Intelligent Management of Highways Congestion based Sensor Networks

Lyamine GUEZOULI[1], Souheila BOUAM[2] and Abdelmadjid ZIDANI[3]

[1] Computer Science Department, Hadj Lakhdar University
Batna, 05000, Algeria

[2] Computer Science Department, Hadj Lakhdar University
Batna, 05000, Algeria

[3] Computer Science Department, Hadj Lakhdar University
Batna, 05000, Algeria

Abstract
The main purpose of this paper is to enable congestion prediction on urban freeways and objectively measure its impact on daily life. Indeed, cars' trafic becomes increasingly difficult and, often causes traffic jams that can last for hours, because of growing number of used cars, in addition to the unforeseen events that may complicate more and more this problem (weather, accidents, road works ...). This is mainly due to the lack of efficient management of roads' congestions. This paper attempts to bring a technological response to significantly reduce the congestion problem. Our approach is based on smart sensors which allow traffic jam detecting and relaying such critical information. Thus, while providing the drivers with context aware information such as those related to the highway status before crossing, we enable them to make decision and select another road avoiding the congested one and reducing, by the way, the congestion itself.

Keywords: *VSN, Smart Sensor, Cluster, Average Speed, Signal Strength.*

1. Introduction

Wireless sensor networks are a specific type of Ad-hoc networks, where nodes are sensors. They usually imply a large number of communicating sensors which use radio links for information sharing and cooperative processing. In such networks, sensors may exchange different types of information, eg on the environment, to build a global view of the control area, which is made available for users by one or more nodes. The data collected through these sensors may be directly conveyed or via other sensors gradually to a "collection point", called base station (or SINK, in the case of a node). This latter can be connected to a powerful machine via Internet or satellite, in order to transmit information on the state of the highway to the users.

Currently, the most used means in the field of the highway monitoring is the video monitoring. However, in our country (Algeria), we must consider the bandwidth which represents a critical resource. So the use of the video monitoring in our country will not be so efficient.

Not far from the problem of the bandwidth, the private life of the user on the highway is another handicap. Indeed, the information transmitted by the surveillance camera is rich and may contain details that can affect the private life of the users (hour of passage, vehicle registration ...).

Our contribution primarily aims to compress the information transmitted concerning the highway state, and to transmit only the useful information. This way, we ensure a better management of highway traffic. However, we will not need camera to supervise the traffic, but rather sensors which will collaborate to ensure an efficient monitoring.

The aim of this paper is to present and discuss our approach to enable congestion prediction on urban freeways. Since we use smart sensors as a way to provide drivers with information on roads' traffic, Section 2 introduces the concept of congestion and a study of its sources, Section 3 covers the various surveillance technologies in highways; we focus on video surveillance technology that presents the most widely used today. In Section 4 we present the utility of using wireless sensor networks to monitor traffic. Section 5 describes the characteristics of wireless sensor networks; we also introduce the concept of smart sensor. Section 6 attempts to highlight the usefulness of Vehicular Ad hoc NETworks, particularly while providing services to road users that can significantly improve road safety, also in this section we introduce the concept of smart sensors in vehicular networks (Vehicular Sensor NETworks). Section 7 introduces clustering algorithms and reviews the main approaches used in the literature. Section 5 tries to point out the characteristics of video monitoring systems and their usability on highways. Section 8 describes our contributions, notably the protocol for creating and managing clusters as well as its evaluation to explicitly motivate the adopted choices. We will show that our approach is mainly focused on concepts of data sharing and exchange to favor congestion detection. Finally, we conclude by highlighting some perspectives of the achieved work.

2. Traffic Congestion and reliability

Before trying to propose a solution to the highways congestion, we should, first, identify the problem. This section provides a snapshot on congestion by summarizing recent trends concerning this issue, highlighting the relationship between congestion and unreliable travel times, and describing efforts to control congestion. In particular, this section develops a framework for understanding the various sources of congestion, the ways to address congestion by targeting these sources, and performance measures for monitoring trends in congestion.

2.1 Trends in congestion

There are several statistics that point to worsening congestion levels. Congestion extends to more time of the day, more roads, and creates more extra travel time than in the past. It has clearly grown and used to mean it took longer to get to or from work in the "rush hour". But congestion now affects more trips, more hours of the day and more of the transportation system. Figure 1 shows the growth in several key dimensions of the congestion problem in cities of more than one million persons.

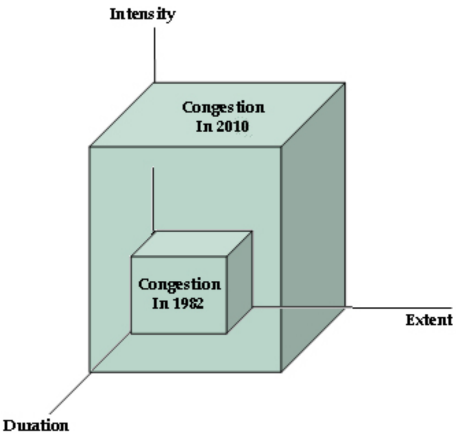

Figure 1. Weekday Peak-Period Congestion Has Grown in Several Ways in the Past Years *(Source: Analysis of data used,* Annual Urban Mobility Report, *Texas Transportation Institute.)*

2.2 Sources of congestion

To know how to remedy to the problem, we should first be aware of sources of it. Congestion is a lot more complex than simply "too many vehicles trying to use the road at the same time," although that is certainly a major part of the problem. Congestion results from the interaction of many different factors and sources of congestion. Congestion has several root causes that can be classified into two main categories:

- **Too much traffic for the available physical capacity to handle –** Just like a pipe carrying water supply or the electrical grid, there are only so many vehicles that can be moved on a roadway for a given. Transportation engineers refer to this as the physical capacity of the highway system. Physical bottlenecks are locations where the physical capacity is restricted, with flows from upstream sections (with higher capacities) being funneled into smaller downstream segments. Bottlenecks can be very specific chokepoints in the system, such as a poorly functioning freeway-to-freeway interchange, or an entire highway corridor where a system of bottlenecks exists, such as a closely spaced series of interchanges with local streets. Physical capacity can be reduced by the addition of intentional bottlenecks, such as traffic signals and toll booths. Bottlenecks can also exist on long upgrades and can be created by surges in traffic, as experienced around resort areas.
- **Traffic-influencing events –** In addition to the physical capacity, external events can have a major effect on traffic flow. These include traffic incidents such as crashes and vehicle breakdowns; work zones; bad weather; special events; and poorly timed traffic signals. When these events occur, their main impact is to minimize the physical capacity of the roadway. Events also may cause changes in traffic demand by causing travelers to rethink their trips (e.g., snow and other types of severe weather).

Figure 2. Sources of Congestion [7]

A composite estimate of how much each of these sources contribute to total congestion is depicted in Figure 2.

2.3 Managing congestion

Transportation engineers and planners have developed a variety of strategies to deal with congestion. These strategies can be grouped as follows:

- Adding more capacity for highway, transit and railroads;
- Operating existing capacity more efficiently; and
- Encouraging travelers to use the system in less congestion-producing ways.

Each of these congestion reducing strategies has a role in major cities. More accurately, they all have a role in some locations and corridors within major cities. Implementing the strategies involves consideration of the size and type of problem, funding, and public approval, environmental and social consequences. The decisions resulting from all these factors will be different, diverse and reflect local, state, and national priorities. When used in combination, however, the strategies can have a powerful impact on congestion growth.

The main problem with many of these strategies is that they can be contrary to market trends, burdening consumers with extra costs and dampening economic efficiency, at least in the short term.

3. Mechanisms of Different Surveillance Technologies

Surveillance technologies can be classified as intrusive, non-intrusive and off-roadway technologies. Intrusive traffic sensors are installed within or across the pavement. Nonintrusive sensors can be installed above or on the side of roads with minimum disruption to traffic flow. Off-roadway technologies do not need any specific equipment to be installed at the test site.

3.1 Intrusive Technologies

Intrusive technologies refer to those that require installation directly onto the pavements, in holes or tunneling under the surfaces. Drawbacks include the disruption of traffic for installation and repair, failures induced by poor road conditions, and system reinstallation caused by road repairs or resurfaces. Examples include inductive loop, pneumatic road tube, piezoelectric cable, and weigh-in-motion system.

Inductive loop detector is the most common vehicle detector used in the traffic surveillance industry. Inductive loop is already a mature technology. It is well recognized as the industrial standard because of its high detection accuracy [1]. However, its biggest disadvantage is that it causes serious traffic disruption during installation and repair. The loop wire is also subjected to stresses of traffic and temperature, making its failure rate relatively high. Advanced algorithms were developed to identify bad detectors based on volume and occupancy measurements [2].

Piezoelectric Sensor (Similar to inductive loop), is installed by embedding it under the pavement. It is constructed by a specially processed material (quartz) that will generate a voltage when subjected to mechanical impact or vibration [3].

Weigh-In-Motion (WIM) system is used to estimate a vehicle's gross weight when its wheels pass over the sensors [4].

3.2 Non-Intrusive Technologies

Non-intrusive technologies do not need any installation on or under the pavement, so that the installation and repair of such a system can be done without disrupting the traffic. The detectors are usually setup on the roadside, or at an overhead position. Examples of this type of technology include:

Microwave Radar – an acronym for RAdio Detection And Ranging [5], is a system that uses radio waves to detect, determine the direction, distance and speed of some target objects.The main advantage of microwave radar is that the system performance is not affected by any weather change. The drawback is that CW Doppler radar cannot detect motionless vehicle unless an auxiliary device is equipped.

Infrared-Based System - Infrared (IR) radiation is electromagnetic radiation with wavelength longer than that of visible light but shorter than that of radio waves. Common systems for traffic surveillance use IR ranging from 100 to 105 GHz [6]. The main advantage of an IR system is its easibility of transmitting multiple beams for multi-zone detection in a single detector unit. The drawback is that its performance is greatly affected by the environment: confusing signal from sunlight, IR energy is absorbed or scattered by atmospheric particulates, (rain and snow…).

Video monitoring systems have nowadays reached an important stage of maturity, in both fields of photography (cameras) and analogic transmissions [7]. The miniaturized CCD cameras have perfect or enlightened daytime vision, and only improved night vision unlit is expected. Remote cameras systems can also use the optical fiber on very long distances, and the systems remain accurate and reliable. In summary, installations using analogic transmission systems are very interesting.

Figure 3. Highway under video monitoring

Based on the characteristics of video monitoring systems on motorways, we can deduce the following limits:

- Complexity of image processing algorithms, with all possible variations explored by some manufacturers or organizations;
- Need to standardize a method of image compression combining quality and low bandwidth;
- The various principles of remote mobile cameras;
- Analogical and digital multiplexing techniques difficulty;
- Open door on the digital transmission of signals from end to end on the transmission chain.
- A security level is usually limited in case of default on a main cable transmission.

4. Motivation for Using Wireless Sensor Networks

The increasing traffic congestion is a growing problem in many countries. The 2011 Urban Mobility Report [7] shows that the total cost of congestion for 85 U.S. urban areas, for example, is estimated to be 65 billion dollars per year, which come from 3.5 billion hours of delay and 5.7 billion gallons of excess fuel consumed. Besides building new roads and bridges to ease congestion, Intelligent Transportation Systems (ITS) seek to maximize the capacity of existing traffic networks and minimize the associated delay.

Accurate and reliable real-time traffic data from surveillance systems is essential for the efficient and successful execution of all ITS systems. For example, traveler information system, freeway and arterial management systems, emergency management and parking management rely on the coverage and accuracy of the real-time traffic information [8]. In order to maximize the benefits from all these ITS technologies, a large scale deployment of traffic controls on all major freeways and local streets must be under taken. Therefore, real-time traffic information at all these sites is required. This presents a serious challenge to the surveillance industry.

Because of the highly intrusive characteristic of inductive loop detectors, the quest for researching a reliable and cost-effective alternative system, which can provide traffic data at the same accuracy level as inductive loop systems, while minimizing the disruption during installation and maintenance, has been underway for some time. The motivation of developing wireless sensor networks based surveillance system is to provide a direct replacement for the inductive loop systems, and extend the coverage of ITS applications Because of the highly intrusive characteristic of inductive loop detectors, the quest for researching a reliable and cost-effective alternative system, which can provide traffic data at the same accuracy level as inductive loop systems, while minimizing the disruption during installation and maintenance, has been underway for some time. The motivation of developing wireless sensor networks based surveillance system is to provide a direct replacement for the inductive loop systems, and extend the coverage of ITS applications.

Flexibility - Wireless sensor networks have a high level of flexibility in their deployment configuration. Since the sensor nodes can be placed virtually anywhere on the road as long as they are within communication range, customized configurations can be adopted for different applications and environments. This unique characteristic is a big advantage over all other surveillance technologies.

Multi-Functional - A multi-functions wireless surveillance system can be developed by adding other sensing modalities to the existing sensor node platforms. Temperature sensors can be added to detect ice and snow; humidity sensors can be added to detect rain and fog; accelerometers can be added to monitor structures of bridge and pavement. This multifunctional characteristic further extends the possibility of more advanced ITS applications.

Wireless Communication Capability - Research on safety control by inter-vehicle communication (IVC) and road-to-vehicle communication (RVC) is being actively conducted. The sensor nodes can be used to extend the communication networks of IVC and RVC by simply using the standard protocol, IEEE 802.11p and Dedicated Short Range Communications (DSRC).

These factors give a strong reason for investing more resources on the research and development of wireless sensor networks for traffic surveillance.

5. Sensor networks

There are many models of sensors that correspond to different applications needs deploying in a network. Yet they are all mainly composed of three parts in common: The acquisition unit, the processing unit and the transmission unit.

Energy is the critical factor of a sensor network. Indeed, this is a limited resource and crucial because not replaceable.

5.1 Transmission of information in a wireless sensor network

Transmission of information in a network can be done in two ways:

- Direct sending: Each node is closely linked to the collection unit, and no intermediary can be involved in this direct privileged link (as it is illustrated by figure 4 – left part).
- Sending by ad hoc routing: When nodes are not connected to the collection unit, direct transmissions are not possible, thus routing information rules should be applied (as it is illustrated by figure 4 – right part).

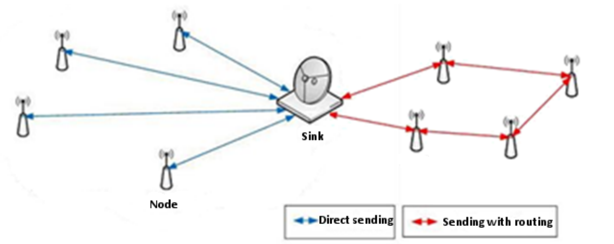

Figure 4. Information transmission mode in a Sensor Network

5.2 Routing Constraints

The Ad hoc routing protocols are not specifically dedicated to wireless sensor networks. Routing in sensor networks must take into account a basic constraint which is energy consumption. Despite the fact that wireless sensor networks are related to ad hoc networks, the specificities, objectives and requirements of such networks can differ.

However, for sensor networks, we can distinguish only few dedicated protocols, which may be classified into four categories: *Hierarchical protocols, location-based protocols, data-centric protocols,* and *consideration of network stream.*

5.3 Smart Sensors

Smart sensors are hardware devices including the sensor, processing and communication circuits. Their relation with higher processing layers extends well beyond a simple signal transmission. The most followed approach to realize a smart sensor is that combining the measure function with the information processing function. This is exactly what is achieved when the device incorporates a microprocessor perception. The treatment algorithm used in this case is programmable and can be changed later (development, adaptation, redesign ...)[9][10].

6. Vehicular Ad hoc & Sensor Networks

The emergence of wireless communications introduced the exchange of information in the area of vehicular networks; all began with Vehicular Ad hoc NETworks based on wireless communication between vehicles. However, with the inclusion of sensors in Vehicular Networks (Vehicular Sensor NETworks), the exchange of information in such networks has become increasingly easy managed, considering the facility of exploitation the sensors.

6.1 Vehicular Ad hoc NETworks (VANETs)

Vehicular Ad hoc NETworks have recently been increasingly attracting the transport authorities and the research community [11][12]. With a low cost of deployment, Vanets become, nowadays, the nucleus of an Intelligent Transport System (ITS) that can provide new services to road users and improve significantly road safety. VANETs' development has benefited from the emergence and proliferation of wireless devices used for inter-vehicles communications (IVC) as well as vehicles with the infrastructure located along the roads and control centers (RVC).

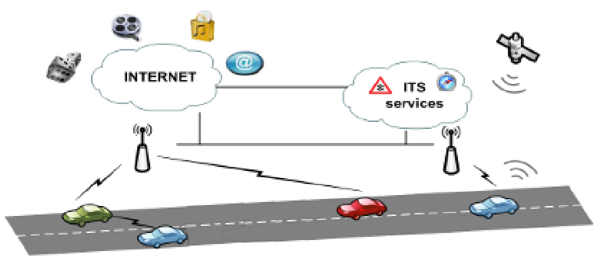

Figure 5. Example of information sharing in a VANET

These new ways of communication are essentially defined to provide the required information that enables a better management of road traffic as well as to provide assistance for drivers in an emergency case. In addition to security applications, VANETs can also be used to provide guidance and telemetry, or comforts services like Internet, telephony, etc…

6.2 Vehicular Sensor NETworks (VSNETs)

The Vehicular Sensor Networks are a special case of wireless sensor networks where the sensors are mobile. By this term, we insinuate networks of vehicles where each actor has an embedded sensor, which leads to sensors mobility.

Contrary to the models based, only, on fixed electromagnetic sensors, VSNETs are cooperative systems that will allow interaction between multiple vehicles or between vehicles and infrastructures already located in place. Thus, intelligence shared pertinent information is distributed among various network elements, fixed or mobile ones, which will allow us to develop more flexible and efficient applications that it would be, sometimes, impossible to set up only with a static architecture.

The advantages of applications using mobile and embedded sensors are numerous: the data from the vehicles and the infrastructure are generally complementary, and trivial. Let's note that several types of these systems are available, depending on the level of cooperation that the infrastructure is able to support, and of the application will framing the network [13]:

- Autonomous systems (AS), where no communication is established, but where the vehicles have onboard sensors that would measure the current events around the vehicle: detection of accidents, obstacles, checking the safety distance, etc…
- Oriented-infrastructure cooperative systems, where a vehicle will only be able to communicate with the infrastructure (sensors, control boxes), to access data directly related to road traffic (I2V), or to provide (V2I).
- Oriented-vehicles Cooperative systems, where a vehicle will only be able to communicate with other vehicles to acquire pertinent information on road traffic may use two types of communications:
    - Step by step (V2V), where communication is provided only between two neighboring vehicles, using sensors.
    - Global communications, where different actors have a system connected to a common oracle (eg PDAs, GPS and some others).
- Interactive systems (IS), where a given vehicle will share information with other vehicles, but also with the infrastructure. In such case, the advantage is considerable. Indeed, in addition to the ability to process information aggregated from both sides of the system, important data can also flow through the network via vehicles. The concept of sharing takes on its meaning.

Among the existing works in the field of VSNETs, we can cite [14] which describe a network vehicular (V2V): Using a wireless sensor network combined with Bluetooth communications to improve overall networks security.

In [15], the authors propose a wireless sensor network consisting of three types of nodes: vehicles, electromagnetic sensors, and controllers at an intersection. The road sensors continuously disseminate information reflecting their specific positions. So vehicles receiving data over three different sensors will then be able to calculate their positions by triangulation and send the results as well as their speeds to the controller, which will be able to make decisions like changing traffic lights on the intersection (V2I).

In [16], authors develop a similar model but expand its use at several intersections. From this work, the authors go so far as to propose a prototype in [17].

7. Clusters forming in a vehicular network

The objective of clustering algorithms is to assign a particular role to certain nodes of the ad hoc network. In any clustering applied scheme, the main role is the one of the chief of the cluster, called *clusterhead*. A single clusterhead is elected by each cluster. We call member, a node of the cluster associated with a clusterhead, and we call a gateway, a neighboring node with at least one other cluster. A gateway is used to transmit messages from one cluster to another.

The clustering algorithms are classified according to their manner of controlling the cluster size. In a K-jumps cluster [18], each member must not exceed the maximum of K-jumps of the clusterhead. In a multi jumps cluster [19], there is no limit of many jumps, and however the size of the cluster (of many nodes) is limited. Lastly, some clusters are organized out of tree [20] where the members of the cluster are the nodes of this tree.

The weak point of the ad hoc protocols based on the geographical position (from a point of view of scaling) is the geographic location of the destination. In [21], the authors propose a solution to improve the scalability of a protocol using geographical location of clusters in a network of vehicles. An algorithm for cluster forming in 2-jumps is described with designation of gateway nodes. A simple geographic protocol type MFR (Most Forward within Radius) [22] is used, and location of the destination is done by simply broadcasting messages LREQ and LREP. However, only a clusterhead or a gateway transmits these messages, limiting the overhead of a greedy broadcast. Unfortunately the paper compares the algorithm only with AODV and DSR, whereas a comparison with the use of a service of localization with appointment such as GLS or GHLS would have been more relevant.

Other works propose algorithms that were adapted to the vehicles and networks clusters forming dealing with their evaluation. In [23], the authors take into account the speed or position of adjacent vehicles in clusterhead election algorithm (kjumps Lowest ID and Highest-Degree), to increase the stability of the cluster. In [24], the presented work is an extension to consider the direction of vehicles travel: two vehicles traveling in opposite directions cannot be in the same cluster. The authors also add a test to take a clusterhead priority, the clusterhead which was the longest in the past.

It is also possible to take into account the unique dynamics of a network of vehicles. For example, there is an oscillatory effect of the distance between vehicles. In [25] this effect is taken into account with a distance criterion (geographical) limit between two clusterheads.

8. Contributions

If we talk about numbers, an HD camera is able to take 15 frames per second. Each image "weighing" 5 MB. The camera can shoot the equivalent of 75 MB per second. And for 15 h, the exchange of information between the camera and the base station will record 4 TB (4 good disks) of data. The images are then digitized to determine the position of all vehicles (position on the line, speed, lane change), every tenth of a second at least. Why such precision (20 cm per pixel)? Simply because the researchers wanted to know in details the trajectories and any other information to be aware of the traffic congestion causes.

8.1 Protocol for creating and managing Vehicular Sensor Clusters (VSCluster)

Forming groups of nodes, commonly called clusters; make it possible to create a hierarchical network in order to minimize information exchanges to maintain routing tables. In a vehicular network, mobile nodes move at similar speeds and in the same direction, a cluster of nodes is then generally stable.

It is interesting to exploit this stability in vehicular networks: it is no longer a node that registers with an access point, but the entire cluster, thus decreasing the number of entities that must manage mobility.

The study of cluster forming is strongly linked to the basic clustering algorithms. After research, we choose to focus on the protocol signal strength based link Advanced Stability estimation model (ASBM)[26] which is proposed to improve the method for evaluating the stability of the link protocol SSA (Signal Stability-based Adaptive Routing [27]) with a new metric calculation. The SBM model is slightly modified to take into account, in addition to signal strength, the derivative of its position: the differentiated force signal (Differentiated Signal Strength - DSS). DSS indicates whether the signal strength increases or decreases. If it increases, it is interpreted by the fact that the two nodes are close to each other, and that the link between them will last longer. Whereas, in SSA, only the links (whose signal strength exceeds a certain limit) are considered stable. In ASBM links signal is weak but it increases if nodes that are closer, are also considered stable. On the basis of ASBM, and at a given time, each network node is either clusterhead or a member node of the cluster.

We have chosen to work with a vehicular network based sensor VSNET (Vehicular Sensor Network), which is a particular type of VANETs (Vehicular Ad hoc Networks). The choice of using sensors in a vehicle is because of the reputation of the sensors on one side; on the other hand we need to save information throughout the path to be supervised. The architecture of a sensor has a storage space, so it will facilitate our task.

Initially each vehicle is alone in its own VSCluster, and thus head VSCluster. Then there are initially as many VSClusters as vehicles in the network. A node declares its presence to its neighbors by sending periodically a hello message containing its identifier, and the identifier of its VSCluster.

Forming and maintaining VSCluster are regimented by two distinct processes: the fusion and the scission of VSCluster.

8.1.1 Fusion process

The fusion allows a VSCluster to grow up by recruiting new vehicles.

For example, in order to initiate fusion of VSCluster VSC1 in VSCluster VSC2, the VSC1 clusterhead should be the neighbor of a node (clusterhead or not) contained in the VSCluster VSC2. Based on the information contained in the hello message sent by the neighbor, the VSC1 clusterhead decides to stand or not the fusion. The condition is defined by ASBM, obviously based on the signal strength between the clusterhead and VSC1 VSC2.

If the condition is true, the VSC1 clusterhead sends a Join VSCluster Request (**JCReq**) message to neighboring node who forwards it to VSC2 clusterhead. The VSC2 clusterhead checks the size of both VSClusters, if it is below the VSCluster size limit, it then sends a Join VSCluster Reply (**JCRep**) message to VSC1 clusterhead confirming the fusion. If the size exceeds this limit, then the VSC2 clusterhead does nothing and the fusion process is aborted.

On receiving the message **JCRep**, the VSC1 clusterhead sends a Node Join (**NJ**) message to VSC2 clusterhead listing the nodes of its VSCluster, broadcasts a VSCluser Info (**CI**) message to members of his VSCluster to carry out updates.

On receiving the **NJ** message, VSC2 clusterhead adds nodes in the message in his VSCluster nodes table. On receiving a **CI** message, a member of VSCluster affects its VSCluster identifier to the identifier of the VSC2 clusterhead. These two actions allow all members of old VSCluster to join the VSC2, the fusion process is completed.

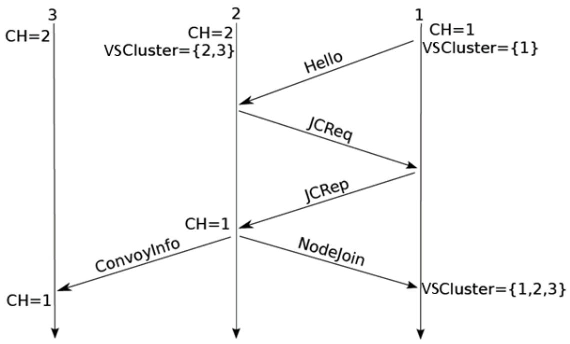

Figure 6. Example of a message exchange in a VSClusters fusion

8.1.2 Scission process

The scission occures when the VSCluster is no longer connected: there is a node that cannot communicate with the head of VSCluster. The management of VSCluster splitting allows maintenance of the cluster. The procedure for choosing a new clusterhead launches on the basis of ASBM.

The new clusterhead sends a message vsCluster Info (**CI**) to its neighbors, those with which it has good signal strength.

On receiving the CI message, a member of VSCluster affects its VSCluster identifier to the new clusterhead identifier and acknowledges reception of the message to its new clusterhead. When receiving the acknowledgment, the new clusterhead adds VSCluster member at his table. The upstream clusterhead, receiving no acknowledgment message to CI, considers that its members are no longer part of his VSCluster and removes them from its table. The demerger process is completed.

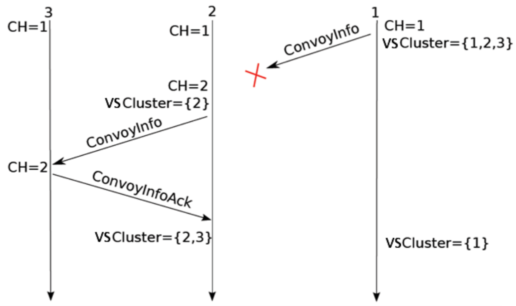

Figure 7. Example of a message exchange in a VSClusters scission

8.1.3 Evaluation of the protocol

We implemented the VSCluster forming algorithm forming in the simulator J-Sim. Indeed, the routing of sent messages and distributed by the forming protocol is based on the VSClusters ASBM described above.

The default simulation parameters are given in Table I.

Table 1. Default simulation parameters

Simulation time	600s
Interval for sending Hello messages	2s
Size of a data packet	512bits
Length of Highway	10km
radio range	250m
Target speed of a vehicle	120km/h
Number of channels	3
Segment length was monitored	1km

We are interested in the following metrics:

- Number of nodes covered by a VSCluster,
- Number of failures VSClusters,
- Average speed & Number of VSClusters

Figure 8. explains that the number of broken paths increases with the density of vehicles, so, we can conclude that mobility increases with traffic density.

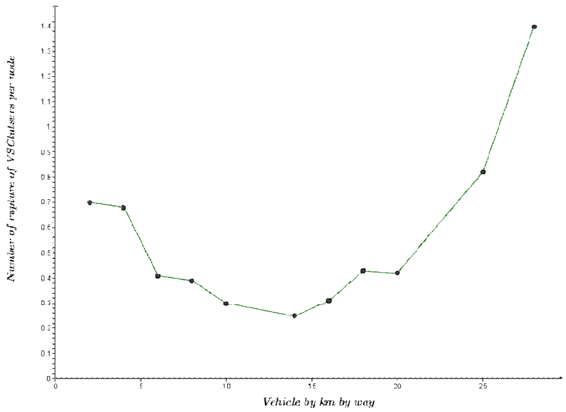

Figure 8. Number of rupture of VSClusters per node depending on traffic density

The objective of forming VSClusters is to get the least possible clusters' number, so the largest clusters possible. However, the number of broken VSClusters depends on the size of VSClusters.

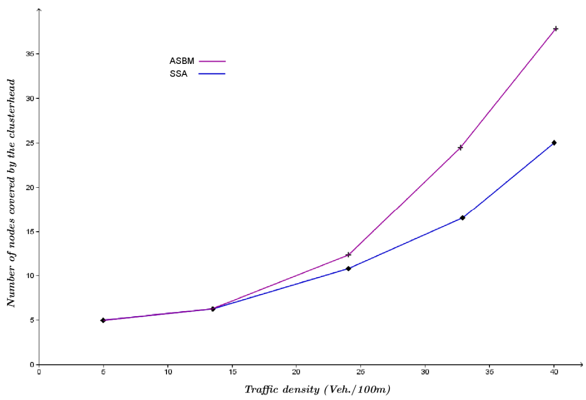

Figure 9. Number of nodes covered according to the traffic density

In clustering, the essential point is to form a small number of clusters, each of which includes a large number of nodes. Indeed, cluster forming on the basis of ASBM is shown in Figure 9, in this way we minimize the contact with the vehicle sensor infrastructure.

8.2 Protocol for sending information about traffic conditions to the driver

A driver should have information on traffic conditions for various interface, either from the internet on websites dedicated to broadcast such information (eg www.infotrafic.com), also on Radio or TV stations that that care of transmitting summaries of the traffic during the day, or even better on display panels planted on highways to disseminate information on real-time traffic conditions.

We saw before that generally the traffic flow is provided by a video monitoring system, and also we presented the limitations of such solution, essentially the great mass of exchanged information, also by the need to allow various compression applications, and the task of processing the exchanged information.

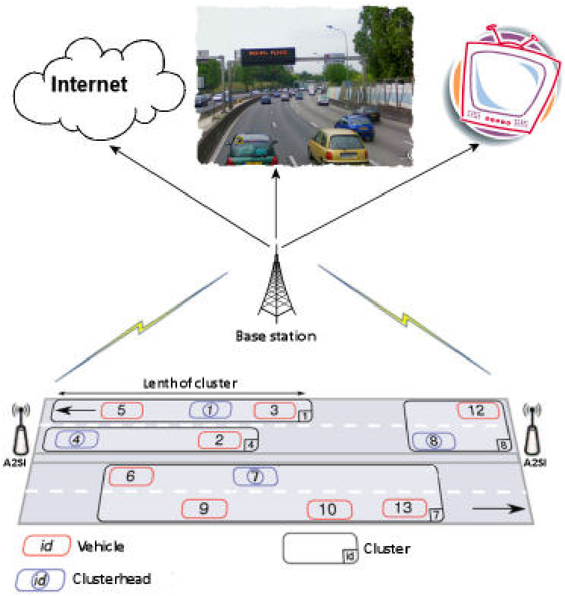

Figure 10. Information exchange from VSCluster to the driver

We propose a solution to remedy to these problems by improving the information exchange. Clearly, the information that arrives to the driver is information that comes from an observation station or base station, this station is connected to sensors that are placed on well-defined positions in a section of the highway where we are monitoring the flow of traffic that pass by.

Our contribution is based on the concept of Average Speed Smart Sensor (A2SI). The mechanism of operation of this kind of sensor is a mechanism of collaboration between sensor upstream and sensor downstream. Indeed, at the entry in the section to be monitored, the VSCluster clusterhead meets a A2SI that passes a packet to deliver to another A2SI downstream. The structure of the package is as follows:

Table 2. PACKET EXCHANGED BETWEEN CLUSTERHEAD AND A2SI

Information	Generated by
@IPs: @ IP source sensor (upstream)	A2SI upstream
@IPd: @IP destination sensor (downstream)	A2SI upstream
L: Length of the section to supervised	A2SI upstream
TR: time to receive packet	Clusterhead
TS: time to send packet	Clusterhead
AS: Average speed = L / (TS - TR)	Clusterhead

Upon receiving this packet, the clusterhead affects the time of receipt packet on the 4th field (TR). Then he keeps this packet on his storage space (hence the advantage of working with sensors). The packet will be kept until the clusterhead sensor meets with destination address mentioned in the packet. Before it passes the packet to the destination sensor, the clusterhead calculates its average speed, and uses it in the 6th field (AS). The calculated average speed is based on the duration of passage and the length of the section. We suppose that the length of the section to be supervised is known by A2SI.

Note that the calculated average speed is triggered only when the clusterhead meets A2SI downstream, it will receive, then, the packet duly completed. Information exchange between A2SI downstream and the base station is provided in a periodic manner (eg. every 5 minutes), during this period the A2SI downstream is responsible of collecting the average speeds of clusterhead that crosses it, at the end of the period it calculates the average of the average speeds of clusterheads, and this information is representing traffic fluidity to drivers. A traffic which has a fluidity of 80km/h is less charged than a traffic which has a fluidity of 30km/h.

In the context of proving the usefulness of working with clusters, and after the experiment of a group of 50 vehicles, we obtained the histograms in Figure 11 that represents the average speed of each vehicle that crosses the A2SI. The average speed of all nodes is 53.66 km/h, whereas the average is taken only form clusterhead is 51.20km/h, representing a value near the population studied, reinforcing the usefulness to work only with clusterheads, which is a choice that will optimize the interaction of nodes with A2SI.

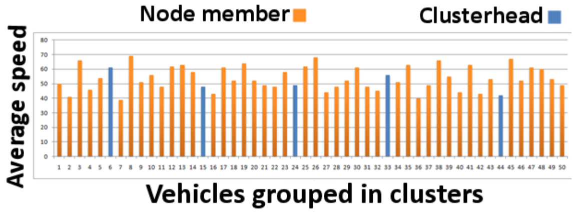

Figure 11. Representation of vehicle speed grouped in clusters

9. Conclusion

We presented an original algorithm of clustering adapted to vehicular network, called formation VSClusters algorithm. The VSCluster is formed by taking into account the quality of links between nodes. Simulations performed using a simulator of vehicular networks in a highway context showed the good stability of VSClusters (little rupture) and adequate distribution of the size and length of VSClusters. These results suggest that it is possible to exploit the properties of a VSCluster (relative stability between the nodes of a VSCluster), to manage mobility more finely. In contrast to classical hybrid Ad hoc network, it is not the node which registers individually for infrastructure, but the VSCluster that is containing nodes.

The comparison between VANets and VSNets based VSClusters remains necessary to demonstrate the real value of using a VSCluster in a vehicular highway network. It is also possible to study the intra-VSCluster services to provide services accessible by all nodes in the network, while exploiting the two-level hierarchy: VSCluster and infrastructure.

Finally, experiments on a real vehicular network would allow us to better understand the robustness of our protocol in an environment where physical phenomena (Doppler effect, multipath, interference, etc...) will cause packet loss. It would also be interesting to be aware of the mobility differences between our model and a real vehicular network on highway.

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Mr. Lyamine Guezouli is a PhD student at Department of Computer Science, University Hadj Lakhdar, Batna - Algeria. He holds a B.Sc. and a M.Sc in Computer Science from Batna. His current research aims to provide optimal routing in wireless sensor networks. He already published obtained results in international conferneces and is actively participating in research projects at Batna University

Dr. Souheila Bouam received her B.Sc. Degree in Computer Engineering from University of Batna (Algeria) in 1999, then her M.Sc. and Ph.D degrees in Computer Science and Networks from the University of Versailles (France) in 2002, and 2005 respectively. She was assistant teatcher at Versailles and Marnes la Vallées Universities (France) from 2002 to 2005. Now, she is associate professor at University of Batna (Algeria). Dr. Bouam's research interests are mainly focused on the area of wireless ad hoc and sensor networks, Qos and security in wireless networks. Her works appears in highly respected international conferences, including, IEEE VTC, PIMRC, …. She has supervised and co-supervised several graduate students in these areas.