Avoiding Discontinuity in VANET using a Content-Based Opprtunistic Routing

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Abstract: ***The goal of Vehicular Ad Hoc Network (VANET) is to contribute to safer and more efficient roads in the future by providing timely information to drivers and interested authorities. In the last few years, VANETs have been quite a hot research area and attract so much attention of both academia and industry, due to their particular characteristics, such as high dynamic topology and intermittent connectivity. In this context VANET have great challenges in terms of data exchange and routing in order to avoid the discontinuity. In this article, a proposal of a content-based communication approach is presented as a solution to bypass non predictable mobility and loss of connectivity.***

Keywords: VANET, publish-subscribe, MANET, opportunistic, routing

1. Discontinuity in VANET

VANET may exhibit a bipolar behavior, i.e., the network can either be fully connected or sparsely connected depending on the time of day.

VANET can be represented as a subset of ad-hoc mobile networks, which supports the communication of data inter-vehicles or between vehicles and fixed devices present on the edges of the road (eg traffic signs). This network is characterized by a high mobility of its nodes. Each node can have a different speed which generates a non-predictable topology which tends each time to a set of connected areas. This is depicted in the figure below. The result forms a large disconnected network of vehicles. Fragmented network will be constructed by implementing a set of routing techniques in accordance with the high volatility that characterizes this kind of network.

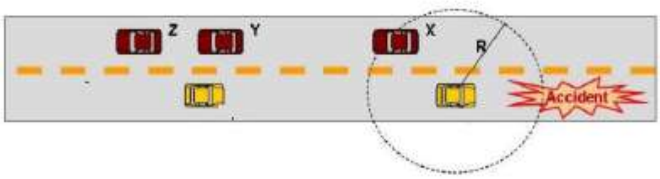

Figure 1: Example of disconnected networks of VANET

In this context, all proactive protocols (protocols where the routes are computed in advance regardless of current communications) are inapplicable because too many signaling messages are needed for the topology to be up to date. A more robust approach is the use of reactive routing protocols: path discovery is used only at the initiation of a communication.

The opportunistic protocols coincide with the discontinuous nature and the high volatility that characterize these networks since it will take advantage of its properties and the mobile nodes will play the role of message carrier.(4) In our work, we are interested in exploiting the communication solutions adopted by fragmented networks for use by vehicle networks independently of any other platform that characterizes VANETs at the application level, particularly road maps that make the routes deterministic.

2. Applications in VANET

The main purpose of VANET is to provide:

1) Prevention and road safety: VANETs can significantly improve road safety by alerting the driver to a dangerous situation. They also help to expand the vision of the driver's view, alerts in case of imminent violations or traffic lights, notification in case of emergency braking;
2) Traffic optimization: Car traffic can be greatly improved through the collection and sharing of data collected by vehicles.
3) Comfort of the passengers: the vehicular networks can also improve the comfort of the passengers.
4) Other Application: Outside of road safety and efficiency, the VANET can also support other applications such as internet access, parking, informative entertainment, traffic updates, etc. Yet security has remained the main focus of VANET research.

To make the vehicles communicate, we need a system that is easy to set up and viable outside. A special electronic device will be placed inside each vehicle, which will provide ad-hoc network connectivity for the passengers.

Each vehicle has a communication platform called OBU (On Board Unit). This platform is used by one or more applications called AUs (Applications Units). The access points along the roads and constituting the fixed infrastructure are called RSUs (Road-Side Units).

Vehicles equipped with OBUs will be nodes in the ad-hoc network and they will be able to receive and relay other messages in the wireless network.

The OBU comprises: (1) transmitter; (2) omnidirectional antenna; (3) Processor; (4) GPS device; (5) Digital maps; and (6) Sensors. VANET in publish subscribe context

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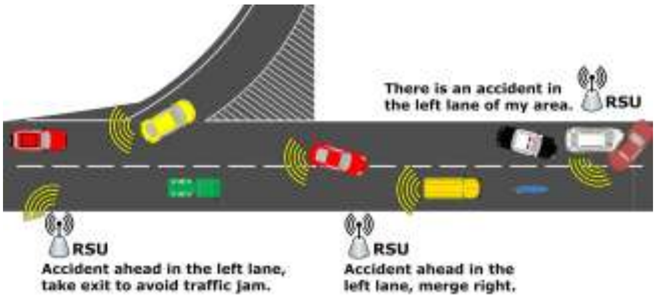
Data exchange in VANETs can help users to be informed about traffic conditions, to share multimedia content, to coordinate the movement of vehicles, etc.(5)

This exchange is carried out between the nodes of the network always keeping the total independence between the transmitter and the receiver of the information in an anonymous and decoupled mode. n this case the receivers are not addressed directly but they are indirectly addressed by the content of notifications. Each vehicle expresses its need by subscribing for specific information regardless of who produces it. Subsequently, it will be notified asynchronously of all the information that is already submitted by their producers which coincides with their need mentioned in the subscription. Thus each vehicle subscribing to a topic should not be blocked waiting for incoming notifications like the client / server model, but it can maintain the execution of concurrent operations.

All this will be done well only by the publish-subscribe communication model according to the DDS specification since this standard is well suited to the critical nature of the exchange which is generally aim to the safety of drivers in the road. The following figure gives an example of this application network where vehicles can communicate several types of information according to their subscriptions as well as the different events that occur.



Fgure 2: Information exchange according to V2V and V2I communication

3. Routing Solution in VANET

The nodes of VANET are generally dynamic and autonomous. This dynamicity usually causes loss of connectivity frequently.(6) The network appears mostly in the form of a non-connected graph consists of a set of islets of connectivity. Fragmentation of the mobile network increases with the dynamicity and the high mobility of its nodes. This is why the routing in these fragmented mobile networks must be based on the routing protocols that are dedicated for this kind of networks in accordance with the store, carry and forward principle. This allows an event to be carried by a mobile terminal from one island to another, and to be relayed later to other interested terminals.(7)

The difference between this routing technique adopted by conventional fragmented mobile networks and that to be adopted by fragmented mobile networks based on publish-subscribe is that in the first type, the target is a well-defined recipient and in the second type the target is a set of interested people .

We must then mix routing techniques in fragmented mobile networks with publish-subscribe communication.

4. Description of the Solution to Avoid Discontinuity

In our work, we designed a content-based solution capable to operate in highly fragmented mobile ad hoc networks, particularly exploited in inter-vehicular communication.

This will be achieved by using the publish-subscribe model according to the DDS standard by exploiting the opportunistic and epidemic communication model dedicated to DMANETs. (8)

This model relies on the cooperation of highly mobile nodes and is based on the general epidemic principle of gossiping. To do this, the majority of network elements will have a storage capacity to temporarily store messages in transit. Mobility allows nodes to physically transport messages hosted by a node of an area to another. We will then benefit from the Store, Carry and Forward technique that has already been described above. It consists in storing the message, transporting it by a mobile terminal acting as a carrier. It will relay it to another carrier or directly to the recipient. This exchange takes place opportunistically since no clear structure of the network nor any mobility is programmed.

This technique has the advantage that it does not require end-to-end connectivity between the sender and the receiver, hence its importance in the content-based communication but with an improvement so that it has to identify the receiver according to his interests.

The proposed model is structured in layers:
- The upper layer is interested in the possible application in our network which concerns for example information relating to road traffic (e.g. notification of slowdowns, presence of work areas or traffic jams, etc.).
- The underlying layer is based on communication using the publish-subscribe model to route information between publishers and stakeholders using the opportunistic approach. This layer has a local cache that stores messages during the move in the network and before publishing.(9) It is this layer that allows the exchange between nodes according to their interests using the technique Store, Carry and Forward.
- The underlying layer is actually a DDS - Data Distribution Service API. It is the one that ensures the real communication between the nodes of the network.
- The lower layer: provides communication within the same islet of connectivity which is temporary. This interaction between neighbors requires transmissions to one or more hopes. This is ensured by approved routing protocols such as OLSR.

This solution is dedicated for any network characterized by high mobility on a large scale with short life of connectivity islets.

This is the case of VANETs with these two V2V and V2I communication modes.

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The different layers are depicted in the figure below.

Application: Information exchange of road traffic
Publish-subscribe model + local cache
DDS API
opportunistic routing
Real Time OS

Fgure 3: layer structuring of the node

5. Store carry and forwardalgorithm using publish-subscribe

1) Principle

The solution is intended to provide communication between information transmitters and subscribers in disconnected network of vehicles.

The solution model will use the "store carry and forward" protocol to route messages and the DDS middleware to publish them to interested vehicles. So it's a combination of the opportunistic routing protocol with the DDS API. Multi-hop routing occurs when the node (vehicle) is in the same block. In addition to its role of storage, routing and dissemination of information, each terminal must be able to filter this information by distinguishing between its different types and must also subscribe to information of interest.

2) Structure of the message

The message exchange between publishers, carriers and subscribers can be represented by a structure that consists of these fields:

Code: It can be an integer value, it is unique and it will appoint a well-defined type of information. This is especially useful when storing the message in the cache .Indeed it prevents terminal to get multiple copies of the same message.

Service: it refers to how the service belongs to the current topic.

Info : information about the current message (eg . the number of the vehicle, the identifier of the publisher or the identifier of the road side unit).

Expiration_date: that is the duration of the importance of the information exchanged. This date is set by the application service side of the editor.

Content: represents the actual information corresponding to the code mentioned in the first field.

Example:

The structure of a message m1:

code	service	info	content
10	info.road	producer : 156TUNIS456 expiration_date: 2012-06-07/10:12:24	1km:TUNIS-BEJA

3) Susbscription according to DDS

This operation consists in filling the list of topics to which the terminal is interested. Thus the terminal must define expressions for filtering the exchanged messages.

This allows you to consume the messages that interest you later and also to know the messages that must be sent in case of the use of selfish behavior.

Filtering expressions consist of conjunctions and disjunctions of a set of atomic expressions acting on the attributes of the message structure mentioned above.

Depending on the nature of the attribute, it is desirable to be able to use different comparators.

So if Ei is the expression corresponding to a topic
Ei = e1 op e2 ... op en: op is an operator of conjunction or disjunction.

ei is an expression acting on the attributes of the message. So the list of interest of a given terminal x is a conjunction or disjunction of a set of expressions Ei.

Ix= E1 op E2 …. Ek-1op Ek
Example : E1=e1 ou e2=(service = «info.route») or (info.editor= «156TUNIS456»)

4) The principle of the algorithm

```
Process : opp-pub-sub()
{i : number of the node
inti : interest of i
ci : description of the cache of i
Thread_Reception() ;
// thread blocked waiting for a message of
//discover from other terminals
Thread_Emission() ; // thread to broadcast
a message of Neighbor Discovery
```

```
Thread_Emission(i)
{while (1)
{wait(Δt) //Δt : the period of time between
//two broadcasts
discover_diff(annonce(ref, inti, ci))
}}
// ref: denotes the reference of the ad
```

```
Thread_Reception(i)
//i is the identifier of the current node
{ while (1)
{listen()
if (arrivage(annonce(ref, intk,ck)))
compare (ck,inti,M) //with M is the set of
messages of ck
//witch correspond to inti. It is the
intersection between ck and inti.
MAJ(table_proximity) //update the table of
proximity
demand(M)
}}
```


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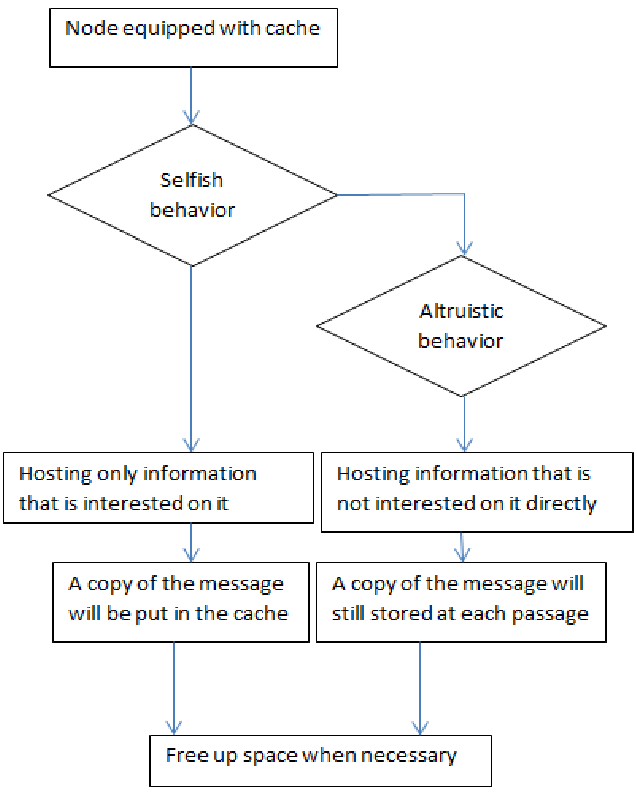
```
MAJ(annonce, table_proximity)
{
if (annonce.sender belongs to {table_proximity[i][identity]})
// the current node receives an announcement from the same transmitter
        {if(annonce.ref != table_proximity[i][annonce.sender][ref])
        modify_entry(table_proximity[i][annonce.sender])}
 //modify the table row neighborhood witch the identity of the neighbor
// is the issuer of the announcement; to update the value of the last
//announcement received.
else
        insert_entry(table_proximity[i][annonce.sender])}
// This instruction allows to insert a new line by filling its various fields from
//the content of the announcement received (identity of the sender,
// the reference of the announcement and the set of requests is empty).
}
```

5) Using of caching in the solution

Our model of communication requires that a terminal is capable of hosting messages in transit in a persistent storage space and limited in where transported messages will be stored.

The action of message storage in the cache always depends on the type of node behavior that keeps. Indeed, if this is selfish behavior (the terminal hosts in its cache only the information that he is interested on it), a copy of the message will be put in the cache if it matches the profile of current interest.

If it is an altruistic behavior (the terminal can host in its cache information that does not interested in directly), a copy of the message will still stored at each passage. To manage this limited space, a cache manager maintains a policy of management to free up space when necessary.



Fgure 4: Behavior of the node and using og the cache

To facilitate cache management (add, search, sort ...), it must be organized in two parts.

The first part is reserved for control information (code, service, info, date_expiration). The second part is reserved for data.

This will, on one hand, reduce processing messages stored, and secondly, minimize the cost in terms of resource use. Indeed, when you restart a terminal, the cache manager does recharge memory control information that is very inferior in size to that of the data.

The payload of a message is loaded into memory only when the message must be delivered to a local service or needs to be broadcast on the radio medium.

The Persistent of the cache must be ensured to avoid frequent losses of connections which result primarily from excessive volatility of nodes due to the nature of network application.

6. Conclusion

Our proposal consists of applying publish/subscribe communication framework for efficient information dissemination among disconnected VANETs. In order to avoid discontinuity in this kind of network, we combined the opportunistic routing with a content-based communication using DDS middleware. This can be a stimulus for discussion, and can be a starting point for further deepening in communication techniques in content-based mobile environments and further varying the scope of application.

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