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Communication framework for vehicle ad hoc network on freeways

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Abstract Providing an efficient and stable communication framework of Vehicular Ad hoc Network (VANET) is an emerging issue. Most of conventional VANET communication schemes only support short range transmission, vehicles need to relay traffic data or frequently switch to different roadside units. Such an ad hoc-based method suffers a high jitter delay and makes it difficult to develop travel and real-time multimedia services, such as traffic information dissemination and fleet management. Fortunately, existing novel wireless technologies, e.g. WiMAX mobile multi-relay (MMR), provide long transmission range and high transmission rate in mobile environments. This study presents a Safety/Vehicular Information Delivery (SVID) framework, an application-layer VANET communication protocol. A power-abundant, large size vehicle, called SIP-based relay vehicle (SRV), e.g. long distance transportation bus, plays as a relay station (RS) providing the connectivity to other small vehicles around it. To provide VANET services in SVID, this work adopts a SIP-based mechanism. The proposed scheme can provide more efficient communication than conventional VANET ad hoc mode. Simulation results show that the proposed scheme achieves a low SIP transaction time, jitter delay, frame loss rate while avoiding the broadcast storm problem.

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1 Introduction

Research on Inter-vehicle communication (IVC) is progressing rapidly because it applies to real-life activities and leads to a great market potential. Using IVC, people in vehicles can acquire traffic condition messages for adjusting their navigation, improving both safety and speed of travel. To support IVC, a Vehicular Ad-hoc Network (VANET) [1] has been widely discussed to provide communication among vehicles using the Wireless Access in the Vehicular Environment (WAVE) standard and dedicated short-range communications (DSRC) techniques. However, several new challenges have arisen: (1) rapidly changing topology; (2) frequent dis-connection as a result of low vehicle density; (3) predicable vehicular movement, especially on freeways; (4) energy is less an issue because it can be supplied by the engine. Although the WAVE and DSRC technologies support the communication among vehicles, they still suffer high transmission delay and high deployment cost. Moreover, vehicles move at a high velocity on freeways. Multimedia applications and time-sensitive messages are difficult to develop over both schemes because packets are routed by data disseminating [2] or delay tolerant [3] schemes. Therefore, a new communication model is required for VANET applications.

A new version of the Worldwide Interoperability for Microwave Access (WiMAX) standard, called WiMAX Mobile Multihop Relay (WiMAX MMR) [4], has been proposed to support relay function. A relay node can move arbitrarily improving the reachability of WiMAX networks. Our idea is to have relay nodes driving on the freeway to provide

WiMAX relay capability to other vehicles. That is, relay vehicles can forward safety messages efficiently by broadcasting and provide Internet access to neighboring vehicles.

This study attempts to devise and develop a novel communication framework, called SIP-Based Safety/Vehicular Information Delivery (SVID) Framework, to efficiently transmit safety and time-sensitive traffic information in VANET. SVID is designed for vehicles on freeways. The major contribution of this paper is to allow a power-abundant vehicle, e.g. transportation buses, serves as Session Initiation Protocol (SIP)-based relay vehicle (SRV), to provide relay functions to its surrounding Ancillary Vehicles (AV). All SRVs are connected to one of the Multihop Relay Base Stations (MR-BS). AVs can access information of other vehicles through an SRV using proposed safety information dissemination and active navigation information update mechanisms. To solve addressing problem, this framework adopts the SIP protocol [5, 6] to maintain vehicular identification location. Vehicular applications thus can be developed based on the SIP protocol. For example, the proposed scheme develops the SIP FLOOD and PULL/ADVISE methods to provide traffic information and fleet management. An AV can adjust navigation immediately to react to a traffic event when it receives a FLOOD message. In addition, the PULL/ADVISE mechanism provides a membership management and travel plan update to an existing fleet. Therefore, a member can join and follow a fleet exactly once it receives a travel plan message from a leading vehicle.

The proposed scheme is evaluated through the NCTUns [7] simulator. To simulate the proposed scheme in the application layer of the simulator, this paper uses SIPp [8] and SER [9] programs to generate and manage SIP messages. This paper evaluates two scenarios: first is the overall performance of the proposed scheme, another is the proposed scheme under realistic vehicular mobility pattern. The simulation results demonstrate that the proposed scheme achieves better SIP transaction time, jitter delay, frame loss rate than conventional VANET ad hoc mode. Also, the proposed scheme can avoid the broadcast storm problem.

The rest of this paper is organized as follows. Section 2 discusses the motivation, objectives, and requirements of this study. Section 3 then presents the system model and provides an overview of SVID. Next, Sect. 4 summarizes the performance analysis results. Section 5 presents conclusions, along with recommendations for future research.

2 Motivation, objectives, and requirements

To achieve a better transmission efficiency in VANET, several communication and service frameworks have been proposed in the literature. Yang et al. [10] proposed a method of segmenting a road and using channel-sharing to relay packets to a segment head (SH) and base station (BS). A vehicle in a road segment is elected as the SH which is able to aggregate packets from other vehicles in the segment and relay to other SHs or BS. Dikaiakos et al. [11] introduced an application level VANET mechanism capable of pushing and pulling traffic condition information. The mechanism adopted ad hoc model to disseminate data. Similar to a mobile ad-hoc network (MANET), each vehicle has a large transmission overhead to flood the request and response because the message is routed hop-by-hop, and it is difficult to avoid the broadcast storm problem [12]. Mussabbir et al. [13] proposed an improved Fast Mobile IPv6 (FMIPv6) mechanism to support network mobility (NEMO) in vehicular environments and utilized IEEE 802.21 protocol to improve the handover performance by caching network information. However, it still has the header overhead problem. Tseng et al. [14] also proposed an enhanced SIP-based network mobility (SIP-NEMO) [15] scheme to improve handover in VANET. But, they did not consider to enhance vehicular safety. Wisitpongphan et al. [1] proposed a probability-based broadcast forwarding scheme to solve the broadcast storm problem in VANET.

However, aforementioned solutions suffer following shortcomings:

1. Difficult to support vehicular applications: in vehicular environment, a vehicle may need information of the traffic condition and travel from other vehicles. Current investigations only discuss the idea for applying conventional IP- or MAC-layer infrastructure to VANET. The vehicle thus does not know the location of the queried vehicle, and is difficult to send a query message to a specific vehicle.
2. Long transmission delay: in these schemes, packets must be buffered for a while before forwarding to a road side unit (RSU) or a neighboring vehicle. As a result, time-sensitive applications are difficult to deploy in vehicular environments.
3. Header and routing overhead: for example, the FMIPv6 with NEMO scheme incurs high header overhead and routing cost because tunneling packets from the corresponding node to the mobile node.
4. Heavy processing loading: in [10], a SH needs to relay packets which consumes a lot of processing and transmission power.

Therefore, how to develop a framework with high efficient communication, global reachability, and low deployment cost for time-sensitive applications is still an open issue. The proposed SVID uses SIP protocol and WiMAX MMR techniques to achieve these goals. SIP is an application layer protocol on top of the TCP/IP protocol stack. Multimedia applications, such as Voice over IP (VoIP) and video streaming, can use SIP to initiate, modify, and terminate sessions. Moreover, SIP also supports text-based message format, and is very flexible for service providers to create new SIP signaling methods. Therefore, applying SIP to the WiMAX MMR framework can provide global reachability and high multimedia session management capability. In summary, SVID is devised according to the following requirements.

- Vehicular information transmission: Information about the velocity, direction, and geographical position of a vehicle won the most attention in VANET. SVID should provide vehicular information to the system and other vehicles using SIP signaling messages.
- Supporting various vehicular applications: All SIP-based applications can be operated in the proposed framework regardless of the SIP version or the location of the service provider.
- Global reachability: A SIP client should be able to access the proposed framework. Notably, a SIP client can be a node from the Internet or an AV.
- Arbitrary configuration: An AV should auto-configure network configurations when it connects to a different wireless access point. Therefore, the SIP-URI of an AV does not need to be changed.
- Interoperability: SVID should coexist and be compatible with the current SIP framework.

3 SIP-based safety/vehicular information delivery (SVID) framework

To apply SIP with WiMAX MMR to VANET, SVID uses a core network (CN) to manage the framework and forward signaling messages to service providers; SVID also uses a high speed data network (HSDN) to transmit messages to appropriate locations. The system clock of the proposed framework is synchronized with a global positioning system (GPS).

3.1 System overview and terminology

Figure 1 depicts the proposed system architecture which uses a snapshot of a small freeway district as an example. The direction of the traffic is indicated by an arrow near the middle of the road. In this snapshot, a number of vehicles of various sizes are traveling on the road. As aforementioned, the proposed architecture uses the WiMAX MMR technique to provide connectivity to all vehicles. This work assumes that an energy-abundant vehicle will provide the multi-relay function of the WiMAX MMR technique to surrounding vehicles, and that MR-BSs are widely deployed along the load. All MR-BSs communicate with the CN. The following section describes the details of the CN and HSDN.

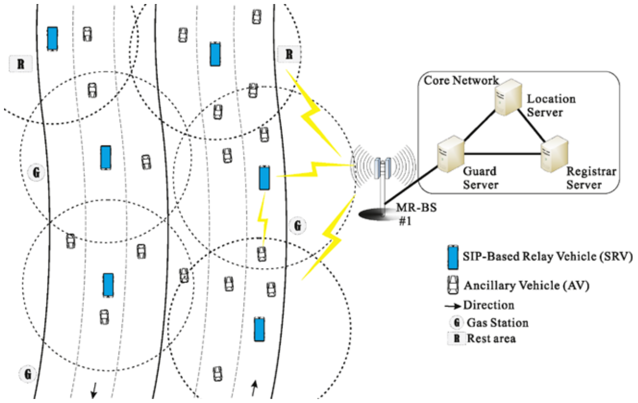


Fig. 1 The architecture of the SIP-Based Safety/Vehicular Information Delivery (SVID)

The main function of the CN is to provide switching, routing, and respond to SIP requests using pre-declared policies. The CN includes three major components, namely, guard, location, and registrar servers. The *guard server* can route requests to the current location of a SIP client based on call-routing policies and maintain the transaction. The guard server can also redirect the SIP signaling message to the correct position when a SIP client (e.g. AV and SRV) moves to a different domain of a guard server. Additionally, to protect the private information of an AV, the guard server deletes automatically the vehicular information of the SIP client since the message is sent out to the Internet. The *location server* maintains the recent history information and predict the next position information of the SIP client. The record of the location server should be updated upon receiving the update message from the registrar server. The *registrar server* is able to authenticate and authorize a SIP client. The mechanism of the authorization uses Message-Digest algorithm 5 (MD5) or SIP security (SIPS). According to pre-declared user policies, the registrar server can accept or decline a transaction. To secure transmitted messages between the components, SIP messages in the CN are tunneled.

The HSDN provides and maintains connectivity to AVs using WiMAX MMR technique, and consists of two components: MR-BSs and SRVs. The *MR-BSs* provide connectivity, management, and control of the SRVs. All non WiMAX signaling messages are backward transmitted to the CN through a MR-BS. The *SRV* is a mobile relay station, which provides WiMAX MMR connectivity to AVs. The SRV can relay messages to and from a MR-BS using non-transparency and centralized or distributed mode. Therefore, the SRV must broadcast downlink (DL) frame-start preamble, Frame Control Header (FCH), MAP, and channel descriptor messages to AVs. To support SIP transaction and provide SRV position information, the SRV is also equipped with an original SIP proxy server and GPS adapter.

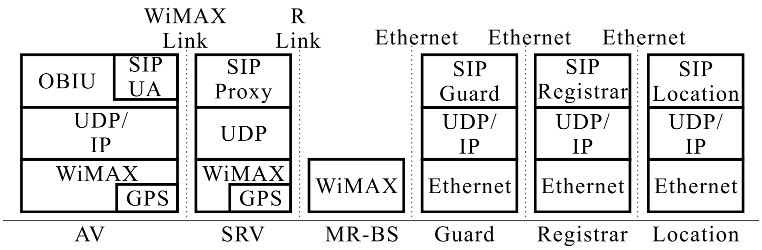


Fig. 2 Protocol architecture of SVID

Finally, an *AV* is a small vehicle, e.g. sedan, located within the transmission range of a SRV. An AV is equipped with a number of sensors to detect and gather vehicular information, including a GPS adapter, an On-board intelligent unit (OBIU), and a WiMAX MMR communication interface for inter-vehicle communication. The OBIU is able to perform self-diagnostic and reporting. All subsystems, e.g. GPS, wireless communication interface, and sensors, are connected to the OBIU to store and retrieve data. This work also assumes that the driver or passengers use an in-car computer to access the Internet and other vehicles through SVID. The in-car computer supports the functions of the SIP user agent (UA), navigation, traffic jam avoidance and alert reporting. The navigation software is embedded in the in-car computer to display the road networks of the geographic area. Additionally, each AV and SRV acquires a unique Internet protocol (IP) address which is assigned from the MR-BS. The assigned IP address will not be changed as long as the vehicle is in the SVID system.

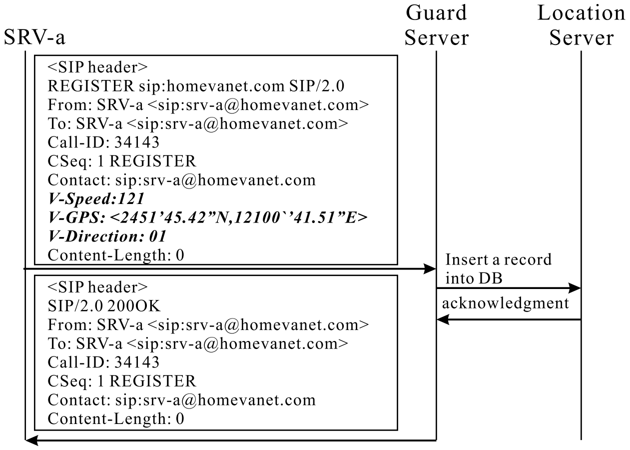
Figure 2 shows the protocol stack of the SVID environment. The protocol stack of AV is composed of SIP UA, OBIU, UDP/IP, and WiMAX. To achieve the proposed scheme, a SIP UA is installed on the OBIU of an AV. The SIP UA is able to communicate with the original SIP framework through the WiMAX MMR interface. Moreover, the SIP UA also performs the proposed vehicular services, such as FLOOD and PULL/ADVISE procedures. Additionally, the MR-BS manages and maintains the WiMAX MMR networks. The MR-BS thus does not equip with UDP/IP layer and above. Upon receiving a SIP message, the MR-BS forwards the message to the CN.

3.2 Transactions of proposed scheme

To provide and maintain the vehicular information of the AV, SVID adopts following three SIP signaling messages: REGISTER, FLOOD, and PULL/ADVISE. The translation details are described as follows.

3.2.1 SRV registration procedure

In the proposed framework, each SRV or AV must register with the registrar server upon entering the system. The SRV is a SIP mobile proxy server, and does not arbitrarily change the parameters of the WiMAX MMR interface. Therefore, the SRV adopts 407 proxy authorization procedure, and the registration message of the SRV is sent to the guard and registrar servers. If the registrar server accepts the message, it then transmits a 200OK message back to the SRV, and updates the location server database. The expiration time of the register message is set up to 600.



```
<SIP header>
REGISTER sip:homevanet.com SIP/2.0
From: SRV-a <sip:srv-a@homevanet.com>
To: SRV-a <sip:srv-a@homevanet.com>
Call-ID: 34143
CSeq: 1 REGISTER
Contact: sip:srv-a@homevanet.com
V-Speed:121
V-GPS: <2451’45.42”N,12100`’41.51”E>
V-Direction: 01
Content-Length: 0
```

```
<SIP header>
SIP/2.0 200OK
From: SRV-a <sip:srv-a@homevanet.com>
To: SRV-a <sip:srv-a@homevanet.com>
Call-ID: 34143
CSeq: 1 REGISTER
Contact: sip:srv-a@homevanet.com
Content-Length: 0
```

Fig. 3 The transaction of the SRV registration procedure

Figure 3 shows an example of the SRV registration procedure and content of the signaling messages. For simplicity, this work only discusses SRV registration procedure using normal SIP registration procedure. Once a SRV, denoted as SRV-a in Fig. 3, with a SIP identification (SIP-URI) initiates a WiMAX MMR interface, it acquires a primary connection identification (CID) and an IP address from the MR-BS. The SRV then sends a registration message with vehicular information to the guard server. The proposed scheme inserts three headers into the SIP register message to provide vehicular information: Vehicular Speed (V-Speed), Vehicular GPS (V-GPS), and Vehicular Direction (V-Direction). This vehicular information is acquired from the GPS of the SRV. Additionally, the parameter of the V-Direction is a normalized value as shown in Table 1.

3.2.2 AV registration procedure

To provide high security, an AV has to be carefully authorized by the SRV and registrar server. The AV should authenticate with an immediately SRV using 401 client authorization procedure. Upon receiving the registration message of the AV, the SRV then forwards it to the registrar server for authorizing the request. Finally, the registrar server sends a final response message (e.g. 200OK) to the SRV and AV to confirm such request. Otherwise, the registrar server sends "401 unauthorized" message to the AV through the SRV. Figure 4 shows a simple example of the AV registration transaction and content of the signaling messages. When initiating contact with an access SRV, an AV obtains a primary CID and an IP address which are assigned from the SRV and MR-BS, respectively. The AV then performs a registration procedure to determine which services are provided by the proposed framework. Similar to the SRV registration procedure, the AV sends the registration request with the vehicular information to the access SRV. The access SRV forwards this registration message to the registrar server, and initiates a timer, denoted as $T2$. Once the registrar server accepts the request, it then responds with a 200OK message to the AV through the access SRV. Notably, the guard server and the access SRV have to cache the vehicular information and list of authorized AVs. Moreover, to maintain the message reachability, the expiration time of the AV registration message is set up to 60 seconds.

Table 1 Mapping between proceeding direction and codes

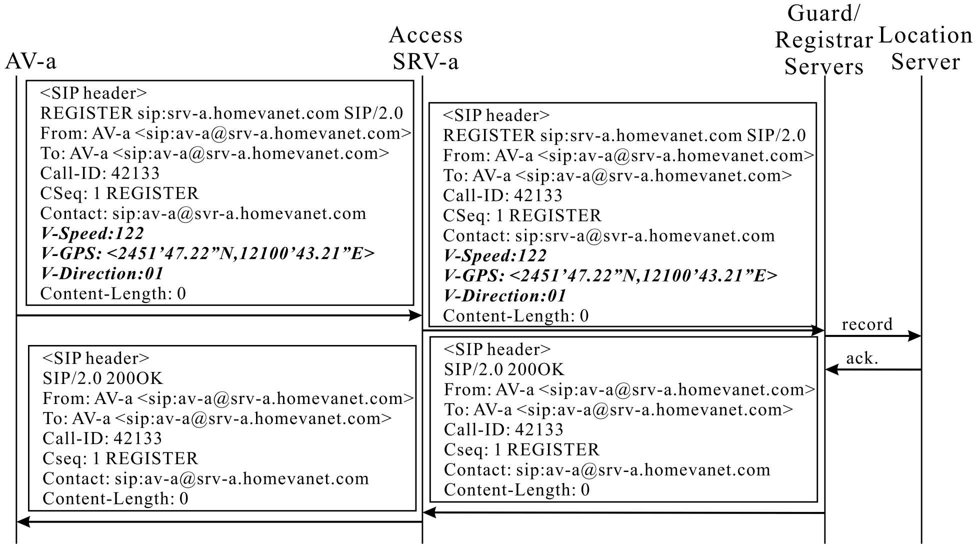
Bit	Direction
000	North
001	North East
010	East
011	South East
100	South
101	South West
110	West
111	North West

3.2.3 Safety information dissemination mechanism

The proposed SVID framework includes a new SIP signaling message, called FLOOD, to enhance vehicle safety. This allows a vehicle to actively flood emergency traffic information to all nearby vehicles in the event of an emergency. The FLOOD message is a high priority message, and MR-BSs and SRVs must broadcast on-the-fly when they receive a FLOOD request. Moreover, each MR-BS and SRV must reserve some network resources, such as control channels, for the FLOOD messages using WiMAX scheduling mechanism, and record the received time for traffic event investigation. When the guard server receives a FLOOD message, it broadcasts to all SRVs. The SRVs then check the traffic event of the broadcasted FLOOD message. If location of the event occurred is behind the transmission coverage of a SRV, the SRV ignores the message. Otherwise, the SRV broadcasts the FLOOD message continuously for $64 * T1$ seconds, and transmits again per $16 * T1$ seconds, where T1 is 500 milliseconds. This procedure does not use the provisional and the final confirmation message, namely 200OK, because the FLOOD message is disseminated by the SRVs to as many AVs as possible.

The FLOOD message includes five attached header fields, including V-Speed, V-GPS, V-Direction, Event, and Degree. The information for the first three headers is acquired by the GPS adapter. The "Event" header field records the traffic event. The "Degree" header field shows the priority of the traffic event. The OBIU generates the information of the Event and Degree header fields. Note that the information of the degree is a normalized value, where "05" denotes

Fig. 4 The transaction of the AV registration procedure

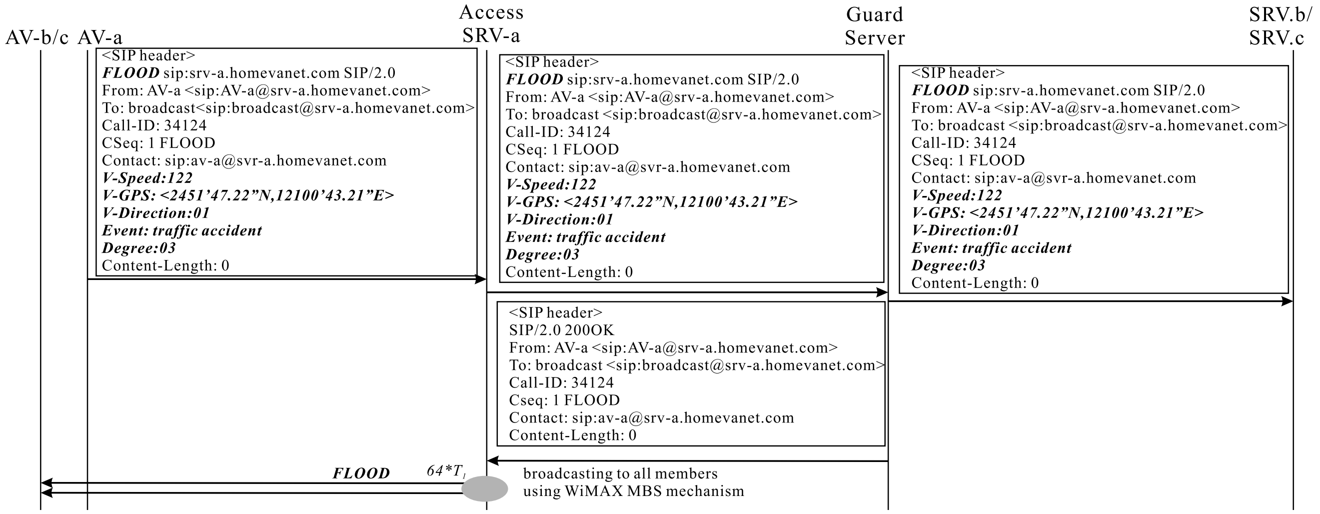


```
<SIP header>
REGISTER sip:srv-a.homevanet.com SIP/2.0
From: AV-a <sip:av-a@srv-a.homevanet.com>
To: AV-a <sip:av-a@srv-a.homevanet.com>
Call-ID: 42133
CSeq: 1 REGISTER
Contact: sip:av-a@svr-a.homevanet.com
V-Speed:122
V-GPS: <2451'47.22"N,12100'43.21"E>
V-Direction:01
Content-Length: 0
```

```
<SIP header>
REGISTER sip:srv-a.homevanet.com SIP/2.0
From: AV-a <sip:av-a@srv-a.homevanet.com>
To: AV-a <sip:av-a@srv-a.homevanet.com>
Call-ID: 42133
CSeq: 1 REGISTER
Contact: sip:srv-a@svr-a.homevanet.com
V-Speed:122
V-GPS: <2451'47.22"N,12100'43.21"E>
V-Direction:01
Content-Length: 0
```

```
<SIP header>
SIP/2.0 200OK
From: AV-a <sip:av-a@srv-a.homevanet.com>
To: AV-a <sip:av-a@srv-a.homevanet.com>
Call-ID: 42133
Cseq: 1 REGISTER
Contact: sip:av-a@srv-a.homevanet.com
Content-Length: 0
```

```
<SIP header>
SIP/2.0 200OK
From: AV-a <sip:av-a@srv-a.homevanet.com>
To: AV-a <sip:av-a@srv-a.homevanet.com>
Call-ID: 42133
Cseq: 1 REGISTER
Contact: sip:av-a@srv-a.homevanet.com
Content-Length: 0
```



```
<SIP header>
FLOOD sip:srv-a.homevanet.com SIP/2.0
From: AV-a <sip:AV-a@srv-a.homevanet.com>
To: broadcast<sip:broadcast@srv-a.homevanet.com>
Call-ID: 34124
CSeq: 1 FLOOD
Contact: sip:av-a@svr-a.homevanet.com
V-Speed:122
V-GPS: <2451'47.22"N,12100'43.21"E>
V-Direction:01
Event: traffic accident
Degree:03
Content-Length: 0
```

```
<SIP header>
FLOOD sip:srv-a.homevanet.com SIP/2.0
From: AV-a <sip:AV-a@srv-a.homevanet.com>
To: broadcast <sip:broadcast@srv-a.homevanet.com>
Call-ID: 34124
CSeq: 1 FLOOD
Contact: sip:av-a@svr-a.homevanet.com
V-Speed:122
V-GPS: <2451'47.22"N,12100'43.21"E>
V-Direction:01
Event: traffic accident
Degree:03
Content-Length: 0
```

```
<SIP header>
FLOOD sip:srv-a.homevanet.com SIP/2.0
From: AV-a <sip:AV-a@srv-a.homevanet.com>
To: broadcast <sip:broadcast@srv-a.homevanet.com>
Call-ID: 34124
CSeq: 1 FLOOD
Contact: sip:av-a@svr-a.homevanet.com
V-Speed:122
V-GPS: <2451'47.22"N,12100'43.21"E>
V-Direction:01
Event: traffic accident
Degree:03
Content-Length: 0
```

```
<SIP header>
SIP/2.0 200OK
From: AV-a <sip:AV-a@srv-a.homevanet.com>
To: broadcast <sip:broadcast@srv-a.homevanet.com>
Call-ID: 34124
Cseq: 1 FLOOD
Contact: sip:av-a@srv-a.homevanet.com
Content-Length: 0
```

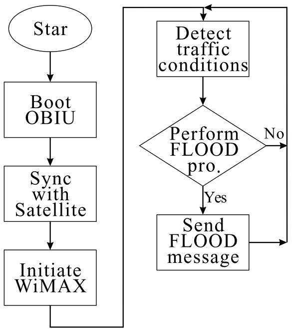
Fig. 5 The emergency information dissemination procedure using FLOOD message

an emergency event with top priority which causes the vehicle to stop immediately, and "01" is the lowest priority event, which may just need to slow down the vehicle, and "00" denotes the event which will be cancelled. In addition, the FLOOD message is a broadcast message, thus the To header field is indicated that the user name is "broadcast". Upon receiving the FLOOD message, the SRV checks the To header field and method name, and then broadcasts using WiMAX multicast/broadcast service (MBS).

Figure 5 displays an example of the FLOOD message. An AV, denoted as AV-a in Fig. 5, sends a FLOOD message with traffic accident event to the access SRV, denoted as SRV-a in Fig. 5, once it detects a traffic event. In the FLOOD message, AV-a suggests the Degree value is "03". Upon receiving the FLOOD message, SRV-a records this event, and broadcasts to all AVs which are located in the same transmission coverage, immediately. SRV-a then forwards the FLOOD message up to the guard server. However, SRV-a broadcasts to AVs continuously during $64 * T1$ seconds. Additionally, if the traffic accident event is not yet relieved, the FLOOD message will be sent again from a AV to SRV and the guard server.

To present the FLOOD procedure more clearly, Fig. 6 shows the flow chart of the FLOOD procedure. When the OBIU of an AV is booted, it then initiates the GPS and WiMAX MMR interfaces. The system time is synchronized with the satellites through the GPS interface. After completing the booting, the OBIU detects the traffic condition continuously. Upon detecting a traffic accident event comes up, the OBIU performs the FLOOD procedure to broadcast the FLOOD message to the immediate neighboring vehicles. Note that the process of the detection continues until the OBIU shutdowns.

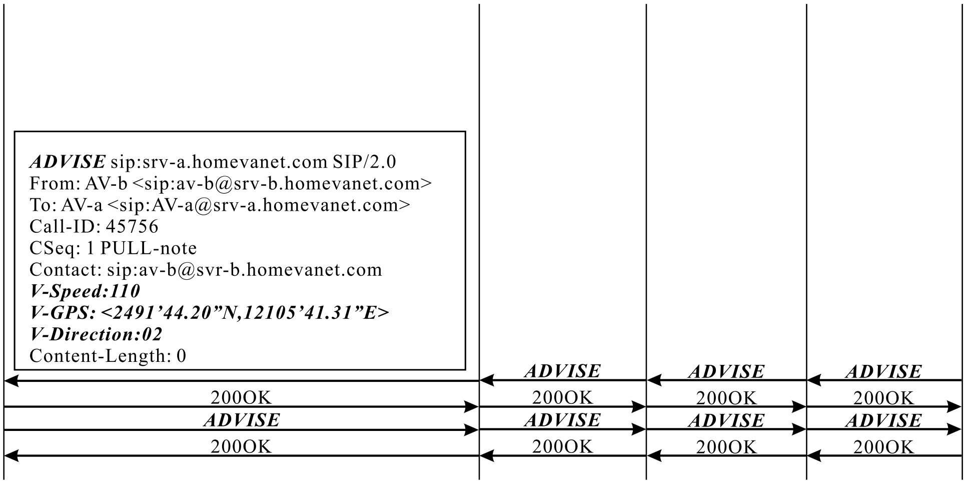
Fig. 6 The flow chart of the FLOOD procedure



3.2.4 *Active navigation information update mechanism*

SVID not only supports emergency information dissemination, but also provides an active navigation update mechanism. An AV can participate an existing fleet. Members in the fleet have the same travel plan and destination. In this case, the fleet has a leading vehicle to manage fleet membership, and make an announcement once the travel plan has been changed. All participant AVs follow the travel plan of the leading AV. The leading vehicle can modify the travel plan based on various traffic conditions, such as weather and traffic jam. Current navigation applications only use the web-based scheme to provide the current position and travel plans of the leading vehicle to fleet participants. However, this query-response mechanism suffers a long transmission delay and has difficulty providing travel plan updates in time. Therefore, a member could lose the new travel plan when the leading vehicle modifies the travel plan.

To support active navigation information update service in the proposed framework, SVID develops a new pair of SIP messages, called PULL/ADVISE. The PULL message describes an existing fleet service from a specific leading AV. Before providing a fleet service, an AV must initiate the fleet



```
ADVISE sip:srv-a.homevanet.com SIP/2.0
From: AV-b <sip:av-b@srv-b.homevanet.com>
To: AV-a <sip:AV-a@srv-a.homevanet.com>
Call-ID: 45756
CSeq: 1 PULL-note
Contact: sip:av-b@svr-b.homevanet.com
V-Speed:110
V-GPS: <2491’44.20”N,12105’41.31”E>
V-Direction:02
Content-Length: 0
```

Fig. 7 An example of active navigation update mechanism using PULL/ADVISE methods

pioneer function of the SIP UA to all participants. A fleet can only have one leading AV. In the authentication process, the leading AV uses access control lists or real-time interaction with a user to authenticate participants.

In response message of the PULL message, if a participant is invalid, the leading AV transmits a “488 Not Acceptable Here” message to the participant to reject the request. Additionally, the leading AV transmits a “503 Service Unavailability” to a participant if the fleet pioneer function has not been initiated. Otherwise, the leading AV transmits a “202 Accepted” message to the participant. The entire authentication mechanism must be completed in $30 * T1$ seconds.

The ADVISE method is a bi-direction transmission scheme capable of notifying the leading vehicle and participants of current position and vehicular information. The leading AV and participants periodically send ADVISE messages with current vehicular information. Upon receiving an ADVISE message, a participant’s OBIU calculates the new travel plan. Note that the participants always travel to the last position of the leading AV. Additionally, the leading AV updates the display screen once it receives the ADVISE message sent from the participants. The ADVISE message must be sent again in $16 * T1$ seconds. Moreover, the leading AV utilizes the SIP BYE method to terminate all fleet service transactions. The participant uses the CANCEL message to cancel a subscribe request before the leading AV allows it. Notably, the PULL/ADVISE method is only available in the SVID framework.

Figure 7 illustrates the proposed PULL/ADVISE procedure, but only shows the details of PULL and ADVISE messages sent from AV-a to SRV-a due to the paper length limitation. To indicate the path taken by the PULL message, SRV-a, guard server, and SRV-b need to insert a via header field on top of message. In this scenario, AV-a subscribes to the fleet service in a leading vehicle, denoted as AV-b in Fig. 7. At initiation, AV-a determines the SIP-URI of AV-b. AV-a and AV-b may connect to different SRVs or the same SRV. However, this scenario assumes that AV-a and AV-b are served by different SRVs. AV-a then sends the PULL message with the vehicular information to AV-b. Upon receiving the PULL message, AV-b updates the membership list, and displays this information on the in-car computer screen. AV-b then responds with a final confirmation message to AV-a. As the vehicle travels, AV-b periodically sends ADVISE messages to AV-b to update the vehicular information, and AV-a immediately computes a new travel plan to follow AV-b.

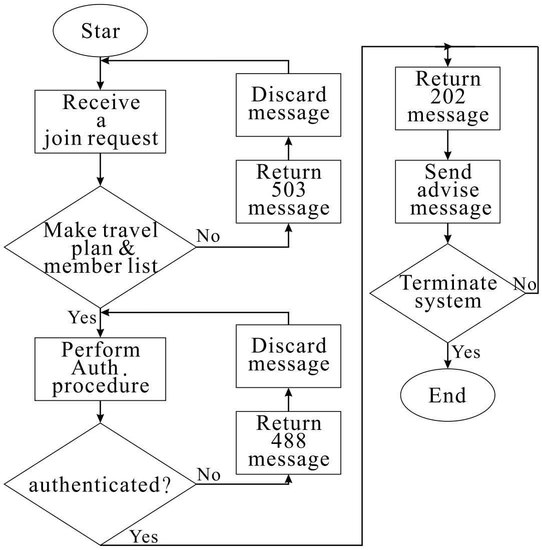


Fig. 8 The flow chart of the PULL/ADVISE procedure

Figure 8 depicts the fleet pioneer function for a leading AV. At initiation, the driver of the leading AV can input the destination information and plan the travel. Therefore, the fleet pioneer function discards all incoming requests because the system is not yet prepared. After finishing the plan, the leading AV accepts and processes the authentication of the members. Once a member is authenticated successfully, the leading AV then sends a "202 Accepted" to the member. Otherwise, the leading AV sends a "488 Not Acceptable Here" message back to the sender and rejects the request. Meanwhile, the leading AV also stars to transmit the ADVISE messages to authenticated members continuously.

3.3 Interoperability

To be compatible with current SIP framework and protect the driver's privacy, the guard server hides the vehicular information when the signaling message is transmitted to the Internet. For a client from the Internet, the translation is similar to the current SIP framework. Therefore, the client uses normal session establishment procedure to configure a session, and does not provide the position information of an AV. Contrarily, if an AV sends a request to other AVs, the guard server does not abandon the vehicular information. Therefore, the AV can know the vehicular information of other AV.

4 SVID evaluation

This section presents the simulation experiments with SVID. The experiment in this study investigates and compares the system performance, includes throughput, jitter, and frame loss rate (FLR), of the conventional VANET ad hoc mode and the proposed SVID mechanisms. This section also compares the safety information dissemination mechanisms of SVID with the conventional VANET ad hoc mode using realistic vehicular mobility patterns.

4.1 Simulation environment

The goal of this experiment is to investigate the feasibility of SVID and analyze its performance in a large-scale freeway network with realistic vehicular mobile patterns. This paper used the network simulator NCTUns 6.0 [7] to build the SIP protocol with WiMAX MMR communication. The NCTUns simulator provides a real-life protocol stack in a Linux kernel, and can run application programs on simulated nodes. In the application layer, the simulation utilizes SER [9] and SIPp [8] to support the functions of the SIP server and SIP message generation, respectively. A simulated vehicle runs the SiPp program to generate SIP messages and sends them to an appropriate destination through the SIP server.

Figure 9 and Table 2 show the simulation environment setting. To simulate a realistic freeway environment, this paper simulates 5 to 80 vehicles on a 9000-meter freeway with 4 lanes in each direction. As for wireless network settings, the transmission ranges of the SRV and MR-BS are 1500 and 6000 meters, respectively. To provide well-communication, the simulation sets up to 8 SRV cells deployed at regular intervals along the freeway. The SRVs use the transparency mode to communicate with the AVs and MR-BSs. Therefore, the MR-BS controls the QoS and performs connection managements. Finally, the MR-BS is equipped with an WiMAX and ethernet interfaces simultaneously.

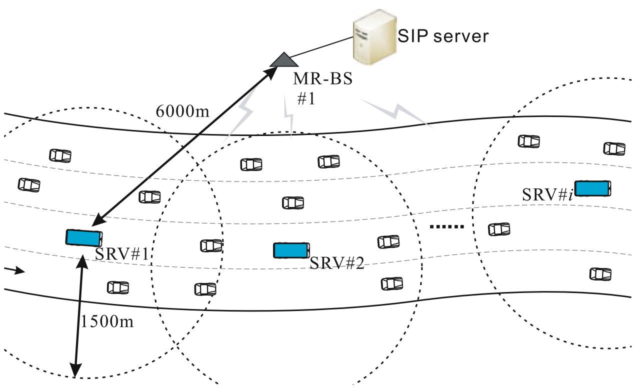


Fig. 9 Simulation topology

Table 2 System and scenario parameters

System parameters	
Simulation time	30–600 sec
Map size	$10000 * 2000$ m^2
Number of vehicles	5–80
Vehicle velocity	110 km/h
Number of lanes	8 with bi-direction
Road length	4 m
Wired line bandwidth	100 Mbps
SVID setting	
MAC protocol	OFDMA
Frequency	2300 MHz
MR-BS transmission range	6000 m
MR-BS transmission power	43 dbm
MR-BS antenna type	Omni
MR-BS antenna height	10 m
SRV transmission range	1500 m
SRV transmission power	43 dbm
SRV antenna type	Omni
SRV antenna height	3 m
AV transmission power	35 dbm
AV antenna height	1.5 m
VANET ad hoc mode setting	
MAC protocol	OFDM
Hello message interval	500 ms
Queue length	50 packets
Transmission range	200 m

Table 3 The transaction time of SIP methods over conventional VANET and SVID

SIP Methods	Msg Length (Bytes)	Transaction time (sec.)	
		SVID	Conventional VANET ad hoc mode
INVITE	459	0.341596	6.852739
REGISTER	381	1.173776	none
BYE	301	0.139748	1.681165

4.2 Scenarios

4.2.1 Overall system performance

To represent the best performance of SVID and the conventional VANET ad hoc mode, this paper assumes that vehicles do not change lanes or speed arbitrarily. In SVID, AVs maintain the same velocity with the serving SRV. In conventional VANET ad hoc mode, the distance between vehicles is set up to 200 meters. In this scenario, 5 to 40 connections are established. The transmission rate is set up to 500 frames per second, and the simulation time is set to 30 seconds. To evaluate the SIP transaction time between two vehicles, this study uses two vehicles to play as the SIP user agent client (UAC) and SIP user agent server (UAS), respectively.

4.2.2 Realistic traffic scenario

This paper adopts the FLOOD mechanism to flood emergency traffic information whenever a traffic event occurs. This paper simulates the FLOOD mechanism of SVID and the conventional VANET ad hoc mode using realistic traffic. To simulate realistic traffic, a vehicle is able to change lanes when encountering a vehicle in front. Moreover, vehicles are classified as normal or crazy. The velocity of a normal vehicle is about 110 km/h, and it can accelerate/decelerate at 5 km/h. Conversely, the crazy vehicle travels at 110 km/h, but accelerates/decelerates at 15 km/h. In this scenario, the SIP FLOOD message is disseminated every 25 seconds. We assume that all vehicles that receive the SIP FLOOD message should respond appropriately to reduce traffic accidents.

4.3 Metrics

To evaluate the performance of SVID, the interested metrics are shown as follows.

- SIP *transaction time* is the time required for a successful SIP transaction. It measures the elapsed time between the point at which a request message is sent and the time at which its final response message is received. This transaction time takes into account both message transmission time and processing time.
- *Throughput* is the average rate of messages successfully delivered to destinations.
- *Jitter* is the average delay-variance in the pulses of a digital transmission. Jitter is measured by a constant bit rate (CBR) of 900 bytes.
- *Frame Loss Rate (FLR)* measures the number of frames not received through the wireless network at a vehicle. Once frame loss occurs, it typically indicates the wireless device is running at over capacity.
- *Dropped frame count* is the number of dropped frames when the queue of a wireless network device overflows, e.g. when a vehicle receives lots of incoming frames but the wireless channel is continually unavailable.
- *Broadcasted frame count* is the average number of fra mes which are broadcasted over the entire wireless network.

4.4 Simulation results

4.4.1 Overall system performance

Table 3 reports the transaction time for three SIP major methods. To display the geographic position of a vehicle, this paper modified the REGISTER message as shown in Figs. 3 and 4. Each result is an average of ten experiments. This paper assumes an AV needs 200 milliseconds to configure audio and video devices, and the registrar server needs 1 second to authenticate a client. SVID adopts the WiMAX MMR technique to transmit messages. Therefore, it only sends the message through three hops (i.e., 2 SRVs and 1 MR-BS). Also, SIP messages are control-plane messages; thus, SRV and MR-BS assign high priority to allocate bandwidth for SIP messages. On the other hand, the conventional VANET ad hoc mode uses the Ad hoc On-Demand Distance Vector Routing (AODV) scheme to discover routing path, and updates the routing table every 500 milliseconds. Generally, the transmission time depends on the transmission range, collision rate, and buffer. Therefore, in the INVITE and BYE mechanisms, the SVID transaction time is shorter than that of the conventional VANET ad hoc mode. In the REGISTER mechanism, because the registrar server requires time to authorize a vehicle, authorization takes 1 second. In the SIP INVITE and BYE mechanisms, because of HSDN, the message reaches the SIP server in a short time. Therefore, both the SIP INVITE and BYE mechanisms require less than 400 milliseconds to complete transaction. However, although the SIP message can be transmitted without the SIP server, the INVITE and BYE messages are still transmitted by an ad hoc mechanism. Thus,

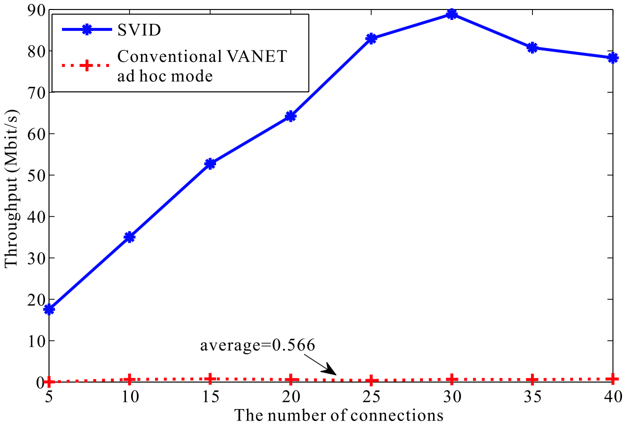


Fig. 10 Throughput for 80 vehicles without the vehicular mobile pattern

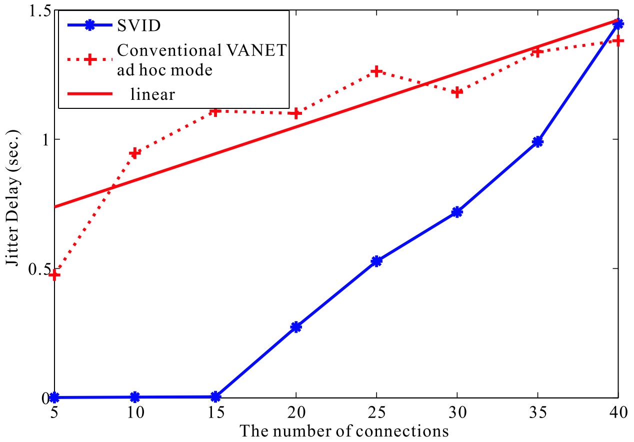


Fig. 11 Jitter delay for 80 vehicles without the vehicular mobile pattern

the conventional VANET ad hoc mode has a longer transaction time than SVID. In addition, no fixed node can support SIP registrar server function in the conventional VANET ad hoc mode. Therefore, the conventional VANET ad hoc mode does not have any registration time while SVID requires 1.17 seconds for SIP registration.

Figure 10 plots the overall throughput for 80 vehicles using the first traffic scenario. As expected, SVID achieves higher performance as the number of connections increases. In the proposed scheme, an AV must establish a connection before it sends a frame to the destination. An admitted connection acquires a transmission opportunity and resources from the MR-BS and SRV to transmit the frame. Therefore, packets of a connection can be sent to the destination smoothly without risk of collision or FLR. In this simulation, system throughput reaches 81 Mbps in 20–25 connections. Conversely, in the conventional VANET ad hoc mode, an AV must maintain the routing table periodically, and the frame is broadcast to the destination. Also, a frame waiting in the queue has a greater chance of facing the collision problem. Hence, the conventional VANET ad hoc mode achieves an average throughput of approximately 0.566 Mpbs only.

Figure 11 depicts the jitter delay for 80 vehicles without the vehicular mobility pattern. The solid line indicates the trendline of the conventional VANET ad hoc mode. Due to frame duration limitations, some frames are queued in the buffer and must wait for the next transmission opportunity when there are more than 15 connections. In our simulation, the best jitter delay of SVID is 0.02 second (i.e. 5 to 15). When the number of connections is increased to more than 15, the jitter delay gradually increases. The value of the SVID jitter delay can be approximated by $y = 0.44z + 0.79$, where $z = (x - 30)/7.9$, and x is the number of connections.

The conventional VANET ad hoc mode has a high jitter delay because of collision. In the best case, the conventional VANET ad hoc mode yields a jitter delay of approximately 0.45 second. However, most of jitters in a conventional VANET ad hoc mode are more than 1 second. The trendline of the conventional VANET ad hoc mode indicates that the conventional VANET ad hoc mode is very difficult to support real-time multimedia services. The value of the jitter delay for the conventional VANET ad hoc mode can be obtained by $y = 0.021x + 0.63$, where x is the number of connections.

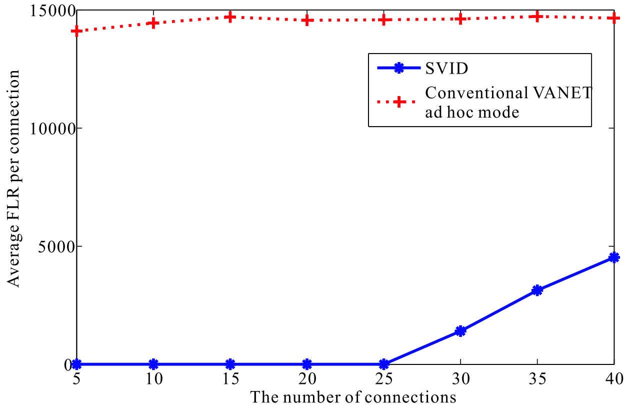


Fig. 12 Average FLR per connection for 80 vehicles without vehicular mobile pattern

Figure 12 plots the average number of FLR per connection for 80 vehicles without the vehicular mobility pattern. SVID provides less FLR than the conventional VANET ad hoc mode. First, when the number of connections is less than 25, due to the MR-BS and SRV are equipped with a big buffer and QoS mechanism for incoming frame, SVID supports zero FLR. However, when the number of connections is more than 25, FLR increases gradually. Generally, each connection perceives approximately 300 frame losses. Conversely, because each AV needs to process the collision

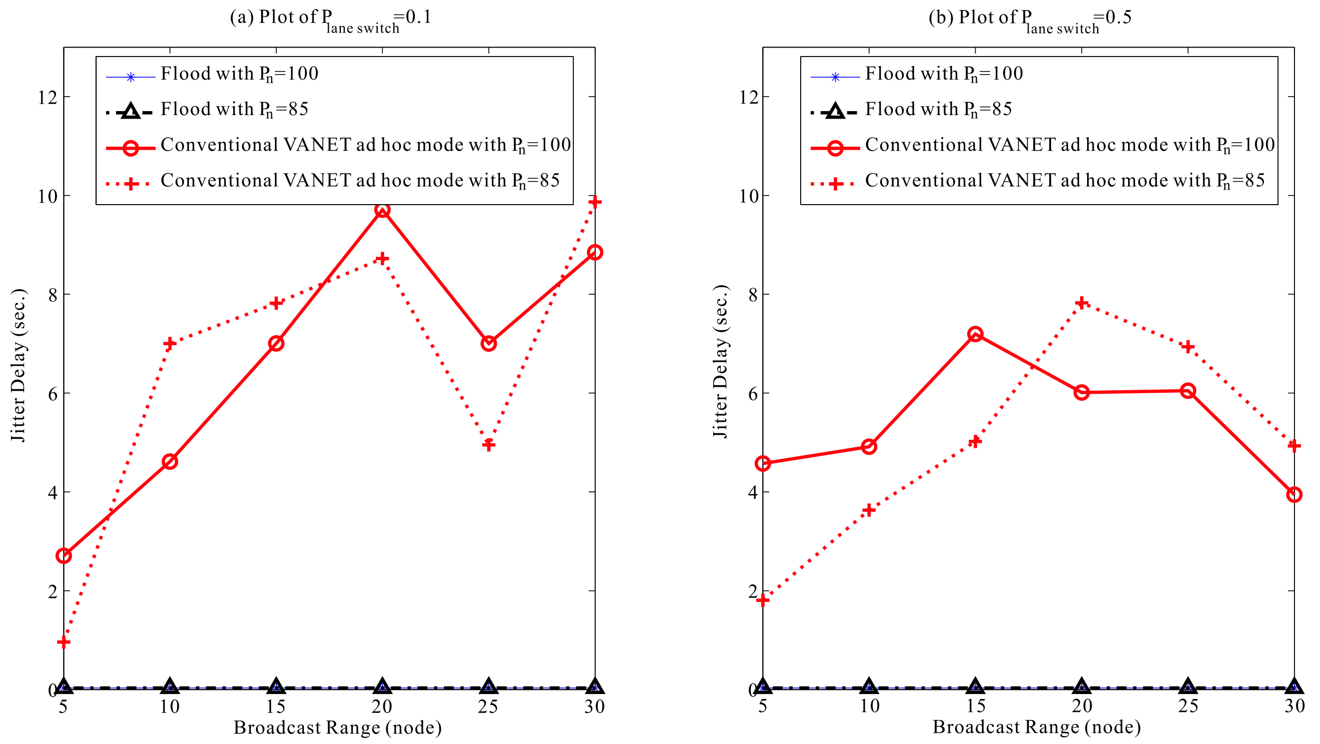


Fig. 13 Jitter delay using FLOOD method (**a**) $P_{laneswitch} = 0.1$ (**b**) $P_{laneswitch} = 0.5$

avoidance mechanism, and does not support the QoS guarantee, this mode suffers high FLR. However, the FLR of the conventional VANET ad hoc mode is almost a straight line, indicating that FLR in the conventional VANET ad hoc mode is independent of the number of connections.

4.4.2 Proposed FLOOD method performance

This paper proposes the SIP Flood mechanism to disseminate current traffic information to avoid traffic events. Unfortunately, the vehicular mobility pattern has a great effect upon the jitter delay, dropped and broadcast messages. This paper uses two parameters to simulate the vehicular mobility pattern: the first parameter is $P_{laneswitch}$ which denotes the probability of a vehicle switching lanes. The second parameter is P_n which is the percentage of normal vehicles. High $P_{laneswitch}$ or low P_n will result a high chance of forming a transmission hole [16] on a road. Figures 13(a) and (b) show the jitter delay of FLOOD when $P_{laneswitch} = 0.1$ and $P_{laneswitch} = 0.5$. The results of SVID in Fig. 13 can be obtained by the last receiver. In SVID, because both the MR-BS and SRV provide a high transmission range, an AV can simply transmit and receive a frame without knowledge of the network topology. Therefore, the jitter delay (Figs. 13(a) and (b)) in both cases is the same. In addition, when the disseminated scope (nodes) increases, the jitter delay does not change. Generally, SVID requires approximately 0.03 second to transmit the FLOOD message. Notably, the distance between the sender and last receiver may be more than 1.5 km, giving the driver enough time to react to the traffic event.

The conventional VANET ad hoc mode requires approximately 5–10 seconds to transmit a FLOOD message. Therefore, any vehicular mobile pattern can significantly affect the jitter delay of the conventional VANET ad hoc mode. This renders that conventional VANET is unsuitable for emergency traffic information transmission.

Figures 14(a) and (b) plot the number of dropped frames using FLOOD method in $P_{laneswitch} = 0.1$ and $P_{laneswitch} = 0.5$, respectively. The SIP FLOOD method is a high priority message, the MR-BS and SRV thus have to allocate bandwidth for the FLOOD message. Therefore, SVID does not yield any dropped frame. Conversely, similar to the jitter delay, the dropped frame of the conventional VANET ad hoc mode is affected by the vehicular mobility pattern. Therefore, the number of drooped frames of the conventional VANET ad hoc mode is relatively high.

Figures 15(a) and (b) plot the average number of broadcast frames using FLOOD method when $P_{laneswitch} = 0.1$ and $P_{laneswitch} = 0.5$. SVID uses one frame to broadcast the FLOOD message based on the WiMAX technique. However, the conventional VANET ad hoc mode produces more than 2000 broadcast frames to disseminate a SIP FLOOD message. Even in the best case ($P_{laneswitch} = 0.5$ and $P_n = 0.85$), the conventional VANET ad hoc mode also produces

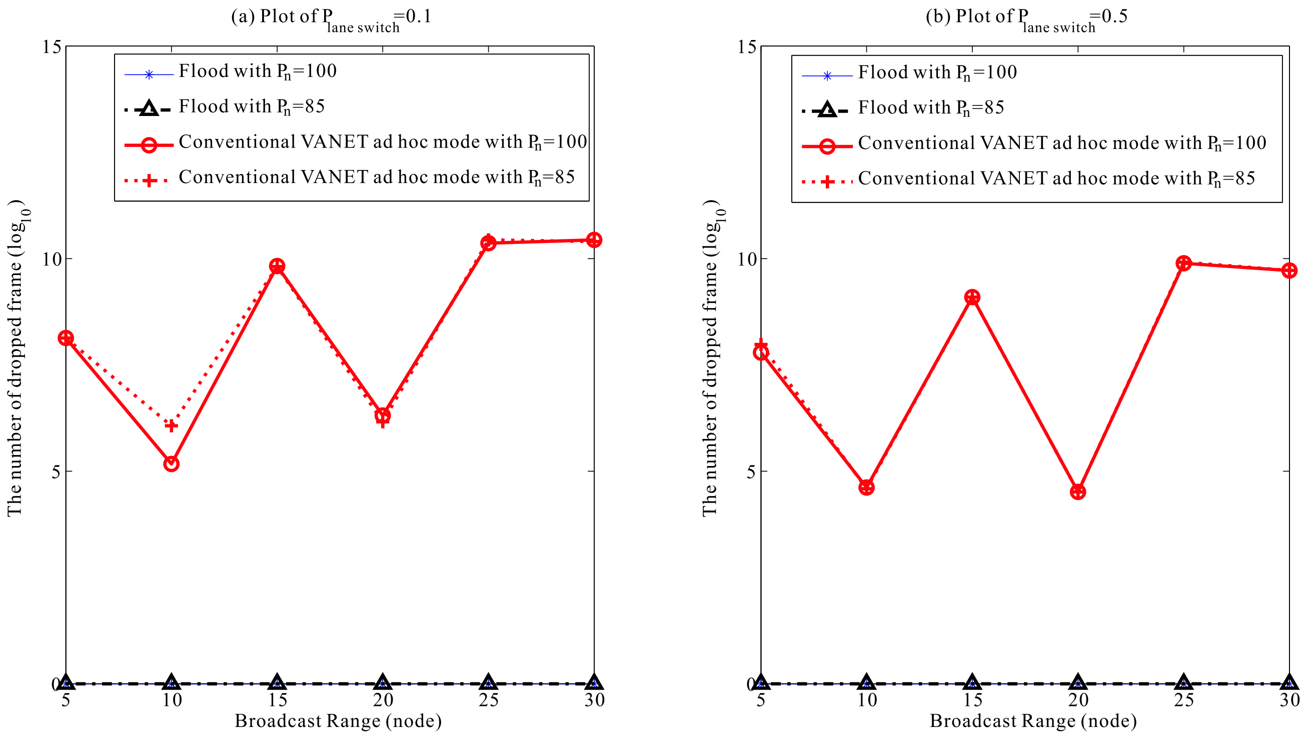


Fig. 14 The number of dropped frames using FLOOD method (**a**) $P_{laneswitch} = 0.1$ (**b**) $P_{laneswitch} = 0.5$

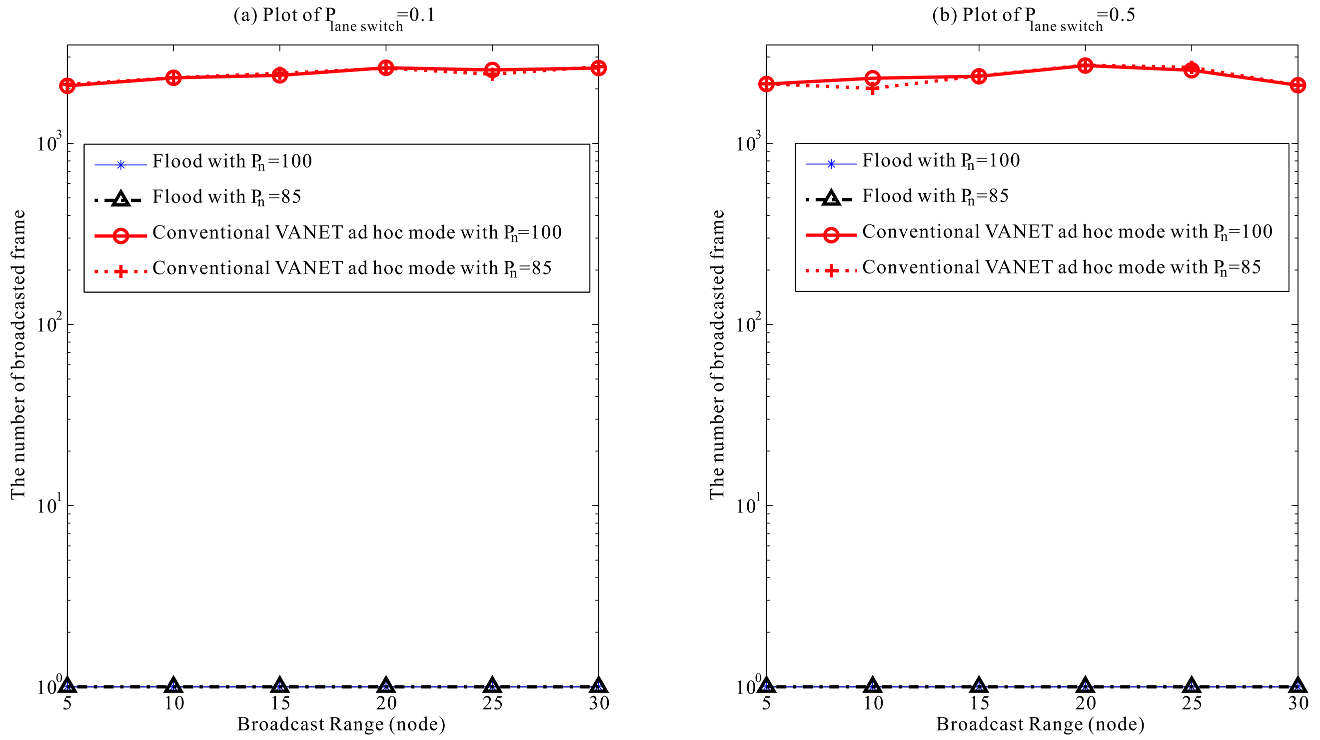


Fig. 15 The average number of broadcasted frames using FLOOD method (**a**) $P_{laneswitch} = 0.1$ (**b**) $P_{laneswitch} = 0.5$

more than 1000 broadcast frames which could result the broadcast storm problem. Therefore, the SVID can support higher resource utilization than the conventional VANET ad hoc mode.

5 Conclusion

This paper studies the problem of providing drivers with time-sensitive information services using safety information dissemination and active navigation information update mechanisms. With GPS and vehicular information, this study can help drivers to adjust their lanes or routes immediately to improve traffic safety.

This paper introduces a SIP-Based Safety/Vehicular Information Delivery (SVID) framework to support centralized, guaranteed transmission, and low transaction delay information dissemination over a Vehicular Ad hoc Network (VANET). This paper also describes the system architecture of SVID. The proposed approach modifies the original SIP REGISTER message to manage vehicular position, and proposes two new SIP methods, i.e., FLOOD and PULL/ADVISE, to provide traffic information. The FLOOD mechanism can disseminate traffic event information whenever a vehicle encounters a traffic accident. In addition, the PULL/ADVISE messages can provide fleet management for a specific group of vehicles. Thus, group members can update their navigation plans as necessary.

Performance evaluation of the proposed SVID scheme shows that SVID achieves better throughput than the conventional VANET ad hoc mode. SVID also achieves a faster SIP transaction time, lower loss of frame, and better jitter delay as compared to the conventional VANET ad hoc mode, even in a high broadcast scope environment. SVID also solves the broadcast storm problem. Therefore, SVID can disseminate traffic information more efficiently than the conventional VANET ad hoc mode.

Our future work will investigate the resource utilization problem in SVID. Base on vehicular mobility pattern and current handover policies, a SRV could be a hot spot whenever its signal to interference plus noise ratio (SINR) value is higher than other SRVs. However, the hot cell suffers from high frame loss rate and transmission delay. To address such problem, we will develop a novel handover policy to switch a connected AV from a hot SRV to other SRV.

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