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Proposal of Commutation Protocol in Hybrid Sensors and Vehicular Networks for Intelligent Transport Systems

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***Abstract*—**Hybrid Sensors and Vehicular Networks (HSVN), represent a hybrid network, which uses several generations of Ad-Hoc networks. It is used especially in Intelligent Transport Systems (ITS). The HSVN allows making collaboration between the Wireless Sensors Network (WSN) deployed on the border of the road and the Vehicular Network (VANET). This collaboration is defined by messages exchanged between the two networks for the purpose to inform the drivers about the state of the road, provide road safety information and more information about traffic on the road. Moreover, this collaboration created by HSVN, also allows the use of a network and the advantage of improving another network. For example, the dissemination of information between the sensors quickly decreases its energy, and therefore, we can use vehicles that do not have energy constraint to disseminate the information between sensors. On the other hand, to solve the disconnection problem in VANET, the sensors can be used as gateways that allow sending the messages received by one vehicle to another. However, because of the short communication range of the sensor and its low capacity of storage and processing of data, it is difficult to ensure the exchange of road messages between it and the vehicle, which can be moving at high speed at the time of exchange. This represents the time where the vehicle is in communication range with the sensor. This work is the proposition of a communication protocol between the sensors and the vehicle used in HSVN. The latter has as the purpose to ensure the exchange of road messages in the available time of exchange.

***Keywords*—**HSVN, ITS, VANET, WSN.

I. Introduction

TRANSPORT in all its forms is important not only to individual's everyday lives, but also to the overall economy of a country. Recently, the means of transport have been evaluated in an exponentially way. This evaluation has as the advantage of ensuring rapid movement for travelers crossing long distances while providing comfort service during the travel. However, on the other hand, this evaluation has also allowed for an increase human and material damage [1], mostly in these recent years. The actualization of a system allows the management and the organization of transport in an intelligent way becomes a necessity.

The ITS [1] is a government-led project deployed in several countries, with the main purpose being improvement in road safety. ITS uses several technologies working together to achieve its goals. The WSN represents a dominant technology used in this system. This latter technology can contribute, because of their properties (sensation, wireless communication, low cost, small size, intelligent, and easy to install and to repair), to the improvement of these systems. However, because of the limitations (low energy, limited processing of sensor, weak storage capacity, and short range of detection and of communication of sensors) of WSN and for the improvement its role into ITS, a network generation, known as the HSVN [2]–[7] has been created. HSVN combines WSN and vehicle ad–hoc network (VANET) working together, for the exchange of road messages. This collaboration created by HSVN, allows taking advantage of one network for improving another network. For example, the dissemination of information between the sensors quickly decreases its energy, and therefore, one solution is to use the vehicles, which do not have the constraint of energy, to disseminate the information between sensors. On the other hand, to solve the disconnection problem in VANET, the sensors can be used as gateways that allow sending the messages received by one vehicle to another. There are three types of communication protocols in HSVN. First, the communication protocols inside a WSN. The purpose of these protocols is to ensure maximum coverage of events taking place on the roads all respecting the constraints of these types of networks. Second, the communication protocols inside a VANET; the purpose of these protocols is the sharing and dissemination of road data between vehicles all respecting the constraints of this type of network. Finally, the communication protocols between a WSN and a VANET. The purpose of these protocols is to ensure the exchange of road messages between the two networks. For this last type, the creation of a reliable communication protocol, poses several problems. These are linked to the problems of each network or linked to the communication performed between the two networks. However, the main problems in the communication between the two networks is related to the nature of the information sent to the vehicle (useful or critical), the short communication range of the sensor, and the different standards used by the two networks, as the sensors are deployed in a static way and vehicles are in a state of displacement at the time.

This work aims to solve these problems, while ensuring a balance between the metrics of the two networks. The results of this work are represented by the proposition of a communication protocol called MEP-HSVN (Message

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Exchange Protocol in HSVN). This protocol uses concepts, models, algorithms, and proposals to ensure the exchange of road messages between the sensor and the vehicle in the available time of exchange. This time represents the time of connection between the two when the vehicle is inside the communication range of the sensor.

This paper is organized as follows: In Section II, we present the related work used to perform communication protocols between WSN and VANET. Then in Section III, we give the basic aspects used by our protocol and explain the method of work of our protocol. In Section IV, we present the simulation results, while the conclusion is presented in Section V.

II. Related Works

A. Approaches Used

To realize a communication protocol between a WSN and a VANET in HSVN, there are two approaches. The first approach [3]–[5] is based on a passive detection made by a sensor to communicate with a vehicle. The communication between the two networks is realized in two phases. The first phase is used to initialize the communication between the two, when the vehicle is inside the communication range of the sensor (Rs), while the second phase is used for the exchange of road messages, which is started after the first phase. Concerning the second approach [6], [7], it is based on an active detection; as the vehicle periodically broadcasts beacon messages, which can be used like a vehicle arrival notification when received by a sensor. In this way, there is no connection initiation phase, as the exchange of road messages between the two entities occurs when the vehicle is in communication range.

1. Points Targeted by the Researchers

The researchers working on the two approaches have tried to find a maximum balance between the metrics of these protocols. The most important metrics are the exchange time, the sensor's energy consumption and the priority of road messages. First, the exchange time is critical because the sensor has a short communication range and vehicles are moving at variable speeds (S) (the strong mobility). Second, the low energy of the sensor is a problem in communication, because the high number of events detected and messages received by a sensor (especially this latter has a capacity limited of storage and processing) and the exchange of messages in a communication, resulting in rapid energy consumption of the sensor. The order of arrival of messages according to their importance (the critical messages must be received ahead of basic messages) is an important metric, in order to avoid the direct causes leading to road accidents.

2. The First Approach

Concerning the first approach, the common points between the propositions are, the first phase is used to initialize the connection between the two networks. In this phase, the sensor-gateway sends a connection request to the vehicle. The vehicle responds with an acknowledgment containing the identifier and the coordinates of its destination. The second phase is started when the sensor detects the vehicle after a detection time (D_{time}). This phase is used for the exchange of road messages; in the first place, after the sensor-gateway prepares the messages into a processing time (P_{time}), it sends messages to the vehicle. After, the latter sends return, messages to the sensor-gateway; (1) defines the available time (Atime) in seconds to make the exchange of road messages. The researchers have worked on increasing this time, respecting all the constraints of these protocols.

$$A_{time} = ((2 \times Rs) / S) - (D_{time} + P_{time}) \quad (1)$$

The researchers have worked on the reducing the quantity of information exchanged between the two networks with the proposition of a simple coding model for the road messages. This model has the purpose of reducing of processing time. The benefits of the researched works can be summarized in the following points: In [3], a road segmentation model has been proposed, which allows decomposing a road into a set of segments numbered for ease in the localization of vehicles and road occurrences. Reference [4] adds to this concept a data model for encoding the information on a road segment in a few numbers of bytes. The segmentation model and the data model, allow also for a reduction of the quantity of information stored in the sensor database. Moreover, a cluster approach [4] is used in the two networks, respectively, for the economy of the energy consumption of the sensors and the elimination of unnecessary treatment. In [5], the researchers have thought of the use a distributed approach in WSN. This approach allows for reducing of the quantity of information stored in the sensor database and avoiding the complex treatment. However, the two-phase connection approach has a major disadvantage on the exchange time of road messages between the two networks. The use of the first phase for initializing the connection between the sensor and the vehicle, takes an additional time (T_{init}) of the available time of exchange (2) despite the exchange time, it is the most important metric in this type of protocol.

$$Atime = (1) - Tinit \quad (2)$$

3. The Second Approach

To avoid the disadvantage of the two-phase approach, the second approach has been proposed. It uses the beacon message like a carrier of vehicle information. When the sensor receives this message, it prepares the messages that will be sent to the vehicle. Upon the detection of the vehicle by the sensor, it sends the messages. By using this concept, they have avoided the initialization phase of connection. The researchers have used the beacon messages, for the following reasons: First, the transmission range of the vehicle is larger than that of the sensor, so theoretically, the sensor receives the beacon message before the vehicle is in communication range. Second, the beacon messages are broadcast periodically at short intervals, this propriety allows increasing the probability of its receipt by the sensors. In this approach, the researchers have worked on reducing the processing time of road messages. For example in [6], the beacon messages are used as carriers of vehicle information and of other useful information sent to the sensor. The advantage of this proposition is that when the sensor detects the vehicle, the exchange of information will be only in one direction (sensor to vehicle), as the sensor has already received the information carried by the vehicle. To avoid overload (road data sent by the vehicle to the sensor) to the beacon message, others researchers have thought to add some data to this message. These data include, for example, the identifier of the vehicle, the coordinates of its destination, and its current speed. We find this concept in [7], which is based on the concept of group (both networks, respectively, are divided into groups). It also proposes a message model that allows for distinguishing between a critical message and a standard message. The advantage of this solution is the message model and the use of another vehicle to retrieve critical messages. However, the approach using beacon messages has a major disadvantage on the exchange time of messages between the two networks in the case of strong collision or interference. With these problems, it is possible that the message beacon broadcast by the vehicle will not be received by the sensor or will be received after an important delay. In this situation, the protocols using this approach can have problems in their operating.

B. Discussion on the Approaches

In the previous sub-section, we have presented the approaches used to realize a communication protocol between WSN and VANET in a hybrid network (HSVN). Each approach has advantages and disadvantages, and each solution proposed has the purpose of exchanging road messages between the two networks in the available time. However, the existing solutions do not answer the entire needs of these protocols. This study identified some of the negative points of these solutions. The most important point shared between all solutions [3]–[7], is the absence of a clear strategy used by the sensor. This strategy has as role, the definition of a policy allowing the management of road messages according their types (useful or critical). In addition, the use of a group approach [4], [7] has advantages concerning the energy consumption of the sensors. But the fact that only the two group's leaders of the both networks communicate between them, there is a probability that important road data will not arrive at other vehicles in a reasonable time, (especially in the case of a low density of vehicles). The distribution of information [5] on the sensors eliminates the complexity of approaches, but it poses the issue of additional time required to respond to a request from a vehicle. The segmentation model and the data model [3], [4] are an interesting option for reducing the amount of information exchanged between the two networks, but we can improve these models through algorithms and concepts to reduce the quantity of information stored and exchanged. A direct result of this improvement is the reduction of the amount of energy consumed by the sensors.

C. Our Proposition

In the next section, we present our communication protocol called MEP-HSVN, which can ensure the exchange of messages between the sensor and the vehicle in the available time. This protocol works according to the strategy proposed to eliminate the disadvantages presented in the previous sub-sections.

III. MEP-HSVN Protocol

A. Basic Aspects of the MEP-HSVN Protocol

1. Concepts

Architecture: We have chosen a heterogeneous architecture because it combines multiple wireless technologies to facilitate the development of more efficient applications. Each wireless technology offers advantages and disadvantages. A heterogeneous architecture focuses on the benefits of a particular technology to offset the disadvantages of another technology used in the final system.

Topology: For WSN, we have chosen a cluster linear topology, where the nodes are clustered in groups (group members represent sensors of detection and of routing); the groups' leaders are the most powerful and represent the sensor-gateways. With this arrangement, it becomes possible for the tasks, which request hardware that is more powerful or energy consuming, to be accomplished by a small sub-set of nodes (sensors-gateways) with additional features, and allows for reduced costs and prolongs the lifetime of the network. For VANET, we have divided the vehicles into clusters (cluster topology).

As the HSVN uses different wireless technologies, the vehicular network requires device -gateways equipped by two wireless interfaces in order to enable the interconnection between the two networks (for example, IEEE802.15.4 and IEEE802.11p). These devices are more expensive and consume more energy. This has motivated us to use the energy saving procedures through the implementation of sensors groups and vehicle groups. On the road, the deployment of a WSN assigns the functionality of a gateway to group leaders; which allows for reducing energy consumption and costs in the rest of the group members. Similarly, the organization of vehicles into groups also saves energy, since gateways are sufficient to communicate with the leader of each group, which can then disseminate the information to the other vehicles.

MAC protocol: We have chosen the IEEE802.15.4 protocol. This high-level protocol allows for small radio communication with reduced energy consumption. It is used for personal dimension networks and is a technology with the purpose to conduct communication over a short distance, like Bluetooth, but in an easier and less expensive way. Its operating range is relatively weak and the protocol is relatively slow; however, it has the two main advantages of low energy consumption and high reliability. The current proposals for research in the field of communications in the vehicular networks are based on the fact that V2V (vehicle to vehicle) uses the IEEE802.11p standard and V2I (vehicle to infrastructure) uses the IEEE802.15.4 standard.

2. Models

Segmentation model: We have decomposed a geographical region to an aggregate of areas. Each area contains a number of segments (Num_{seg}). We decompose the geographic region compared to the number of the roads that are in this geographic region. The decomposition of the area to the segments is relative to the nature of each road in this area. The numbers of areas and segments are a multiple of 2. Thus, 2^{Ac} areas and 2^{Sc} segments, respectively, where A_c is the area code and S_c is the segment code. The localization of an event or a vehicle is given by $A_c.S_c$.

Data model: For each segment, we have used 4 bits to encode several road messages (sixteen events) produced on it and the date size of each event ($S_{evedate}$) detected on this segment. The total size of the data of an area (S_{area}) in bits is given by (3):

$$Sarea = Ac + (Numseg \times (Sc + 4 + Sevedate)) \quad (3)$$

Message model: To ensure delivery of critical messages to vehicles, a message model has been proposed, which allows the sensor or the vehicle to understand the difference between a standard message and a critical message. Fig. 1 shows the method used to develop this model.

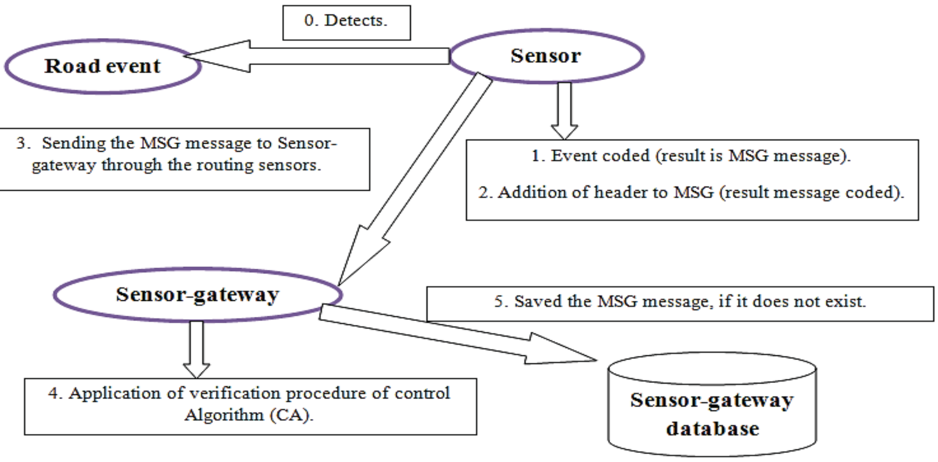

Fig. 1 Message model

The sensor-gateway alone decides if a message is critical or useful using a verification procedure based on fields added to the message header. This header contains the following fields: an identifier of the detection sensor, the message type (0: useful, 1: critical), the sequence number represents the number of hops (the number increases to 1 when the message passes by a sensor), and the capture date which represents the date of the event on the road.

3. Algorithms

We have proposed two algorithms. The first is called the Data Filtering Algorithm (DFA). Fig. 2 shows part of a pseudo-code of this algorithm, which is used in the case of useful messages. This allows the sensor-gateway to save only new data sent from the vehicle. Moreover, it allows to the vehicle to receive only road data related to the direction the vehicle is traveling and its destination. This is called the Control Algorithm (CA), and it uses two procedures. The first procedure is used to verify the message received by the sensor-gateway, this will help to avoid message repetition (Fig. 3). Moreover, it allows also to the sensor-gateway to decide if the message received is critical or useful. The second procedure is used to sort critical messages according their degree of importance. Here, the communication time (C_{time}) in seconds, given by (4), between the sensor and the vehicle in our case is defined by the following times: execution times of DFA (DFA_{time}) and of CA (CA_{time}), receiving time of messages (R_{time}), and sending time of messages (S_{time}).

$$Ctime = DFAtime + CAtime + Rtime + Stime \quad (4)$$

```
Message: MSG = empty;   SDB: The Sensor-Gateway database;
Areas I: areas those are stored in Data Bases of the vehicle and / or Sensor-Gateway.
Areas j: Areas that are saved only in Sensor-Gateway database
BEGIN
Receive (MSG1)    // Source the vehicle V.
// MSG1: contains the coordinates of the destination and identifier of the vehicle V.
Receive (MSG2)    // Source the vehicle V.
// MSG2: contains information about the areas visited by the vehicle.
While (Not-End-MSG (MSG2) = false) do
Begin
If (Exist (Area-Code I) = false) then
Insert-New-INFO (information area I, SDB); // Information does not exist in DBS
Else
While (Area-Code= Area-Code I) Do // for each segment of the area.
Begin
Update (area I, SDB); //Recent information provided by the vehicle or conversely
MSG = ADD (Information, Area-Code I);
End
I = the next area;
End
Analyze-content (MSG1);
While (area J remained in the coordinates of vehicle V) Do
Begin
Insert (MSG, Information area J);
```

Fig. 2 A part of the pseudo-code of the Data Filtering Algorithm (DFA)

```
I.  Verification procedure
 Message: MSG = header + content; CT:  critical messages table;   integer I = 1;
UT: Useful messages table;
Integer  CMSG;                              // number of critical messages in the table CT.
1.  BEGIN
2.  Receive (MSG);                                  // Source detector sensor or routing
    sensor.
3.  Analyze (MSG)                                   // Set if the message is critical or not.
4.  If (type-message (MSG) = 1) then
5.  Begin
6.  While (I < CMSG) Do
7.  Begin
8.  If (IDF-Sensor [I] = IDF-Sensor (MSG) and Date [I] = Date (MSG)) then
9.  Go to Etiquette;
10. I ++;
11. End
12. Save (CT, MSG);     Go to END;
13. Etiquette:   Remove (MSG);                      // MSG message is already there.
14. End
15. Else
16. Save (UT, MSG);
17. END
```

Fig. 3 Verification procedure of CA

B. The Work Method of the MEP-HSVN Protocol

The group leader of vehicles when is entry to a new area, it broadcasts a beacon message modified (BM) (Fig. 4) and a V-MSG message (Fig. 5) containing the information of the areas visited recently by the vehicle. Upon the reception of these messages by the sensor-gateway, it applies CA algorithm and DFA algorithm. When the sensor detects the group leader, it sends it critical messages (CM) (if they exist) in the order obtained by the application of the CA algorithm. After, it sends it the useful messages (UM). Each time the vehicle receives a message from the sensor-gateway, it sends an acknowledgment (ACK). When, the sensor-gateway sends an M message to the vehicle, it is saved for a period P-MSGM in its database.

Identifier of vehicle	Group leader (0/1)
The destination coordinates of the vehicle AreaCode.SegmentCode	
Default content of beacon message	

Fig. 4 Format of beacon message modified

Area (A) Code	*Segment (1) Code*	*Segment (1) information*
	Segment (2) Code	*Segment (2) information*
	Segment (3) Code	*Segment (3) information*
	⋮	⋮
	Segment (n) Code	*Segment (n) information*

Fig. 5 Example of format of the V-MSG message

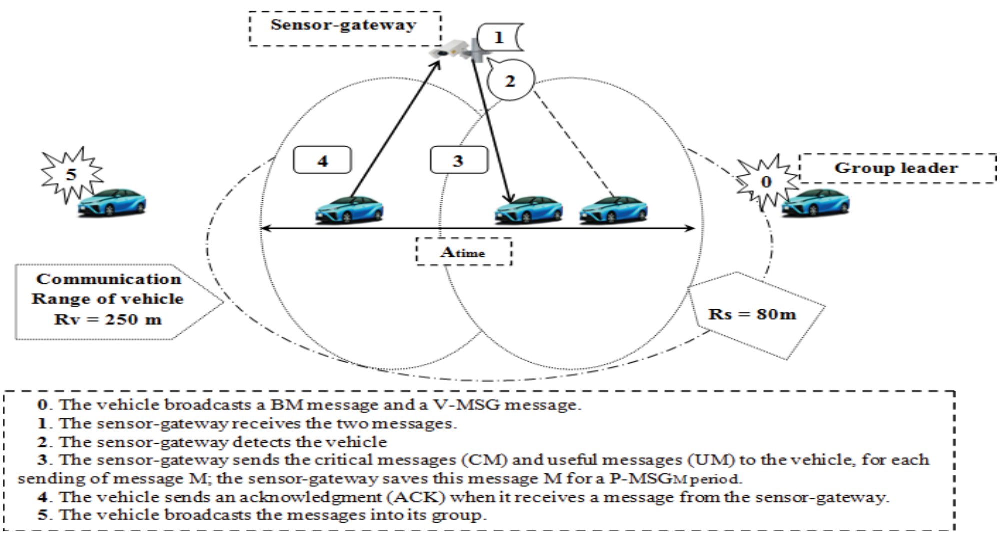

Fig. 6 The exchange of messages between the sensor-gateway and the group leader of vehicles

Fig. 6 summarizes the different operations of exchange between the sensor-gateway and the group leader of vehicles. As the exchange time is the most important metric in this type of protocol, it is necessary to examine the exchange time. The time available to make the exchange is given by (1). To increase this time, it is necessary to increase the communication range of the sensor (Rs) or decrease the vehicle speed (S), the detection time (Dtime) or, the processing time (Ptime). Rs and Dtime are linked to the equipment used in the sensor, and therefore, we have not addressed it. The vehicle speed S, is variable and changes according to the environment, and therefore cannot be limited, thus, we have worked on reducing the Ptime by the use of the second approach and the aspects (section A) of our protocol.

From (4), we can see that the processing time (Ptime) is the execution times of the DFA algorithm and the CA algorithm. If we use the first approach, there is no way to allow giving the sensor-gateway additional time to execute the two algorithms, as the sensor-gateway cannot process messages except when it detects a vehicle. In other hand, if we use the second approach, we can give more time to the sensor-gateway. This time represents the detection time (Dtime) less than the reception time (Rtime) of messages, and proves that the second approach gives more time to the sensor-gateway for the processing of messages than the first approach. Moreover, in our solution, this processing time can only be the execution time of the DFA algorithm because the sensor-gateway can receive the critical messages from the sensors before the arrival of vehicle. This allows to sensor-gateway to execute the CA algorithm before it communicates with the vehicle.

In the next sub-section, the theoretical estimation of the exchange time compared to the variable speeds of the vehicle shows the importance of the concepts used by this protocol.

C.Theoretical Estimation of the Exchange Time

We estimate the exchange time compared to the following example:

We suppose that:

- The geographical region contains 128 roads.
- The decomposition of this region is given in Table I.
- The Theoretical debit is equal to 200 Kbps (by the use of IEEE802.15.4 MAC protocol).
- The group leader of vehicles (GL) has information about areas 1, 2, and 3. It will go to the area 3.
- Areas 4, 5, and 6 are in the direction the vehicle is heading to reach its destination.
- We have for example two sensors-gateways (SG) for each area (Table II).
- The databases of sensor-gateways can contain a maximum amount the information in the three different areas.

The quantities of information exchanged are represented by the areas of information exchanged between the sensor-gateways and the vehicle as it moves towards its destination, while Table III provides the information of areas exchanged between the sensor-gateways and the vehicle.

In the case study scenario used in this research, the vehicle is located area 4, which is an area with a higher quantity of information than other areas. The quantities of information exchanged between the sensor-gateway (SG) of this area and the vehicle (GL) are calculated in Table IV. Here, all types of messages exchanged are considered.

TABLE I
DECOMPOSITION OF GEOGRAPHICAL REGION

Geographical region	Area	Number of roads of area	Number of segments by area
128 Roads	1	16 Roads	32
	2		64
	3		128
	4		192
	5		32
	6		64
	7		64
	8		32

TABLE II
SENSORS-GATEWAYS DISTRIBUTION

Areas	Identifier of SG	Areas controlled by SG
1	SG1, SG2	[1,2], [1,2]
2	SG3, SG4	[1,2,3], [1,2,3]
3	SG5, SG6	[2,3,4], [2,3,4]
4	SG7, SG8	[3,4,5], [3,4,5]
5	SG9, SG10	[4,5,6], [4,5,6]
6	SG11, SG12	[5,6,7], [5,6,7]
7	SG13, SG14	[6,7,8], [6,7,8]
8	SG15, SG16	[6,7,8], [6,7,8]

TABLE III
THE AREAS CROSSED BY THE VEHICLE TO REACH ITS DESTINATION

Areas	ID- SG	Information sent to SG	Information sent to GL
3	SG i3	Areas 2 and 3	Areas 3 and 4
4	SG i4	Areas 3 and 4	Areas 4 and 5
5	SG i5	Areas 4 and 5	Areas 5 and 6
6	SG i6	Areas 5 and 6	Area 6

Table IV shows the total of quantities Qt of information exchanged between the sensor-gateway and the vehicle is 3,579 bytes. The required time (REQ_{time}) is 0.017 seconds, which is calculated by (5):

$$REQtime = Qt / Debit \quad (5)$$

Table V shows the available times compared to the different speeds of the vehicle. It is worth noting that the required time to exchange all messages is very small compared to the available time in all scenarios. The sensor has an enough time for the detection of the vehicle and for the processing of messages (for example, for a vehicle speed equal to 100 Km/h, the sensor has 5.7 seconds). Moreover, the proposed solution, can reduce the total quantities Qt and ensure the priority of critical messages compared to useful messages.

TABLE IV
TOTAL QUANTITY OF INFORMATION EXCHANGED BETWEEN THE SENSOR-GATEWAY AND THE GROUP LEADER OF VEHICLES

S → D	message	Size	Quantity (bytes)
GL → SG	BM	Size (IDF, Coordination, Content-default)	29
	VMSG	Areas 3 et 4	2080
	ACK	Acknowledgment	14
SG → GL	MSG CM	Areas 4 et 5	1456
Data total			3579

The reduction of the information exchanged is conducted through the application of the DFA algorithm, which allows the sensor to save only new information that has not already been saved in its database. Similarly, the sensor-gateway sends only information about areas that are along the of the vehicle's destination. The priority of critical messages is ensured by the application of the CA algorithm, which allows the sensor-gateway to send, as a priority, critical messages sorted by their degree of importance, to the vehicle before sending useful messages.

TABLE V
AVAILABLE TIME AND REQUIRE TIME COMPARED TO THE VARIABLE SPEED OF THE GROUP LEADER OF VEHICLES

Speed (Km/h)	Environment	Atime - (Dtime+Ptime) (s)	REQtime (s)
60	Town	9.6	
100	Rural road	5.7	0.018
130	High-way	4.43	

The segmentation model and the data model also allow the sensor-gateways to save limited quantities of information in its databases, as shown in Table VI.

TABLE VI
MAXIMUM SIZES OF DATABASES OF SENSORS-GATEWAYS

IDF of SG by area	Maximal Quantity stoked (Kilo-Bytes)	Areas controlled by SG
SG a1	0,82	[1,2]
SG a2	1,46	[1,2,3]
SG a3	2,5	[2,3,4]
SG a4	2,29	[3,4,5]
SG a5	1,87	[4,5,6]
SG a6	1,04	[5,6,7]
SG a7	1,04	[6,7,8]
SG a8	1,04	[6,7,8]

D.Solutions Used by MEP-HSVN Protocol

In the previous section, the results show how the proposed protocol ensures the exchange of critical messages and useful messages in the available time, while also ensuring the priority of critical messages. However, in a real-life environment, we have the problems of collision and interference, especially in vehicular networks, which will lengthen arrival time of messages. Therefore, there is a need to adapt the proposed protocol to the environment to ensure the arrival of critical messages to the vehicles in the optimal time and to avoid unnecessary duplication of useful messages. The proposed adjustments are presented in three solutions in the next sub-sections.

1. Hybrid Aspect

Of the two approaches (the two-phase connection and the use of messages beacon) used in the proposed protocol, the second approach is preferred because it offers more benefits than the first. However, in the case of strong collision or the presence of interference, the first approach is recommended. That means, in the case, where the sensor tries to detect (through a passive detection) the vehicle but is unable to because it has not received the beacon message from the vehicle. In this situation, the sensor communicates with the vehicle through the two-phase connection by applying 2PC Algorithm (Fig. 7).

2. Relays Vehicles

There is a probability that the group leader vehicle does not receive all messages in the exchange time, as the sensor-gateway saves each useful message sent to the group leader during P-MSG$_M$ periods, if it detects another vehicle, the sensor-gateway sends the messages if these P-MSG$_M$ periods are not finished. In this way, the vehicle receives these messages and it sends them to the group leader. The delay of the P-MSG$_M$ periods are linked to the environment (town, highway, rural road), because compared to the vehicles density, these periods are fixed. These last factors are minor, where we have high density of vehicles and reciprocity. This solution allows to the group leader to recuperate the messages that has not received them from the sensor-gateway. Moreover, the use of P-MSG$_M$ periods allows avoiding the duplication of the same messages in vehicles group because the sensor-gateway destroys the messages that these periods are finished. Thus, the sensor-gateway communicates with another vehicle in the group only for the exchange of useful messages that these periods are not finished. Fig. 8 gives an example of the use of relays vehicle.

3. Communication between the Sensors-Gateways and all Vehicles

```
Message: MSG = empty;   SDB: The Sensor-Gateway data base;
1. BEGIN
2. If (Detect-Range-Sensor-Gateway (Vehicle V) = true) then
3. Begin
4. Send-To-Vehicle (Request);          // Request of connection with the vehicle
5. Receive-From-Sensor-Gateway (Request);
6. Send-To- Sensor-Gateway (ACK,);
7. Receive-From-Vehicle (ACK);
8. Analyze (ACK);                      // Prepare and processing  of messages
9. While (area remained in the coordinates of vehicle V) Do
10. Begin
11. Insert (MSG, Information area J);
12. To the next area in the vehicle V coordinates;
13. End
14. Send-To-Vehicle (MSG);
15. Receive-From-Sensor-Gateway (MSG);
16. Send-To-Sensor-Gateway (ACK); //ACK contents information about areas visited by the
    vehicle
17. Update-SDB (areas);                 //Recent information provided by the
    vehicle
18. End
19. END
```

Fig. 7 Two-phase connection algorithm (2PC)

The content of critical messages is very important for inform a driver about a dangerous situation. This last, can be happen at a close position to the displacement position of vehicle. For ensure the delivery quickly of critical messages, we have proposed only the sensors-gateways send the critical messages to each vehicle (detected by these sensors-gateways). This proposition does not present a problem on the energy consumption of sensors-gateways because the size of critical messages is very small compared to that of useful messages. Thus, the general strategy of our protocol will be:

- The sensors-gateways exchange the useful messages only with the group's leaders of vehicles and the rest of other useful messages that did not receive by the group leader

(if they exist) will be sent by the sensors-gateways to relays vehicles.
- The sensors-gateways send the critical messages to all vehicles.

IV. Simulation Results

We have used OMNeT++ 4.3 simulator [8] and MiXiM 2.3 project [9] (For mobility model and MAC protocol) for the performance evaluation of our protocol. The purpose of this protocol is to ensure the exchange of road messages (useful messages) and the quickly transmission of critical messages to the vehicles in the available time, whatever its speed. For this reason, we have worked on:

– The exchange times of packets
– The maximal number of packets exchanged between the sensor-gateway and the vehicles in the available time.

A. Parameters and Environment of the Simulation

1. The Simulation Environment

We have a geographical region contains sixteen areas. We take a part of this geographical region represented by six areas. For this we suppose that:

There are two sensors-gateways. The first sensor-gateway has information about the areas 1, 2, 3, and 4, and its emplacement is on area number three. The second sensor-gateway has information about the areas 3, 4, 5, and 6, and its emplacement is on area number five. The area length is 3 km.

There are 15 critical messages for each sensor-gateway (the total size of these messages is 660 bytes). The size of a critical message is calculated by (3), with the number of segments equals to 1.

A vehicles group moves on area 1. This group contains four vehicles; the first in the direction of sensor-gateway is the group leader. The areas, which are in the direction of vehicles to their destination, are 2, 5, and 6. The group leader sends to the sensor-gateway the areas information of the two areas visited recently by this last. The size of ACK message is 25 bytes and the size of beacon message is 25 bytes.

The size of each area is represented in Table VII, in which we have used (3) to calculate the size. In addition, Table VII gives the total quantities of information exchanged in the following cases:

- Information quantity sent from sensors-gateways (SG) to the vehicles.
- Information quantity sent from the vehicle (GL) to the sensors-gateways.
- Information quantity exchanged between the sensors-gateways and the vehicle. We have taken all types of messages exchanged in the communication.

We have the following exchange cases:

✓ Case1: Exchange between the group leader of vehicles and the first sensor-gateway.
✓ Case2: Exchange between the group leader of vehicles and the second sensor-gateway.

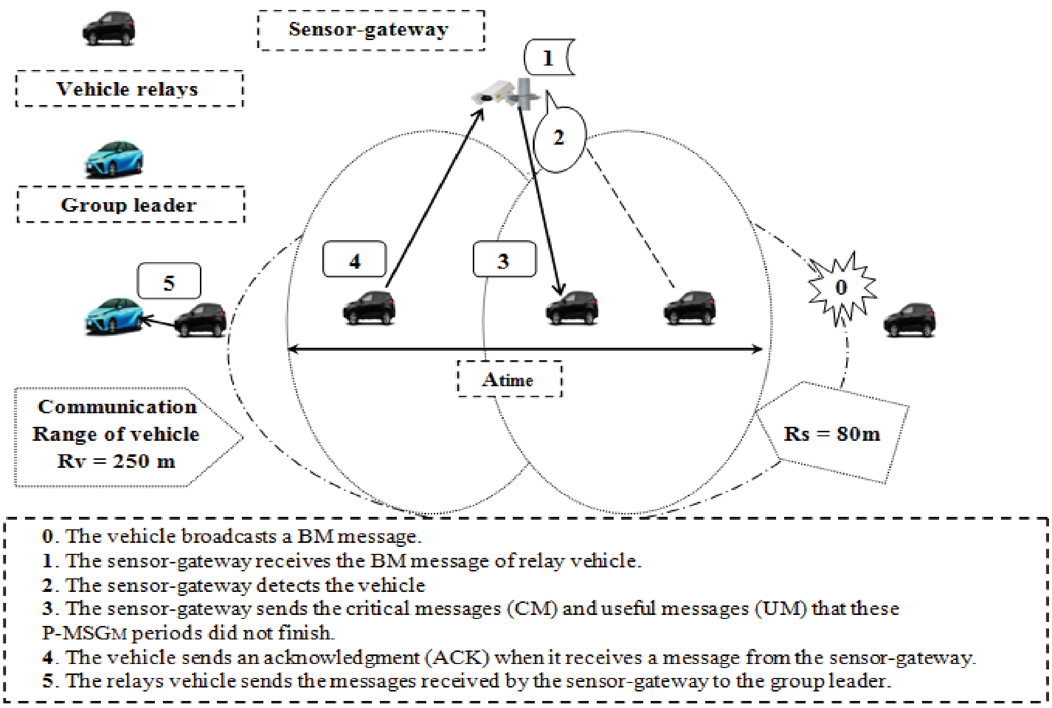

Fig. 8 Example of the use of relays vehicles

2. The Simulation Parameters

The total sizes of messages in the two cases are respectively, 10,740 and 7,444 bytes.

The sensor-gateway do not destroy the messages sent to the vehicle, even in case, it receives the acknowledgment of this last (we have added this hypothesis for see the important of the use of relays vehicles). Table VIII shows the most important simulation parameters used in our work.

TABLE VII
TOTAL OF QUANTITY OF INFORMATION EXCHANGED BETWEEN THE SENSORS AND THE VEHICLES

Area	Number of segments	Data quantity (bytes)	SG→GL (bytes)	GL→SG (bytes)	Data total (bytes)
Area 1	32	688,5			
Area 2	128	2752,5	6044	3441	10740
Area 3	64	1376,5			
Area 4	64	1376,5			
Area 5	32	688,5	3636	2753	7444
Area 6	16	344,5			

TABLE VIII
SIMULATION PARAMETERS

Parameters	Values
Road length	18 Km
Number of sensors nodes	2 sinks nodes
Inter-sensors distance	9 Km
Number of Mobile nodes	4 vehicles
Transmission range of sensor	80 meter
Transmission range of vehicle	200 meter
Data rate	250 Kbps
MAC protocol	IEEE802.15.4
Size of Packets	20 and 100 bytes
Period of broadcast of BM	1 second
P-MSGM Periods	between 0,5 and 3 s

B. Interpretation of Results

1. The Exchange Times of Packets

The main purpose of our protocol is the exchange times of packets between the sensor and the vehicle compared to the variable speeds of the vehicle. These times can show if the protocol ensures the data exchange in the available time. We have tested our protocol into the two cases of data exchange. We have also compared our protocol at two protocols, the first, is two-phase connection protocol [4] and the second is protocol with the use of beacon messages [7]. Fig. 9 shows the exchange times between the first sensor-gateway and the group leader of vehicles (Case 1). Fig. 10 shows the exchange times between the second sensor-gateway and the group leader of vehicles (Case 2).

We note that in all scenarios, whatever the vehicle speed and into the two cases of exchange, that: In the three protocols, we have enough time for the data exchange between the sensors-gateways and the vehicles. We have these results because the segmentation model and the data model, have allowed reducing of quantity of information exchanged. For example, we take the situation (Fig. 9) where the vehicle speed is maximal (120 Km/h) (the available time with this speed, equals to 4.8 seconds) we have the following exchange times in the order for the three protocols: 3.89, 3.2, and 3.02 seconds.

The exchange times of the proposed protocol are shorter than those suggested in other protocols. Moreover, the protocol, with the use of beacon messages in most scenarios, has exchange times shorter than those in the two-phase connection protocol. This explains, our choice concerning the use of approach using beacon messages for priority.

We have these results because using DFA algorithm in our protocol, we have reduced the amount of data sent by the sensors-gateways to the group leader (Case1: 10740 to *7173.5*, Case2: 7444 to *4566*). Moreover, the use of CA algorithm allows to the vehicle the reception of critical messages in first place before the reception of useful messages, this gives more time to the drivers for avoid a dangerous situation.

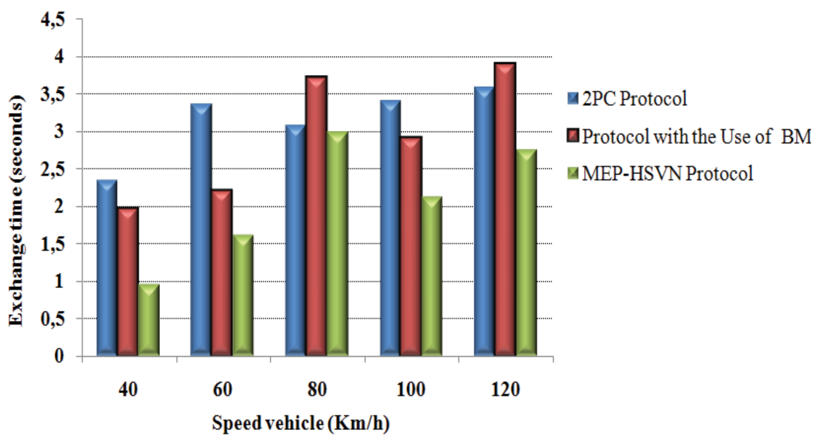

Fig. 9 Comparison of exchange times between protocols compared to variables speeds of vehicle (Case 1)

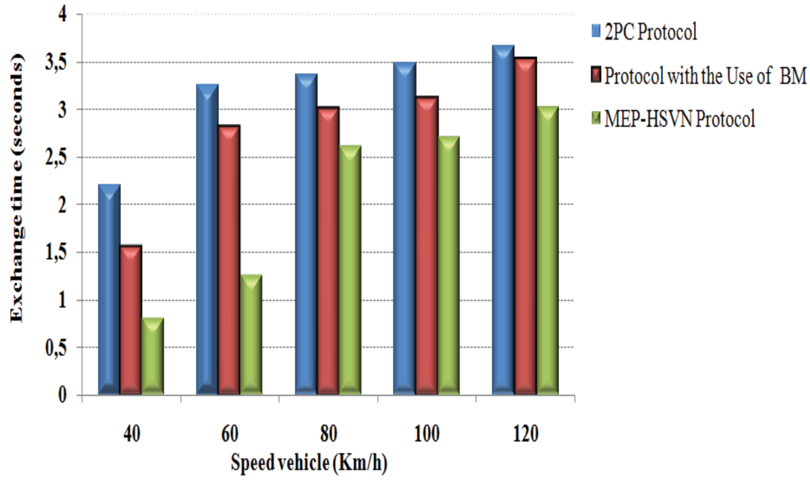

Fig. 10 Comparison of exchange times between protocols compared to variables speeds of vehicle (Case2)

2. The Maximum Number of Packets Exchanged

To determine the maximum quantity of data that can be exchanged between the sensor-gateway and the vehicles in the available time, we have tested our protocol using the following strategy. We simulate the data exchange by the use of packets of fixed size, which are equal to 200 bytes. These packets contain different road data and there are 40 packets represent the critical messages, which are sent to each vehicle (Sub-Section III *D* 3). Moreover, our purpose is also, to see the role of relays vehicles for this, we have used different P-MSGM periods changed in the test (Sub-Section III.B) compared to the vehicles speeds. Fig. 11 shows the maximal number of packets exchanged between the sensor-gateway and the vehicles in the available time compared to variables speeds of vehicles.

From Fig. 11, we observe that for example, at a speed equals to 80 Km/h, the total size of data exchanged between the sensor-gateway and the group leader of vehicles in the available time, equals to 204.6 Kilo-bytes so we can add to this exchange others types of data like a picture or a video. Concerning, the relays vehicles, we note that the vehicle N°2, has received some packets which do not received by the group leader of vehicles. For example, at speed equals to 120 Km/h, the vehicle N°2 receives 400 packets from the sensor-gateway. There are 40 packets represent the critical messages sent to the vehicle N°2 and 360 packets which have been sent to the group leader of vehicles but it did not receive them. In this way, the group leader of the vehicles can recover the useful messages from the relays vehicles. The choice of P-MSGM periods represents an important parameter for avoid the redundancy of the same useful messages.

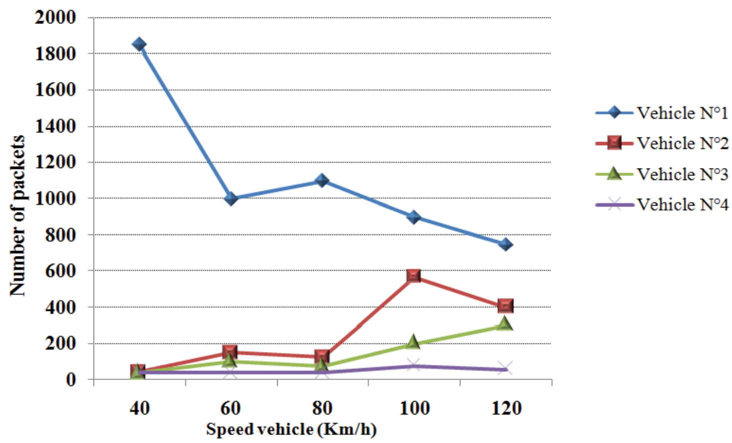

Fig. 11 The maximum number of packets exchanged between the sensor-gateway and the vehicles in the available time

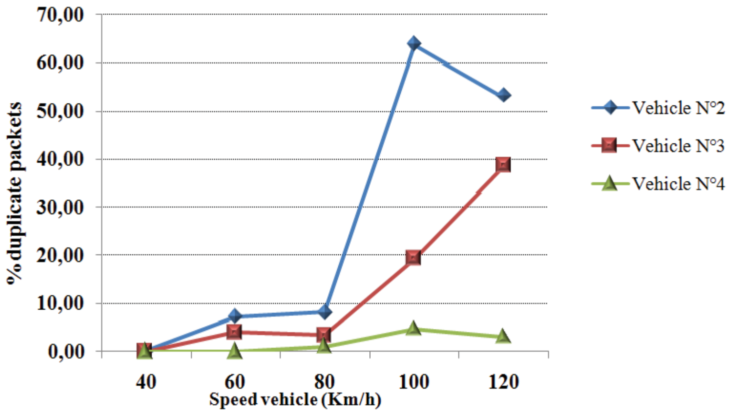

Fig. 12 The average rate of duplication of packets sent to the group leader

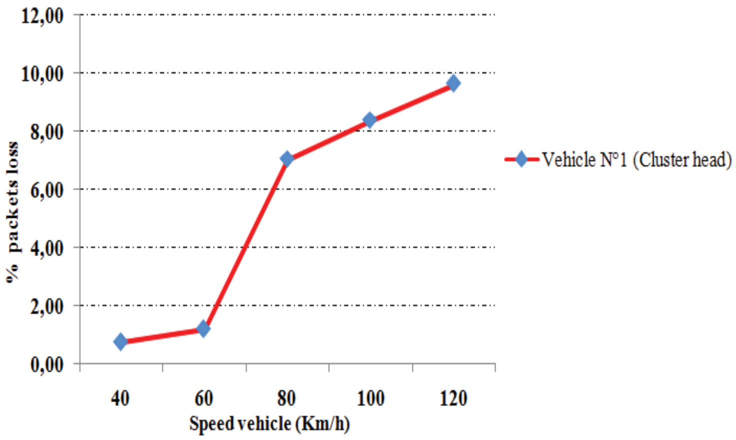

Fig. 13 The average loss rate of packets sent to the group leader

Fig. 12 gives the average rate of duplication of packets sent to the group leader. We note that, this last is small when the vehicle moves by a low speed (the most P-MSGM periods of packets are finished). In the case, we increase these periods we obtain a high duplication rate, for example at speed equals to 100 Km/h, we have the duplication rate of packets for the vehicle N°2, equals to 66% (P-MSGM = 3 seconds). In addition, we have a weak duplication rate in the cases of vehicle N°4 and an average rate of duplication in the cases of vehicles N°2 and N°3. The vehicle speed, the network conditions, and the choice of P-MSGM, represent the parameters that allow or denied the use of relays vehicles for the recuperation of useful messages sent by the sensor-gateway to the group leader of vehicles but it did not receive them.

Fig. 13 shows the average loss rate of packets between the sensors-gateways and the group leader of vehicles when the data exchange between the two compared to variable speeds of vehicle. Our protocol proves that is reliable because we have obtained a weak loss rate of packets (in all scenarios, whatever vehicle speed, this loss rate is less than 10%). We note that the loss rate is increased when the vehicle speed is high. We can justify this result when vehicle speed is high, as the sensor has a problem detecting the vehicle, which is also linked to the MAC protocol used.

V. CONCLUSION

In this article, we have presented a communication protocol between a WSN and a VANET in HSVN. This protocol uses solutions allowing the improvement of its performances. We can summarize its solutions in the following points: hybrid operating (the use of beacon messages and a two-phase connection) compared to the network conditions. Moreover, we have used a segmentation model, a data model, and a message model for the following purposes: the reducing of processing time of messages and the quantity of data exchanged between the two networks and the distinction between the useful messages and the critical messages. We have also proposed two algorithms. The first is used to avoid the duplication of the same messages and it allows sending the messages only which the vehicle has need. The second algorithm is used for the organization of the critical messages according of their degree of importance. We have always kept the idea that the two networks use a cluster topology for economize the energy consumption in the WSN and for avoid the duplication in the VANET. However, we have added the concept of relays vehicles in the case the communication between the two groups leaders of both networks do not finish in success. Finally, to ensure the quick delivery of critical messages, we have proposed that the sensors-gateways communicate with all vehicles. The authors perceived that

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improvement of the proposed protocol could be made by testing it in simulation environments, which have communication protocols inside WSN and inside VANET, and the addition of others metrics in the simulation such as the energy consumption of the sensors.

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