assumptions. Description of our network service middleware mechanisms and protocols is presented in section 4. The communication schemes have been investigated in section 5. In section 6, we provide the simulation and experimental results. We discuss some related work in section 7 and finally we conclude the paper in section 8.

2. EXPOSING THE NETWORK FOR SOCIAL SERVICES

2.1. EPHEMERAL SOCIAL VEHICULAR NETWORK

In the following, we shed some light on the type of social network that could be hosted on our proposed vehicular network. Foremost, a social network formed over a vehicular network is essentially ephemeral. In other words, establishing long-term relationships over this network is not probable; unfamiliar vehicles come together for a while and they will be separated. Thus, the social applications and services that is presented in this social network are based on this property and we name it ephemeral social vehicular network. An ephemeral social network leads to anonymity of the users in which the real identity of the users is not important. In this regard, if special attention is paid to maintain the anonymity of the users and prevent leaking user's actual identity, then some concerns and security issues that prevail in modern social networks such as privacy do not potentially exist in this ephemeral social network.

This ephemeral social vehicular network with its unique features is able to host many applications. For instance, Schroeter, et al. [2, 17] mentioned an innovation hotspot for new social applications and services to interact with others surrounding the car. They also derived some examples to identify these opportunities. They mentioned some of these scenarios; they recommended reward achievements by leaving tips e.g., drivers are allowed to rate the behavior of other drivers. Then the drivers reward with badges for friendly or consistent driving, courteous way-giving, good parking, minimal breaking, etc., which in turn will be displayed to other drivers using these crowd-sourced ratings. As another example, the users of this social network can convey a better sense of the immediate surroundings to motorists by expressing their feelings and emotions. These social and emotional information may cause connections with other vehicles and prevent selfish and anti-social behavior problems
that may arise in the absence of such information. Vehicles based on the current surrounding situation can be encouraged to share information with others or use their mutual service [18].

These are just some of the examples to explain the benefits of this social network. For instance, in designing various algorithms, the information of this social network could be used to provide the incentive requirements to perform different tasks [19-21] or reduce the false positive error rates in intrusion detection systems [22] etc. However, to the best of our knowledge there is no suitable vehicular network that has established and managed such a social vehicular network.

2.2. SCENARIO

In order to establish a vehicular network for social communication and providing relevant services and applications, we propose a network model to manage social groups and highlight the information management mechanisms. The main idea is providing a network for social service around the issues that occur surrounding the vehicles. This network will provide the passengers and drivers with the ability to use the network platform and participate in social communications.

In recent years, the rapid development of mobile app markets and of mobile commerce have been drivers of smartphone and tablet adoption. We have predicted that in this network in addition to standard vehicle communication protocol i.e. IEEE 802.11p, supports a low-power Wi-Fi access point in vehicles. Thus, the passengers are able to install the required social services and connect to this vehicular network platform. Additionally, each of these devices can process the basic mechanism of network infrastructure and store the provided information. They are also a resource for storing the information in a distributed manner and disclose them to the others when required.

![Figure 1. Scenario](image-url)

In order to create such an opportunity, we propose a network service as a middleware. In this middleware, a convoy of vehicles forms a social group and the information of their interactions will be shared and disseminated in this group. An important point here is the loss of social groups obtained information due to formation of temporary groups and lack of fixed network infrastructures between the vehicles. One of the main objectives of our work is preparing the necessary platform for wide-range sharing of information between vehicles which leads to increasing the availability of the information and make it more useable. Today, the increasing use of vehicles in metropolitan areas is caused for strongly frequented roads which is appropriate for our scenario. In doing so, in agreement with sharing the data with the social group users, the middleware shares and disseminates information with groups in the opposite direction and RSUs. The key point here is an assumption that each social group can share their data with the social groups that move in the reverse direction. This assumption causes the data of the various groups to widely spread in the area. As a result, if the road traffic in that area is adequate, the groups that previously were not present in the area will receive the data even if those groups do not meet each other. It is also possible for the RSUs to install some of the social applications to interact with the social groups. They participate in passing groups and exchange the interested information with them. They contribute to storing the data in its location. Another significant requirement is collecting
the information for the exchange of information between the groups. Figure 1 shows how the information is exchanged inter- and intra- groups.

On the other side, the plurality of the collected information may disturb the users and downgrade the value of the system. Our other aim is defining an arrangement for the available information items by their usefulness with respect to a utility value in the vehicles. The core of this operation is indeed the definition of functions to line up the received items based on several parameters (e.g., users’ interests, and social applications policies). Accordingly, the users will be notified when a useful and interesting information item turns up.

2.3. REQUIREMENTS

In order to optimize the process of information dissemination in VANET network with respect to the defined parameters and content, requirements for the scenario are comprehensible.

- Clustering and grouping interactions
  Diversity of social applications as well as the high volume of the exchanged information can cause heavy overhead in the network. Therefore, Messages should be exchanged in the network in a way that they create the least amount of overhead. In this paper, we will use grouping interaction mechanism.

- Compatibility with wide range of application devices
  The advantages of this network are not limited to the drivers. The network should also allow a wide variety of users equipped with the devices like smartphones, tablets, Personal Navigator Devices (PND), embedded On Board Units (OBU) or laptops to use the social applications.

- On time delivery
  Receiving the exchanged information at the right time either intra-group or inter-group is important since most of these information are social and highly dependent on the location of the vehicle. If the information is not received in time, the vehicles could scatter and the collected information are devaluated.

- Compatibility with delayed tolerance
  Due to the lack of fixed information infrastructure in VANET networks, there is no fixed location for data storage. Vehicle social groups should have the capability to temporarily store the data and notify the new groups when facing them. In this way, it is possible to maintain and expand the information in the network.

- Different Transmission Scheme
  Normally, exchange of data between the vehicles is done based on routing. However, exchanging information with disconnected social groups may cause complex routing. Therefore, groups must be able to transmit data to other groups with simple and proper solutions.

3. THE NETWORK ARCHITECTURE

In order to achieve an efficient network for social applications and services, we can imagine the network access platform as a three-layered architecture as shown in Figure 2. We have used a middleware at the core of this strategy which resides as a software application platform in the application layer. The duty of this middleware is to provide a transparent platform to offer services and exchange the social information with other users. This middleware includes the necessary mechanisms to form social groups. It collects and disseminates the social information, as well. The middleware also decides regarding the usefulness of the collected information for each specific user. This middleware should be installed on every devices that operates in the network. The middleware also provides a suitable software interface to ease interactions with the social applications. However, activity in the social application layer depends on the defined policies or the installed applications.

According to the mentioned requirements, two methods are used for data exchange: data directive and data dissemination. The data directive is used to deliver data intra-group, and the data dissemination is applied for data exchange between social-heads of two social groups or between one social-head and one RSU. The data dissemination scheme uses the coding method to increase the data availability by generating encoded data and disseminating it across the network.

The main objectives of this middleware can be categorized in the following components:

- Social Group Management
  In order to reduce the overhead associated with the broadcast and generation of redundant messages in the network, we manage and limit network traffic by selecting a social head for each social group. This component manage the formation of the social group and supervise the validity of the social group.

- Information Management
  This component assigns a unique identifier to each of the social services. The exchanged information is tagged with that identifier. On reception of the information, it will be routed to the appropriate social service regarding its tag. In addition,
each social service may need its specific data structure and this component consider the requirements of each social service. This component also stores and retrieves the information in a database. It removes duplicates and deactivates the redundant information according to the data volume or the social service policies.

- **Utility Supervision**

  Social information will be exchanged continuously in this network. However, due to the plurality of the relevant and irrelevant information exchanged, the useful information should be identified and the user or the social service should be notified to do the appropriate reaction. This component can supervise the utility of the received information with respect to the defined parameters.

In this system, we assume that all the vehicles are moving in frequented roads in a metropolis and are able to detect their direction (using appropriate techniques [23] like GPS). They are also connected to each other wirelessly using a low-power IEEE 802.11p interface, such as DSRC [14]. Each of the vehicles is also equipped with a low-power Wi-Fi access-point and bridge the user's data to the vehicular network and vice versa. Using the Wi-Fi access point in vehicles regarding its wide support in portable devices enables the passengers to use this network. In addition, this access-point operates in low-power mode to prevent interference with other devices.

Meantime, for simplicity of the treatment, we assume that the vehicles all have the same capabilities, particularly regarding the maximum size of the stored messages in the buffer $\beta$. Nodes are considered as fixed and mobile. Fixed nodes operate as Road Side Unit (RSU) and mobile nodes operate as device in the vehicle.

### 4. MECHANISMS OF THE MIDDLEWARE

#### 4.1. GROUP FORMATION PATTERN

The nature of VANET and the high mobility of vehicles lead to lack of information stability in this networks. Moreover, the information is not maintained in a fixed location and easily eliminated. Therefore, using an appropriate method to manage the information flow of an ephemeral social network is essential. The existing clustering methods such as Centralized [24], Group/Cluster based [25], and Hierarchical [26] do not have the ability to maintain the social information for appropriate time. In the following, we propose a pattern to form social groups and manage their information. This pattern have the ability to provide the social services requirements.

In order to establish a vehicular network for social applications and services, the interested users (the passengers and driver) in a convoy of vehicles (vehicles that are moving together in one direction) will start initiating a social group $SG$. The criteria of this situation are two factors of position and direction. In addition to these criteria, the users are said to be within one social group if their vehicles can communicate with each other in one hop or multi hop transmission. The minimum distance between two social groups should also be at least larger than the communication range $R$. In order to form a social group $SG$, several users in adjacent vehicles that their vehicles can communicate with each other in one hop transmission form a cluster $C$. Then, the clusters join each other to form a social group.

Before describing cluster and social group formation, we model social groups and clusters. First, we denote existence of each user or RSU in this protocol with $u_k = \{u_1, u_2, \ldots, u_l\}$ where $k=1, 2, \ldots, l$. and the cluster consisting of several users with its one hop head is denoted by $C_i = \{C_1, C_2, \ldots, C_m\}$ where $i = 1, 2, \ldots, m$. In addition, the cluster-head in each cluster is defined with $h(C_i)$. Social groups which consist of connected clusters in the same direction are denoted with $SG_j = \{SG_1, SG_2, \ldots, SG_n\}$ where $j = 1, 2, \ldots, n$. Besides, the head of a social group as the social-head is denoted with $socialh(SG_i)$.

Up to now, a large number of studies have focused on the optimal methods for clustering nodes in VANETS [15, 16, 27, 28]. However, we need an approach to choose one of the vehicles as the social-head, collect all the data, and broadcast them through
the chain of connected vehicles. According to this requirement, a clustering method has been investigated recently by Fan [29, 30]. This method gives us the ability to choose the cluster-heads for smaller clusters. We extend this method to create a hierarchical structure and choose one of the heads with suitable properties as the social-head. We also propose a protocol for merging the social-groups.

Basically, in this method, the network is partitioned into a group of clusters. In each cluster, a single cluster-head manages all the other members in the cluster. In addition, non-cluster-head nodes with at least one neighbor belonging to other clusters form gateways to other clusters. Therefore, as Figure 3 depicts, the social-head, cluster-head, and gateways form the backbone of the network and provide an infrastructure to broadcast the messages through the social group as described in [29].

![Figure 3. Social Group Formation](image)

This clustering architecture reduces the communication relay points for each node to a small subset of the total network so that, each cluster head aggregates the local member topology and acts as a relay point for communication between its members and the members of other clusters.

The clustering algorithm starts with, each node announcing itself as a cluster-head by putting its own address and id in the beacon to be broadcasted. After receiving beacons from its neighbors, each node has a full knowledge of its current neighbors and makes decision whether to change its current cluster status or not. The status changes are bi-directional, either from the cluster-head to the member node or from the member node to the cluster-head.

Decision to change the status depends on four principle factors: moving direction, leadership duration, projected distance variation, and vehicle id. The Vehicle id is a random value initially assigned to each node. A node looks for a cluster-head from its “candidate pool” formed by all its neighboring cluster-head nodes with the same moving direction and a lower id. The node stays as its original status if it does not find such cluster-head nodes existing around. In addition, the pivotal points in choosing the best in the pool are the leadership duration i.e., the period that a node has been a leader since the last role change, and projected distance variation of all neighboring nodes over time which estimates a degree of its local topology changes. According to this definition, the longer the duration, the more stable the node will be. Therefore, the cluster-head election rules are expressed as follows:

1) Choose the node with the longest leadership duration at first.
2) If all are the same, choose the node with the lowest projected distance variation of all neighboring nodes over time [30].
3) If all are the same, the one with the lowest id (LID) [31] will be elected as the cluster-head.

However, a social-head is necessary to be selected in our architecture. Therefore, similar to cluster-head election, each cluster-head and social-head (if exists) prepares a packet including its vehicle id, leadership duration, volume of stored active data, and its role. Then, the node broadcasts it in regular intervals to the reachable clusters. With reception of this packet, a cluster-heads $h(C_j)$ has a full knowledge of the current cluster-heads and a “candidate pool” is formed, as well. If there is already one social-head in the pool, it will be elected as social-head; otherwise, because stability is pivotal in election, the social-head is elected in the pool once again using three factors of the volume of stored data (Section 4.2), the leadership duration, and lowest id (LID). When a cluster-head chooses a social-head, the social-head id is broadcasted to their members and they must save the social-head id.

Furthermore, social-head merge also leads to the existence of two or more social-heads in the network. Obviously, as the vehicles are moving, the network topology as well as the relevant clusters may change. For example, a group of vehicles stops at a red light and a group behind them may move faster and reach them. In this case, the two groups need to be merged (Figure 4). In this case, just one of the social-heads should remain and the other one will give up its role and send all its data (Section 4.2) to the other social-head. Since a major issue in social-head election is the volume of the data stored in the social-head, in case a social-head observes another social-head in its pool, it should compare the three factors of stored data volume, longest leadership duration, and lowest id (LID) and decides to give up or stay. This process will be explored in details in section 4.2.
After social group formation, each social service in nodes posts its information. These information will be routed to the social-head \( \text{socialh}(SG_i) \). \( \text{socialh}(SG_j) \) broadcasts the posted data in the social group using the algorithm described in [29]. Nevertheless, the nodes are interested in only some of the social services and pick up and store the data they are interested in. More on this topic is presented in section 4.2.

![Figure 4. Merging two groups of vehicles](image)

**4.2. INFORMATION COLLECTION AND EXCHANGE PROTOCOL**

The definition of the information collection process is to collect the surrounding information to provide a database of social events and information according to the social applications requirements. So far, many studies have been performed on information collection and aggregation in vehicular scenarios [32]; Most of them are around aggregating data to reduce data transmission. However, in this middleware, the following important criteria should be provided by the exchanged information:

1. Be compatible with our proposed grouping solution.
2. Be inexpensive in both computing time and storage space, e.g. detect duplicates.
3. Be compatible with publishing and subscribing paradigm [33].
4. Allow the exchange of (parts of) reports between users in order to reduce the overhead of transmission and store the reports in a distributed manner.

In this middleware, the information present such a way that it can be collected in a database. We named this representation ‘report’. Report compose a vector named \( \text{report}_R \) consisting of a set of attributes. Although there is no restriction on the defined characteristics, some of the attributes and parameters are defined as follows:

- \( \text{ty}_R \): type of the social service
- \( \text{id}_R \): the unique identifier of the report \( R \).
- \( \text{vehicle}_i \): the vehicle which posts the report
- \( \text{timestamp}_R \): the creation time of report
- \( \text{synced}_\text{head}_R \): the id of the social header that the report was synced with.
- \( \text{active} \): weather the report is active to be exchanged with the others.
- \( \text{hash}_R \): a unique hash value for the summary. The value of this hash value is the basis for detection of duplicates.
- Specific attributes of the social applications: Different social applications can be placed on top of the middleware and each can have special requirements and policies.

The received reports or the posted reports through the social services should be saved in a local database in the user's device. The proposed structure for this data table is shown in Figure 5. In order to detect the duplicate entries, a hash value is applied as \( h(\text{report} _R < \text{ty}_R, \text{id}_R, \text{timestamp}_R, \text{vehicle}_i, >) \). This hash function returns a unique value for each summary and helps to detect and discard the same summary. Moreover, social applications embed their specific data according to their policies. For example, a social application that reports the free parking slots around specifies the information of each parking slot through specific attributes part.

![Figure 5. Data structure for the local database of reports](image)
It is worth to mention that this database could be used by the social applications to analyze the status or behavior of various subjects of interest. For example, the reports of a social service to comment on the behavior of drivers can be employed to investigate the habits of drivers in an area.

In order to make an intelligent way to wide-range sharing of information as well as increasing the availability of the information and make it more useable, reports will be shared with others. Correspondingly, the social-head is responsible to share the reports in this social group and all of the exchanges take place through sending reports to the head. The head prepares an ephemeral database for this purpose and aggregate all of the received reports in this database. This ephemeral database is independent of the middleware local database. The received reports are initially checked for the existence of duplicates in this database that may happen due to several exchanges of reports between users. The duplicates match with respect to their idk and discarded. Subsequently, the head broadcast the new reports to the social group as described in regular intervals. Since a major part of information management and communication occurs just in the social head, computational overhead is reduced in a large percentage of the nodes. This issue also enable the social-head to apply new rules and policies in the future.

In this section, we also focus on the (partial) exchange of the stored reports with the others. As we emphasized the importance of the report exchanges, one of the raised issues here is reduction of the information overload. In fact, the increase in data volume can lead to:

1- More packet collision and accordingly more retransmission (mainly because of the important size of the packet exchange)
2- Longer delays because of the processing of data before they can be effectively delivered.

Obviously, the importance of a report for a majority of social applications will be declined over time. For example, a report which was posted a month ago cannot be necessarily valid right now due to the changes in the environmental factors. Thus, these reports will become inactive over time and may not be announced to the other users. Thus, when it is necessary for the users to send their reports, a maximum number \((max\_exchange)\) of latest reports for each social service, i.e. with respect to its timestamp, is selected from their local database and will be sent to the social head, by default. Similarly, the social-head applies the rule of maximum number of reports to broadcast the new reports, too. This maximum number may decrease if some of the reports have been deactivated. Deactivation will occur due to social services polices, e.g. the reports are old according to their creation timestamp. Conversely, deactivated reports will be re-activated or eliminated by a social service with respect to its rules and policies. This mechanism helps the data transmission growth rate to remain linear.

In reality, in addition to posting new generated reports by the social applications, representatives called brokers undertake the responsibility of exchanging reports among groups. Three types of brokers is considered in the protocol:

- **Vehicle with a new social-head**

  Due to the rapid changes in the VANET network topology, each vehicle can quickly disconnect from a social group and join a new one and shortly afterwards, it can transfer data to the joined social group (Figure 6). This is also applied when a new social-head is selected or a new social group is formed. In this cases which is detected by choosing a new social head, the user waits for a random time to send its reports to the social-head, in the meantime, the user may receive the social heads information that is broadcast regularly. If any of the received reports is exists in its local database, the user updates the report \(sync\_heads\) attribute in its database to the id of new social-head. When it is time to send, the user filters the active reports that synced with another social-head and sends them to the social-head. This strategy prevents the burst behavior of the nodes when the social groups merge or lose their social-head.

![Figure 6. A recently joined vehicle as a broker](image)

- **Social-head**

  There are cases that the social-heads exchange data with each other. In the first case, when two social groups are merged. As described in section 4.1, social-heads broadcast a beacon in regular intervals. This will cause a social-head notify the existence of another head in its group. They check the parameters according to the protocol and just one of the social-heads \(socialh(SG_i)\) should stay in its role and the other one \(socialh(SG_j)\) should give up, send all of its ephemeral database to \(socialh(SG_i)\), and remove its database. At this step, \(socialh(SG_i)\) aggregates all of this reports in its ephemeral database and at the same time, according to the protocol, the other vehicles are informed from the new social-head; the vehicles with the former social-head act as a broker in the previous scenario.

  In the second case, if two social groups pass each other in the opposite direction, they exchange all their ephemeral databases. In addition, the heads use data dissemination scheme for inter-group communication. More on this topic will be presented in section 5.2.
RSU (Road Side Unit)

As described in section 2.12.2., it is possible for the RSUs to be interested in some of social applications and participate in some of them. However, regarding the limited time of communication between an RSU and a vehicle. An RSU sends its interests for social service in its beacon and the vehicles which have any report of those social service reply in response. In contrast, the RSUs will send their reports to the passing social-heads using data dissemination scheme. Details on this method will be described in section 5.2.

Upon reception of a report, the users and RSUs compare the type of report (type_r) with their social applications. If a match is found, the summary will be aggregated in their databases; otherwise, the report will be discarded. The pseudocode for the exchange protocol is reported in Figure 7.

Figure 7. Pseudocode for the exchange protocol.
4.3. SOCIAL UTILITIES

According to what mentioned so far, a lot of information will be shared in this network. A large portion of this information is irrelevant. Therefore, a method is required to attract the user’s attention if it has sufficient usefulness. A utility function contributes to this issue. This utility function uses the attributes of reportR and other defined factors to determine the usefulness of the report. Overall, comparing the reports regarding all the parameters is not simple and instead, we have to trade off the achievement of one objective against the others. Our aim is to allow each vehicle to locally assign a value to the utility function $U(x_1, x_2, ..., x_n)$ where $x_1, x_2, ..., x_n$ are values of reportR attributes and they consist of specific attributes of the social applications. They are calculated by social applications through their interfaces with the middleware. Subsequently, the network service arranges the utility values in descending order. The utility function is defined according to the following combined goal:

$$f(U(x_1, x_2, ..., x_n)) = \sum_{i=1}^{n} w_i U_i(x_i)$$

(1)

where $w_1, w_2, ..., w_n$ are significance weights indicating the relative importance of each attribute for a social service and $U(x_i)$ is the utility of $x_i$. These weights and utilities are defined by each social service. Furthermore, each user assigns a weight $U_i[0,1]$ to the social applications considering their importance. This factor allows the user to simply declare priority for the reports received from different applications. The utility function in this case is considered as:

$$f(U(x_1, x_2, ..., x_n)) = U_s \times \sum_{i=1}^{n} w_i U_i(x_i)$$

(2)

Some of the factors change with time and we wish to adjust the weights of each parameter dynamically such that they rely on the values of those parameters. In other words, we introduce a self-adaptation of the weightings to control some of reportR attributes. A simple solution to this problem is using adaptive weights $a_i$ in the previous formula along with changing the parameters:

$$f(U(x_1, x_2, ..., x_n)) = U_s \times \sum_{i=1}^{n} a_i(x_i) w_i U_i(x_i)$$

(3)

This adaptation factor can be a composite factor that involves different aspects. Although the model is open and could easily be expanded to involve other aspects. In this paper, three important aspects are defined with the aim of determining the value of the adaptation factor:

i) Critical ranges, $a_{\text{critical}}(x_i)$: By approaching certain ranges, it receives a greater value.

ii) Validity, $a_{\text{validity}}(x_i)$: By detecting valid values for the attribute comparing to the current values, it receives a greater value.

iii) Time elapsed, $a_{\text{time, elapsed}}(x_i)$: The time elapsed from the last time this report is created and it is defined as a decreasing function.

We consider these weights as factors in the following formula:

$$a_i(x_i) = a_{\text{critical}}(x_i) \cdot a_{\text{validity}}(x_i) \cdot a_{\text{time, elapsed}}(x_i)$$

(4)

This factor is assumed to be adaptive with the range of attribute values. For example, we can design the adaptive weights $a_{\text{critical}}(x_i)$ as a function whose domain is $[0, 1]$. By approaching certain ranges, we can use a monotonically increasing function and conversely by getting away, we can use a monotonically decreasing function which cannot be necessarily linear. In this way, we assign an adaptive weight to assure that the utility function is highlighted or tends to move toward zero.

4.4. SOCIAL APPLICATIONS AND SERVICES INTERFACE

The proposed middleware has been designed in order to be used by social applications and publish their data in the vehicular network. The interaction between these applications and middleware is based on sharing reports like ideas, comments, profiles, etc. and announcing feedbacks regarding their utility. Hence, the middleware should provide a suitable interface to ease these interactions. The following example demonstrates a simple interaction between a sample social application and our proposed middleware.

Example

- An application to rate and comment on the other driver’s behavior starts up and registers itself as a social service to the middleware.
- Network service adds the service to its interest list. The middleware process this type of reports afterward.
- The social-head broadcasts reports and the middleware receives them. If the type of report is not in its interest list, the middleware discards the report.
- Otherwise, the middleware calculates the utility function for the reports and notify the social service, if needed.
• The application displays all the vehicles moving around the vehicle and highlights each of them according to the utility factor and their rates or comments.
• The user can choose any of the vehicles and provide its rate to the application.

5. VEHICULAR NETWORK COMMUNICATION MECHANISM

The vehicular network topology is highly dynamic and the vehicular network may quickly change from a densely connected to a sparsely connected or a highly disconnected network. Commonly, it is possible to use the available routing protocols for data delivery in the connected part of the network without high overhead or very large routing tables. However, these methods are not so suitable or efficient for data exchange between two disconnected parts of a network. In this case, the data dissemination is an applicable solution. An appropriate data dissemination mechanism should be scalable and the number of broadcasted messages should be limited. In other words, the data dissemination protocol works properly in sparse networks and does not flood dense networks. In the following subsections, a detailed explanation of data exchange methods and the used coding algorithm are presented.

5.1. DATA DIRECTIVE

The data exchange between each social-head and its social group members is performed by data directive method. Because of communication connectivity between the social group members, data directive relies on common routing methods. To this aim, messages are packetized and packets are either broadcasted to the social group members by socialh(SG_i) or routed to socialh(SG_i) starting from the social group members.

Delivering data using this method helps to avoid large overhead and flooding and keeps routing table as small as possible proportional to the number of social group members.

5.2. DATA DISSEMINATION

Data dissemination is used for data exchange between social-heads or the social-head and RSU. There are several algorithms in data dissemination, each with its advantages and disadvantages. We require an algorithm to perform well in different network topologies, especially in a sparse vehicular network. In doing so, we use DDRC [34] that is a simple data exchange protocol without performing complicated routing.

The DDRC proposes the application of rateless codes [35] for reliable and efficient data dissemination in VANETs. In this algorithm, each social-head divides its packets into smaller packets with the same size. These packets are encoded to a set of bigger size packets using rateless coding then the node broadcasts the set of encoded packets. These nodes are divided into two groups, collectors and carriers. When a collector is getting close to another social-head, it attempts to collect the disseminated packets. If this collector obtains the required number of packets it can decode the message. After decoding the message, the collector node adds the message to its carrier list to encode and disseminate it again for a while and acts as a carrier node. The social-head also aggregates the decoded message reports in its database. In addition, it embeds this database in a new message, encodes it using rateless codes and disseminate it regularly. Therefore, the social-heads can be collector and carriers at the same time. By means of this strategy, a social-head can obtain packets from other social-head over and over, so the rate of successful encoding is increased.

5.3. RELATED CALCULATION OF MOBILITY

Due to the special structure of this vehicular network, we study and analyze the effects of vehicle mobility in this section. This effort is based on [34].

**Theorem 1:** Let $v_{\text{max}}$ be the maximum speed of vehicles on the road and, $M_t$ denotes the time duration that a collector social-head spends in contact with a social group. Given that the inter arrival time of vehicles is Exponential distribution with parameter $\lambda$, then:

$$E[M_t] = \frac{(e^{\lambda R} - 1)\left(\frac{1}{\lambda} - \frac{Re^{-\lambda R}}{1 - e^{-\lambda R}}\right) + 2R}{v_{\text{max}}}$$

**Proof:** It is easy to see that:

$$E[M_t] = \frac{E[SG_{\text{length}}]}{v_{\text{social-h}} + v_{\text{social-g}}} + R + R$$

(6)

The proof is clear and the results are summarized in the following lemmas.
Lemma 1: Based on [34], let $P_d$ be the probability that distance between two following vehicles is longer than the communication range $R$ and $x_{\text{intra}}$, $x_{\text{inter}}$, $SG_N$ and $SG_{\text{length}}$ denote intra-social group spacing, inter-social group spacing, number of vehicle in social group and length of social group, respectively. We have:

$$P_d = e^{-\lambda R}$$  \hspace{1cm} (7)

$$E[x_{\text{intra}}] = \frac{1}{\lambda} - \frac{R e^{-\lambda R}}{1 - e^{-\lambda R}}$$  \hspace{1cm} (8)

$$E[x_{\text{inter}}] = R + \frac{1}{\lambda}$$  \hspace{1cm} (9)

$$E[SG_N] = \frac{1}{P_d}$$  \hspace{1cm} (10)

$$E[SG_{\text{length}}] = E[(SG_N - 1) \cdot x_{\text{intra}}]$$  \hspace{1cm} (11)

We suggest reader to view [34] for better understanding of the above formulas.

Lemma 2: Let $v_{\text{const}}$ be the average vehicle speed during the trip on the road with length of $L$. From simulation, it is easy to see that the average of vehicle speed, $v_{\text{const}}$, is constant during the trip. It can be shown that:

$$v_{\text{const}} \approx \frac{v_{\text{max}}}{2}$$  \hspace{1cm} (12)

Lemma 3: The average communication time $E[M_t]$ between a social-head and a social group is obtained by:

$$E[M_t] = \frac{E[SG_{\text{length}}] + R + R}{v_{\text{social-h}} + v_{\text{social-g}}}$$

$R$ in the above equation is due to the communication range around one social group.

$$v_{\text{social-h}} = v_{\text{const}} + \Delta_1$$

$$v_{\text{social-g}} = v_{\text{const}} + \Delta_2$$

$$v_{\text{social-h}} + v_{\text{social-g}} = 2v_{\text{const}} + \Delta \approx 2v_{\text{const}} \approx V_{\text{max}}$$  \hspace{1cm} (13)

5.4. PERFORMANCE ANALYSIS

This section provides the performance analysis of the network. The decoding distance (DD) of a collector social-head is the basic performance metric that can provide insight to the throughput. DD is known as the distance between each RSU and related decoding point. Correspondingly, decoding point is the position of a collector social-head that can decode a message.

It is assumed that the buffer size is larger than the number of packets. Therefore, there is no dropping packet. The collector social-head can meet the carrier at any distance from an RSU. By meeting each social group carrier, the collector social-head has the opportunity to gather packets. If the average packet size of each vehicle in a social group is $E[pkt - \text{size}]$ and the average rate of packet transmission is $E[pkt - rate]$, then the expected time of gathering one packet is given by:

$$E[T_{1-pkt}] = \frac{E[pkt - size]}{E[pkt - rate]}$$  \hspace{1cm} (14)

As a result, $1/E[T_{1-pkt}]$ packet is obtained from a vehicle in one unit of time. Therefore, a collector social-head can get $E[m_t]$ packets from a carrier social-group in $E[M_t]$ duration of time.

$$E[m_t] = \frac{E[M_t]}{E[T_{1-pkt}]}$$  \hspace{1cm} (15)

It is possible that the carrier social-head does not have suitable packet for collector social-head. Therefore, a collector social-head can get a desired packet with probability of $1/2$. On the other hand, the expected number of vehicles in a social group has been calculated in [12]. Therefore, the total expected number of desired packets in a carrier social-group $E[M_t]$ is given by:

$$E[M_t] = E[m_t], E[SG_N] \frac{1}{2} = \frac{E[M_t], E[pkt - rate]}{2 \cdot P_d \cdot E[pkt - size]}$$  \hspace{1cm} (16)

The collector social-head needs $n$ packets for message decoding that should be collected from social-head of carrier social group. If $n$ is greater than $E[M_t]$ then on average, $E[N_{SG}]$ of social group should be met for message decoding.

$$n = E[M_t] \cdot E[NSG] \rightarrow E[N_{SG}] = \frac{n}{E[M_t]}$$  \hspace{1cm} (17)

Considering the average number of social-group in a road, we can calculate the average length for message decoding (if there is no RSU). It is shown that:
\[ E[\text{driven length for msg decoding}] = E[N_{SG}] \cdot (E[SG_{length}] + E[x_{inter}]) \]
\[ = \frac{n \cdot 2 \cdot P_d \cdot E[\text{pkt} - \text{size}]}{E[M_i]} \cdot \frac{(E[SG_{length}] + E[x_{inter}])}{E[\text{pkt} - \text{rate}]} \cdot \frac{V_{max}}{2} \] (18)

Therefore, the decoding point relative to starting point of the movement is obtained. If the distance of decoding point relative to starting point is decreased, the collector social-head can decode the message closer distance relative to starting point. Thus, DD is increased.

The delay time for message decoding is obtained by dividing (18) to average speed of vehicles. If DD is decreased, the delay time is increased. It means that the collector social-head should travel more distance for message decoding. As a result, more time is spent and the delay time is increased.

\[ E[\text{delay time}] = \frac{n \cdot 2 \cdot P_d \cdot E[\text{pkt} - \text{size}]}{E[M_i]} \cdot \frac{(E[SG_{length}] + E[x_{inter}])}{E[\text{pkt} - \text{rate}]} \cdot \frac{V_{max}}{2} \] (19)

### 6. EVALUATION AND EXPERIMENTAL RESULTS

In this section, we present simulation results of the proposed protocol. Table 1 lists the experimental values of simulation parameters. We consider a highway with 20000m length in which fifty RSUs are placed with 400m distance from each other. Although, the maximum speed is specified, vehicles move in different lanes of the highway at variable speeds. Vehicles enter the road from one end and travel along until reaches the other end. The type of wireless network used in this simulation is Dedicated Short Range Communication (DSRC). It is commonly used for IVC and RVC communication in 5.9 GHz band. Finally, we performed our simulations using ns2 and SUMO. Our simulations were repeated at least 10 times for any point of the graphs. For example, we run our simulation 250 times to obtain all of the points in Fig. 12. We used the average of obtained values in different runs to specify any point in each figure. Owing to the limitations of the ns2, we were not able to run simulations with much larger datasets.

We evaluate several statistics through our experiments in order to assess our protocol. Initially, the network traffic is compared to the broadcast interval time in Figure 8. The network traffic is defined as all the outgoing messages (sending and forwarding packets) of all nodes. Clearly, the network traffic is lower in the larger broadcast interval time. If the network traffic is higher, the network is congested and the probability of collision is increased. So, the lower network traffic is better. Likewise, in a large scale vehicular network, a lower network traffic is favorable and is always considered to be better. Thus, if the number of nodes is increased, it is necessary to increase broadcast interval time. In Figure 8, the standard deviation of chart’s values (.1, .2, .3, .4 and .5) are 37.6, 15.142, 19.44, 31.92 and 27.06, respectively.

Number of social group vehicles in different vehicle entrance rate and speed is considered in Figure 9. As shown in this figure, if vehicle entrance rate is increased, the social group size is severely increased as well. On the other hand, the speed does not have significant influence in social group size. This means that changing the speed without traffic volume (\( \lambda \)) has a negligible effect in the social group size. The standard deviation of social group size is between .42 and 1.56.

<table>
<thead>
<tr>
<th>Table 1. Experimental parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>Simulation time</td>
</tr>
<tr>
<td>Channel Fading Model</td>
</tr>
<tr>
<td>Communication Range (R) for RSUs</td>
</tr>
<tr>
<td>Communication Range (R) for Vehicles</td>
</tr>
<tr>
<td>Number of Vehicles</td>
</tr>
<tr>
<td>Number of RSUs</td>
</tr>
<tr>
<td>Highway length</td>
</tr>
<tr>
<td>Broadcast interval time</td>
</tr>
<tr>
<td>Buffer size</td>
</tr>
<tr>
<td>Requested number of packets for decoding</td>
</tr>
<tr>
<td>Routing protocol</td>
</tr>
</tbody>
</table>

Number of social groups is presented in Figure 10. As shown in Figure 9, if vehicle’s arrival rate is increased, the social group size is increased. Therefore, if the total number of vehicles remains constant, the number of social group is decreased and if the number of vehicles is large enough, the number of social groups is close to our mobility analysis. In Figure 10, the standard deviation of chart’s values (.1, .2, .25, .33 and .5) are .97, .88, 1.64, 1.66 and 0, respectively.

We also investigate the effect of social group size on the end-to-end delay using the DSR routing protocol. Figure 11 represents the end-to-end delay for different social group sizes and as a result, the end-to-end delay is in a close relationship...
with the number of vehicles in the social group. It is owing to the fact that the routing time is increased with the increase in the social group size. The standard deviation of chart’s values (2.5, 8, 12, 27 and 145) are .5, .137, .12, .15 and 1.62, respectively.

The performance of the data dissemination scheme is measured with the aid of decoding distance (DD) over three-quarters of the road. For this purpose, a collector vehicle drives across the road from the other end and collects the packets over the first 15000 meters of driving. Decoding Distance (DD) demonstrates that at what distance to the mentioned point, a collector vehicle can decode messages. The larger decoding distance indicates that the collector vehicle can decode a message in farther distance before reaching the mentioned point. Therefore, if it is larger, the collector vehicle has better opportunity to have better decision. Thus, the larger DD is better. Figure 12 compares the different inter arrival time or vehicular entrance rate (λ) effect on DD. The rate increases as DD increases. If the rate is increased, the social group length (11) is severely increased and the inter cluster spacing (9) is decreased. Therefore, the sum of (9) and (11) is severely increased. On the other hand, $P_d(7)$ is decreased and the communication time between a collector social-head and a carrier social-group (5) is severely increased as the lambda increases. But the increase in (5) is larger than multiple of (7) and sum of (9) and (11) increase. In fact, increase of the lambda causes fewer social groups with more vehicles (more data and more communication time). Consequently, the collector vehicle observes fewer social-heads in the opposite direction and these social-heads have a considerable amount of data. This causes $E$[driven length for msg decoding] in equation (19) to decrease. This means that the vehicles can decode the message at farther distances in relation to the desired location. In other words, the decoding distance increases.

Figure 13 presents the effect of maximum speed on the decoding distance. If the speed is changed and the inter arrival time (entrance rate) remains constant, the decoding distance of the collector vehicle remains approximately constant. This means that changing the speed without traffic volume ($\lambda$) has a minor impact on the decoding distance. Consequently, if the maximum speed is increased, the collector vehicle can reach the decoding point at shorter period of time. The standard deviation of decoding distance in Figure 12 and 13 is between 2.024 and 7.23.

Figure 14 shows the delay time for decoding a message in the collector vehicle. Considering Figure 12, if the entrance rate is increased, the decoding distance is increased or the driven length for message decoding is decreased. Accordingly, if the entrance rate is increased, the collector vehicle can decode the message in shorter period of time. We also show the delay time for message
decoding versus maximum speed in Figure 15. The lines of this figure have a slight slope, but it is not so evident due to the vertical axe unit. The standard deviation of end to end delay in Figure 14 and 15 is between .98 and 2.76.

It is worth noting, that the simulation results are different from analyzing results owing to the channel withdrawal effect. However, the analysis determines an upper bond for decoding distance and a lower bond for delay time.

7. RELATED WORK

This section reviews the important attempts at establishing networks for social services in vehicular scenarios and the related techniques used in this paper:

7.1. SOCIALIZING CAR AND THE INFRASTRUCTURE

Social networking is considered as a remarkably fascinating phenomenon to many scholars. However, in spite of a great deal of research on two-way interactions or sharing contents of interest between vehicles, little is known about the opportunities that a social vehicular network may bring for individuals. Several studies have been done recently on establishing social communication. Alt et al. [6] studied about how a driver can use the opportunity of waiting times in front of the traffic light to start interaction. The interaction between vehicles has also been investigated by [5]. They implemented a virtual “flea market” called FleaNet in order to find a customer/vendor with matching needs/resources. Boldrini et al. [7] proposed a method in opportunistic networks to autonomically learns social information about the users of the network and use this information to predict the users’ future movements. Lequerica, et al. [1] considered the technical challenges in designing the vehicular social networks.

The potential of social networks in the vehicle has influenced some companies to add basic social features to navigation applications and services based on the internet. For example, Waze (http://www.waze.com) as a navigation and GPS system enables the drivers to exchange the traffic information and report traffic incidents. The information posted is only valid for a period of time and geographically referenced. Aha (http://www.aharadio.com) is an application that adjust web content, messages and traffic reports to the vehicle environment. It is basically a personalized radio with interactive features that turn the
web contents and messages from existing social networks into audio streaming. Most of the other existing applications like Navigon, ALK Technologies, Telmap & GyPSii primarily allow their users to post location and route information to their contacts in existing social networks (mainly Facebook and Twitter).

To the best of our knowledge, none of the previous works have taken into account the required vehicular network infrastructure for social applications and services.

7.2. INFORMATION MANAGEMENT

In our approach, information management is investigated from two aspects of information collection and information dissemination. So far, various methods have been proposed for information collection in vehicular scenarios. The primary factor was to reduce the overhead of transmission; Information aggregation techniques [32] was applied dominantly in this field. Most of these methods are based on techniques, such as Centralized [24], Group/Cluster based [25], and Hierarchical [26]. For example, Dietzel et al. [36] proposed a structure-free aggregation scheme that focused on flexible decision metrics. It is not necessary to define aggregate structures, like fixed road segments, a hierarchy, or a group of nodes. Hence, the scheme is structure free. Fuzzy logic rules are employed to base aggregation decisions on qualitative metrics, such as induced quality loss due to aggregation. Rawshdeh and Mahmud [37] proposed grouping of vehicles with similar mobility patterns by multi-metric cluster-head (CH) election technique. This technique can be used by vehicles to determine their suitability on the fly to lead the cluster and aggregate the data. This approach takes the speed in addition to the location and direction into consideration to accurately identify nodes showing similar mobility pattern and group them in one cluster. However, an efficient communication with other clusters is not considered. Saleet and Basir [38] presented the Region-based Location Service Management Protocol (RLSMP). Their work utilized aggregation and geographical clustering to minimize the number of location updates and querying messages for location management of vehicles. RLSMP improves network scalability but suffers from the problem of increased number of packet collisions, retransmissions, and longer delays. Furthermore, a hierarchical data aggregation scheme for aggregating free parking slots using globally known map data for segmentation was proposed by Lochert et al.’s study [26]. In this protocol, a vehicle needs detailed data about its surroundings but only rough aggregates about farther areas. The major benefit of using Flajolet-Martin sketches in the work is achieving a probabilistic but duplicate insensitive sum of free parking spaces. The data map pre-defines the aggregation hierarchy.

In order to inform the other vehicles from the events and interactions that take place in the social vehicular network, an efficient information dissemination protocol is necessary. Many of the dissemination protocols for VANETs are based on the following techniques: flooding, broadcasting, neighbor knowledge based exchange, and cluster based approach [39]. For example, Cheng et al. [40] proposed a method to apply Cellular Automata (CA) clustering using the Zone Of Interest (ZOI) for mobicast communications in VANET. This paper formed a group of VANET-related interests using both an interest profile (ontology) of drivers and information about vehicles. Then, the information is mobicast in ZOI. A context-based grouping mechanism has been presented by Paridel et al. [41]. This work considered contextual properties, such as location, direction, and information interest, and benefit from the mobility patterns of the vehicles and the road layouts to broadcast information with minimum overhead. Moussannif et al. [42] addressed the problem of providing a set of services by structuring the network into clusters and using Content Based Routing (CBR) and geographic routing for inter-cluster communication. Each cluster uses a tree structure with a cluster-head as the root of the tree. The cluster-head maintains a summary of the subscribers and route information to them using brokers. Fan [29] considered a simple scheme to form clusters and proposed an efficient broadcast method. We used this approach as our base algorithm and added social-head election procedure to fit our needs.

7.3. DATA DISSEMINTATION AND DATA TRANSMISSION SCHEMES

Routing based data transmission schemes in VANETs has been considerably studied and many different protocols have been proposed. The routing protocols are classified into five categories as follows: ad hoc, position-based, cluster based, broadcast, and geocast routing [27, 43].

Moreover, several investigations on Store-Carry-Forward (SCF) data dissemination have been performed in VANET, such as SODAD [44], VADD [45], and MDDV [46]. In some protocols, SCF is used but after forwarding a packet, a copy is kept in the original node for further forwarding, if required [34, 47].

The problem of distributing data from one info-station to vehicles on a highway has been previously described [48]. The scenario is simple, but it is applicable only for dense networks. Moreover, congestion is also one of the major problems in VANET that leads to a reduction in data delivery ratio. Thus, buffering and Data Pouring (DP) have been suggested [49]. In this scheme, the vehicle density must be large enough to sustain network connectivity.

The application of network coding and rateless codes in vehicular networks has been previously investigated [50-52]. The DDRC algorithm [34] merges the roadside-to-vehicle and vehicle-to-vehicle communication and a reliable data dissemination without a need for complex routing protocols is obtained. The DDRC uses rateless coding for efficient and reliable data dissemination in VANET. This algorithm is also simple and well distributed [53]. Therefore, it is selected for data exchange between vehicles in one part of our data transmission schemes.
8. CONCLUSION AND FUTURE WORK

In this paper, we proposed a novel vehicular network infrastructure for social applications. We explored a feasible scenario of a vehicular network to manage social groups of an ephemeral social network and their information. This scenario is implemented through presenting a three-layer architecture with a highlighted network service middleware. This middleware includes mechanisms to control the formation of dynamic social groups and declares the necessary protocols. The middleware also supplies different functionalities from managing and monitoring the information collection and exchange process to supervising the information utility. In our architecture, we used one node as the social-head to reduce the overhead of controlling these issues and provide the network with the possibility of applying future social rules or policies. Different communication schemes are also used for inter- and intra-group data exchange to achieve maximum efficiency, and increase the range of communication. Particularly, we used data dissemination scheme to spread out the information to the sparse part of the vehicular network. In doing so, we evaluated this architecture from different perspectives. We analyzed the constant speed mobility in our data dissemination scheme and inspected the social vehicular group performance and scalability. The simulation experiments on the group formation mechanism showed that our grouping functionality performed well in different speed and road traffic conditions. Furthermore, our simulation showed that the speed had a minor impact on the social group size, but the arrival rate of the vehicles in the road was a significant parameter in this regard. The arrival rate also had direct influence on the decoding distance and the delay time of message decoding. However, speed had no effect on decoding distance but had impact on the message decoding delay time.

In future work, the ephemeral social network and its applications should be studied in more detail in different perspectives such as security. For instance, different safeguards for hacking, counterfeiting the identity and also privacy issues such as correlating the information of the other data sources with the anonymous users should be investigated.

REFERENCES


