Decentralized Event-Based Vehicular Social Networks and Case Study

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Abstract

People often drive cars from all directions to social spots, such as shopping mall, football count, venue, museum, etc., to participate in some events. The participants constitute a relatively stable Event-Based Social Network (EBSN), which facilitates communication for a specific period of time and location. The motivation of the paper is that the users driving to participating in the same event have the same destination and similar interest, who are likely to share information about the social spot and interact with each other for entertainment along the route. Thus, the paper proposes a Event-based Vehicular Social Network (EBVSN) to facilitate a temporal-spatial communication between participants in vehicles or pedestrians. The EBVSN is to provide EBSN utilities on VANET even cellular or WIFI infrastructure may not be reliable. Since users in EBVSN move to the same destination, the connection between them is relatively stable, and even the closer to the destination, the denser is the network. Considering information silos among EBVSN and other online social networks as well as privacy, the EBVSN is designed to be decentralized social network, where multiple event organizers are distributed in various social spots and provide social utilities and data storage at individual local servers. The establishment of EBVSN, message dissemination, and data request/response are conducted by the entities of EBVSN Application, EBVSN Service, EBVSN Client, and WAVE stack. EBVSN Service at RSU periodically broadcasts an announcement message about the event and disseminate messages to users on behalf of EBVSN Application, and acts as an intermediary for data request and response. A use case is also given where the users who are driving to the football count to watch a game constitute an EBVSN initialization.

Keywords: vehicular social network, event-based social network, decentralized social network, VANET

1 Introduction

With the rapid development of smart devices and the advanced communication technologies, it is possible for drivers and passengers to communicate with other people on the road[6]. In the past, the communication between vehicles was achieved by equipping the vehicle with an on-board unit (OBU)[1]. The Vehicular Ad-hoc Network (VANET) facilitates intelligent transportation systems, enabling a variety of applications for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications.

By now, there has still been lack of research on mobile social networks in the vehicle environment, which is not conductive to social applications. While driving or riding, the vehicle acts as a carrier of the mobile communication device and the user, and combines the Vehicular Ad-hoc Network with the social network to form a Vehicular Social Network(VSN)[9]. VSN is a mobile communication system that

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considers the social relationship between vehicles. It includes both a social network describing the social relationships between users and a VANET for communication between vehicles[6]. VSNs use VANET as the communication infrastructure for data transmission via V2V or V2I.

Vehicular Social Networks (VSNs) inherit the characteristics of legacy social networks, but they also have their own features. In principle, the VSN is a social network built on VANET, considering human factors such as human mobility, human selfishness, and human preferences[4]. Applications of the VSNs may be based on the purpose of VANET, such as security applications, but may also involve entertainment applications[11]. Users can reduce the occurrence of traffic accidents by publishing or sharing traffic information (such as accidents, congestion, etc.), and users can also find others with the same interests by sharing information.

At present, a lot of research has been proposed for Vehicular Social Networks. Stephen[9] proposed a RoadSpeak system for commuting scenarios. Every day, many people drive for hours between home and office. These daily road commutes are highly predictable and regular. Therefore, the user selects the VSN that he wants to join during the commuting before going out and the driver automatically joins the VSN after reaching a certain location and communicates with other commuters through the voice chat message. However, this solution has problems with user authentication and the risk of exposing privacy. SPRING[5] uses the aggregation of vehicles in social spots such as intersections and the intermediation of social spots to define and calculate the social centerlines of intersections, and select social spots with higher social centers as suitable RSU placements to improve the utilization of storage devices. However, this scheme is not ideal in improving the efficiency of message transmission, and it is assumed that the destination has been fixed and known. NaviTweet[8] is a social vehicle navigation system that integrates vehicle-provided information into a vehicle navigation system to calculate a personalized path. Therefore, drivers belonging to the same community can share the driving experience with other drivers by using voice. All these tweets are automatically aggregated into the tweet digests of each community group based on location information. But this solution does not take into considering the user's security and selfishness.

Event-based online social services provide a convenient online platform for people to organize and participate in social events. With the rapid development of these event-based services, a new social network, Event-based Social Network[3] (EBSN), has been proposed. As shown in Figure 1, the interactions between users are linked by social relationships to form an online social network[2].

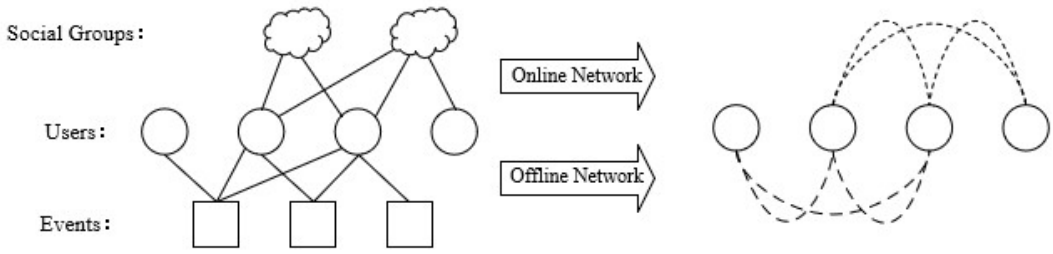

Figure 1: The description of EBSNs

The EBSN is defined as a heterogeneous network $G =< U, A^{on}, A^{off} >$, which consists of a set of users U, online interactions between users A^{on}, and offline interactions between users A^{off}. Users can interact with each other online without the need of physical contact, while social events motivate offline interactions between users.[3].

Considering an example when a group of users driving to watch a football game, they have the

same destination of football count and expect to meet people with similar interests. They are likely to share information about the social spot and interact with each other for entertainment while in the road. Considering social event are generally held in social spots, VSN can be a variant of the offline network of EBSN when users participate in the event by vehicles. Since social spots are referred to the locations where many vehicles will visit, for example, a shopping mall, a restaurant, or a cinema[7], vehicles are denser near social spots, which is beneficial to constitute a stable mobile social network via VANET.

This paper proposes a novel Event-based Vehicular social network (EBVSN) model to facilitate communication between users who are participating in the same event by vehicles or pedestrians. EBVSN is a combination of EBSN and VSN, where users participate in the same social event move to the same social spot, the connection between them is relatively stable, and the closer to the destination, the denser the network. In the other hand, users in the EBVSN usually have the similar interest. To meet the privacy requirement of OSN on VANET, EBVSN is designed to be a decentralized social network, where multiple event organizers distributed in various social spots in a decentralized manner. In this way, it allows users to have more control over their own data. Considering the privacy issue, EBVSN allows the user to generate unlinkable pseudonyms for multiple EBVSNs, which cannot be associated with each other. Thus, the user's interest and location privacy are protected. We also give a use case for a group of football game fans. In this scenario, they may join the online group in advance, but the most interesting part is they can also enjoy the vehicular social network when driving to the football count to watch the game.

2 EBVSN Model

This section describes the definition of EBVSN and introduces EBVSN establishment, message disseminate and data request/response respectively.

2.1 Event-based Vehicular Social Network Definition

An Event-based Vehicular Social Network (EBVSN) is a social network of users and vehicles, which is defined as $EBVSN =< U, V, A^{on}, A^{VSN} >$ where A^{on} is the online interactions between users in U, the same as in EBSN, A^{VSN} is the event-based temporal-spatial interactions between users in U carried by vehicles V, and VSN is referred to as $< time, location, interest >$. The illustration of A^{VSN} is depicted in Figure 2.

Due to the temporal and spatial characteristics of social events, users participating in the same social event will constitute a temporary social network over a period of time in the communication coverage of the social spot. Assume vehicles be equipped with an embedded vehicle computing system that supports V2V and V2I communication, the smart phone established a connection with the vehicle, and RSUs deployed at social spots, the social interactions can be conducted within a fixed communication area covered by the RSU. It can act as the intermediary of packet forwarding between EBVSN application and EBVSN client, thus, the traffic between a user and and a cellular station or a WIFI AP is saved.

The EBVSN Application is defined as a higher-layer entity that establishes EBVSN and manages the VSN, which may be deployed at remote server or on the RSU close to the social spot. The EBVSN Service is responsible for EBVSN establishment and message dissemination, which is deployed on the RSU. The EBVSN Client is responsible for social utilities based on data requests, which is installed on the user's mobile phone and connected to the vehicle. The interaction between the EBVSN Service and the EBVSN Client is through WAVE stack.

Since EBVSN Application will know the location information of each user, and users who join the same EBVSN participate in the same social event, it is highly likely that they have the same interest.

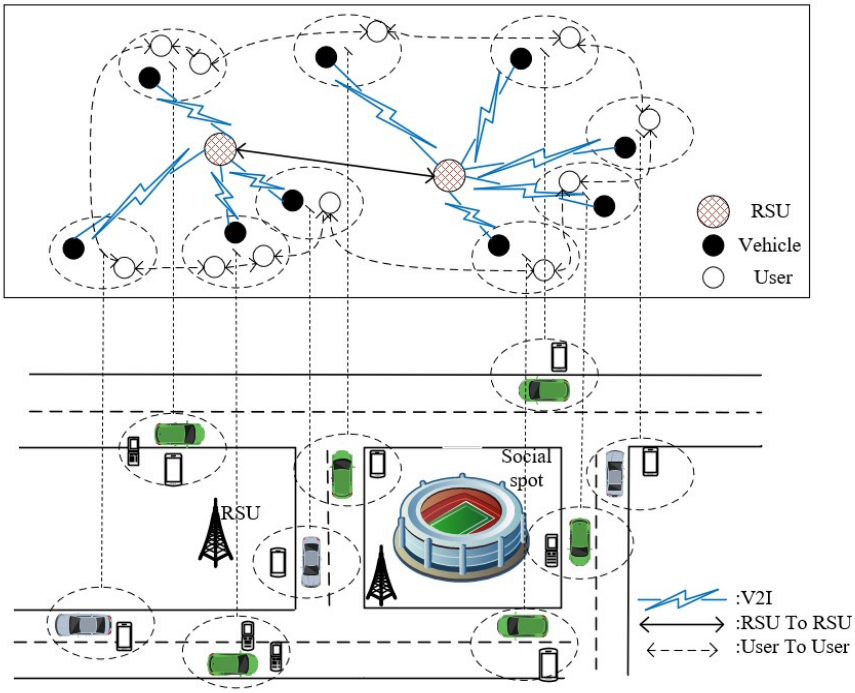

Figure 2: Event-based Temporal-spatial Interactions between users and vehicles in EBVSN

This is different from the privacy issues of traditional social networks that must be addressed. Therefore, when users join EBVSN, they will generate an unlinkable pseudonym based on the group key. Users communicate with each other under pseudonyms in the EBVSN, so location privacy and interest privacy are protected.

2.2 EBVSN Establishment

Before the event begins, EBVSN Application sends the message including *appID*, *connectionID* to EBVSN Service to register in host device over https. *AppID* identifies an EBVSN Application and *connectionID* identifies the connection of the EBVSN Application to the EBVSN Service. EBVSN Service deploys on the RSUs nearby event location. Each EBVSN Service sends a broadcast message to the vehicle node within the coverage to establish a VSN. If the vehicle node receiving the message is interested, that is, the user is going to the social spot to participate in the event, or the user is willing to participate in the social event, the node generates a pseudonym. And before node joins the EBVSN Application, EBVSN Client generates an asymmetric cryptographic key pair in advance. The message confirming the join are returned to the EBVSN Service. EBVSN Service is aware of EBVSN client in the communication zone. The EBVSN Service sends the user profile containing the user's pseudonym and *linkID* to the EBVSN Application over https, where *linkID* identifies the connection of the EBVSN Application to the EBVSN client. The EBVSN Application generates a group key and a list of group members based on the received user member information, the group key and group members are sent to the EBVSN Service via https protocol. The EBVSN Service then sends the group key and group members to the EBVSN Client through WAVE Stack.

Due to the mobility of the vehicle nodes, the EBVSN Service broadcasts the announcement message to the nearby vehicles periodically until the event is ended. The process of EBVSN establishment is shown in Figure 3.

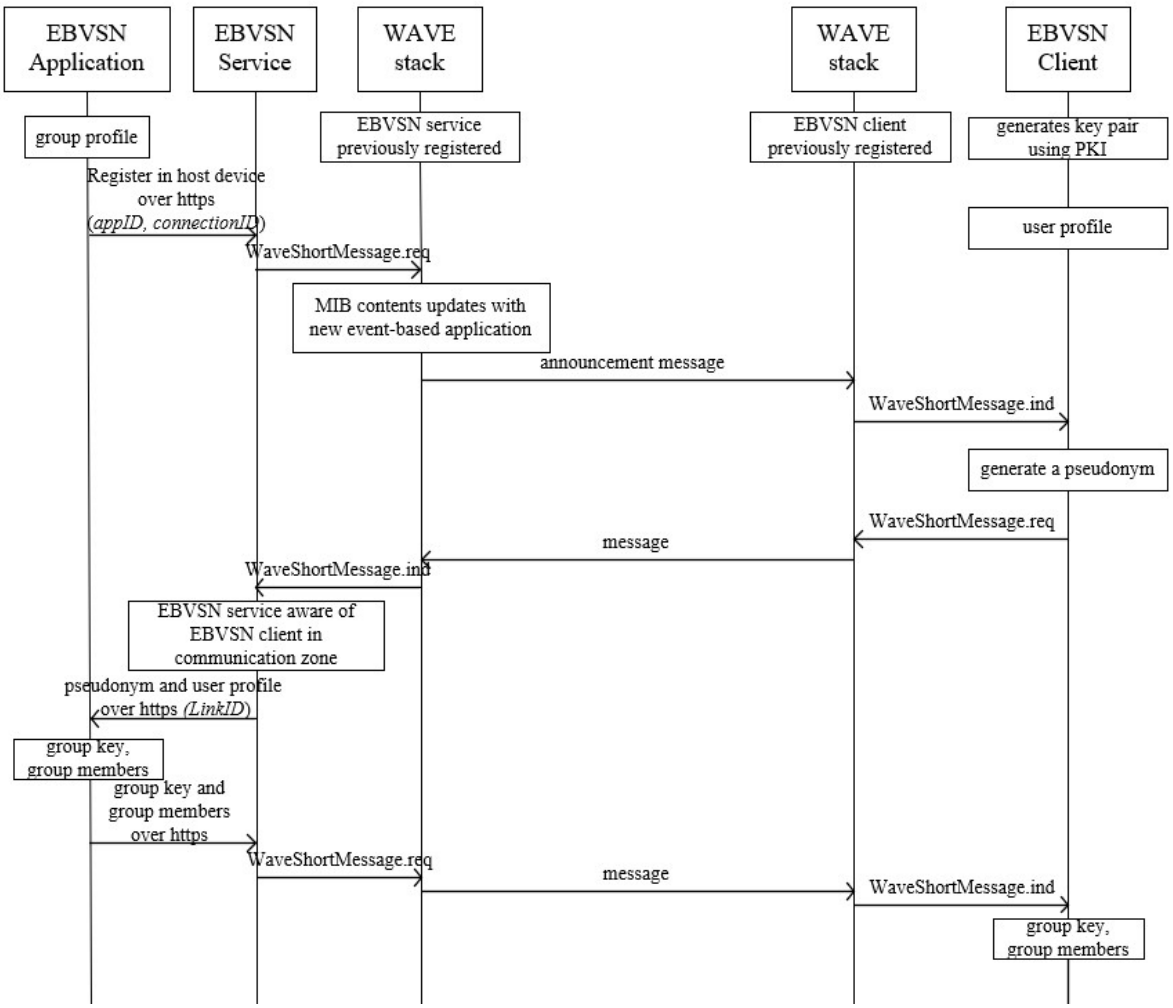

Figure 3: Processes in EBVSN

User Creation. Users create accounts in the EBVSN Application via https protocol. The EBVSN Client generates an asymmetric cryptographic key pair (using PKI) verified by EBVSN Application.

EBVSN Membership. Admission to a EBVSN is handled by the EBVSN Application. To be admitted to a EBVSN, a user submits his user profile. This data allows the EBVSN Application to verify that the user attempting to join the EBVSN is legitimate or not. If the EBVSN Application validates the user, and allows him to join the EBVSN, the group key is transmitted back to the EBVSN Client to be used by the EBVSN Client in the future for that EBVSN.

Connection Handler. An EBVSN client may only enter one EBVSN Application at a time. When an EBVSN Client connects to an EBVSN Service, the EBVSN Application perform the admission control. To initiate the process of admission control, an EBVSN Client transmits the profile to an EBVSN Service. The server validates the user based on the user's information. The EBVSN Application then hands the client connection off for the requested EBVSN group.

Service Primitives. As [10] shows, the WSM-WaveShortMessage.request primitive is used by a higher layer entity to request sending a WAVE Short Message. Upon receipt of the WSM-WaveShortMessage.request primitive, the WSMP(WAVE Short Message Protocol) delivers the WSM to the LLC sublayer. The WSM-WaveShortMessage.indication primitive indicates to a higher layer entity that a WSM has been re-

ceived. The WSM-WaveShortMessage.indication primitive is generated by the WSMP to deliver WSM information to a higher layer entity or entities indicated in the MIB (i.e., Management Information Base) WsmServiceRequestTable. The received data is processed as determined by the receiving higher layer entity.

2.3 Message Dissemination

When a node wants to send a message to the VSN, it first signs the message and then encrypts the signed message under the public key of EBVSN Application. The encrypted message is sent to the EBVSN Application via WAVE Stack and EBVSN Service. After receiving the encrypted message, the EBVSN Application verifies the sender and decrypts the message under the private key, and then sends the message to the EBVSN Service, then each EBVSN Service sends the message to the VSN members stored in the EBVSN Service and within its own communication range.

2.4 Data Request/Response

The EBVSN Application transmits the URL of the data resource to all nodes in the EBVSN through the message dissemination. If the user wants to retrieve the data, he sends a request message to the EBVSN Application. The request message is first transmitted to the EBVSN Service. It then sent to the EBVSN Application by the EBVSN Service. After receiving the request message, the EBVSN Application confirms the data that the requester wants to obtain according to the link information, and then encrypts data with the group key, and the encrypted message is along the original path return to the requester. After receiving the message, the data requester decrypts with the group key to obtain the data.

3 Use Case

We describe a usage scenario for EBVSN model. Suppose Alice is ready to watch the football game at the football count at 7 o'clock in the evening. Before Alice goes out, assumed she has logged in to the EBVSN Application with a *webID*. Alice may participate in an interest-based group labelled $football$ where she communicates with others via cellular or WIFI at home. When Alice gets into his car, she sets her smart phone in its cradle. As she travels to the football count, the EBVSN Client running on his smart phone tracks her location via the built-in GPS receiver. As close to the football count, Alice receives an (voiced) announcement message, from the EBVSN Service, hosted in RSU, to invite her to join the event-based temporal-spatial social network labelled $live\_football$. She may reply an (voiced) acceptance message to enjoy it. In this way, Alice's user profile will be added to the temporary social network $live\_football$.

After joining the EBVSN $live\_football$, Alice can watch news feed of the event organizer and meet other members to share information with each other, such as parking lot and restaurants.Suppose Alice is driving very close to the football count, she wants to get information about the parking lot, it happens that she finds the link of the parking lot information shared by Bob in the news feed. The link information has been disseminated by the EBVSN Service hosed in RSU at the football count to all members.The EBVSN Client transmits the request message to the EBVSN Application through V2I communication in VANET to retrieve the data, as introduced in Section 2.4.

When the football game is over, the EBVSN Application of the game deactivates the $live\_football$ related EBVSN Service, and EBVSN Client in Alice's mobile phone automatically terminates.

Table 1 lists the API that the EBVSN Service exports for use by EBVSN Application, and also be used to extend EBVSN clients to provide enhanced functionality.

Table 1: API Function and Function Description of EBVSN Application

API Function	Function Description
createUser($< pseudonym >, < cprofile >$)	Create user named $< pseudonym >$ in the EBVSN and set its initial profile to $< cprofile >$.
getUserProfile($< pseudonym >$)	Fetches the user profile data for $< pseudonym >$.
setUserProfile($< pseudonym >, < cprofile >$)	Updates the user profile data for $< pseudonym >$ to $< cprofile >$.
createGroup ($< groupname >, < gprofile >$)	Create an EBVSN group named $< groupname >$ in the VSN and set it?? initial profile to $< gprofile >$.
getGroupProfile($< groupname >$)	Fetches the group profile data for $< groupname >$.
setGroupProfile($< groupname >, < gprofile >$)	Updates the group profile data for $< groupname >$ to $< gprofile >$.
enumGroups()	Enumerates the current list of existing groups.
enumUsers($< groupname >$)	Enumerates the current list of users connected to the group $< groupname >$.
lookupGroupKey($< groupname >$)	Fetches the current public group key for $< groupname >$ group.
generateGroupKey($< groupname >$)	Generates a new group key pair for group $< groupname >$.
generateKey($< pseudonym >$)	Generates an asymmetric cryptographic key pair for user $< pseudonym >$.

4 Conclusion

This paper presents a novel Event-based Vehicular Social Network model and proposes a definition framework. It allows users who drive to participate in the same social event join the EBVSN on their route to the destination by facilitating communication between users via VANET. We present a use case to show the application scenario of EBVSN. In the future, we plan to simulate the actual application of the model and evaluate the performance.

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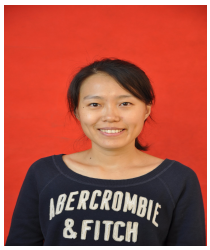

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