Improving performance of Map Updates through Satellite Communications in Vehicular Networks

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In this paper, we propose to extend the WAVE Architecture with satellite, WiFi and cellular technologies. Many applications can be considered in vehicular networks which can be provided through one or several communication systems. In this paper, the map update application has been considered over different technologies. Simulations were run using NS3 simulator to compare the behavior of files downloads with 802.11p and with other technologies. The aim is to optimize the necessary amount of resource, and to determine the best combination of technologies to download maps.

I. Introduction

VANET(Vehicular ad-hoc network) technologies have received an increasing attention during the last few years. One of the most developed architectures in this domain is the Wireless Access for Vehicular Environments (WAVE). The U.S. Federal Communication Commission had granted 75 MHz of spectrum in the 5.9GHz band in 1999. This band is called Dedicated Short Range Communications (DSRC). The DSRC was dedicated to inter-vehicular communications in the Intelligent Transportation Systems (ITS). In Europe the ETSI allocated 30 MHz of spectrum in the 5.9GHz band for DSRC, in 2008.

The DSRC, has been integrated in a 802.11 working group and will use the future IEEE 802.11p standard.

The National Highway Traffic Safety Administration (NHTSA) in USA, like the ERTICO in Europe works in the ITS. The goal is to improve passenger safety and reduce fatalities.

A framework for quasi-continuous communications in a VANET environment has been created, it was called CALM (Continuous Air-interface Long and Medium range) framework. CALM provides a standardized set of air interface protocols and parameters for medium and long ranges. It also allows high speed ITS communications using one or more of several media, with multi-point and networking protocols within each media. Finally interactions with upper layer protocols enable data transfer between media. The main drawback of this framework is its complexity.

Several projects considered the use of satellite links, dedicated to high mobility environments (wireless clients moving at high speed). For instance, the SISTER project aims to use the Galileo satellite constellation, not only for location applications.

The ActMAP and FeedMAP are two examples of applications that propose map updates. However they were only developed in a unicast context. We propose to consider these two applications using the extended WAVE that includes Satellite Technology.

The paper is organized as follows: first, we describe the extension of WAVE in Section II. In section III, a typical application is described. In section IV, we analyzed the different solutions to provide this application over the different technologies. In section V, we simulate a scenario to validate the architecture.

II. Architecture

We propose an extension for the WAVE architecture (Extended WAVE Architecture), which aims to simplify the CALM Framework, allowing the interaction with other technologies besides the 802.11p. Among

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possible technologies we can highlight: WiFi, cellular networks and satellite networks because of their low cost, large deployment and/or wide coverage.

Figure 1 shows the general scheme of the extended WAVE. The main components are: Road side-unit(RSU), On board-unit(OBU)[a], Satellites (Galileo, sat-comm), terrestrial broadcast, hot-spots and cellular antennas.

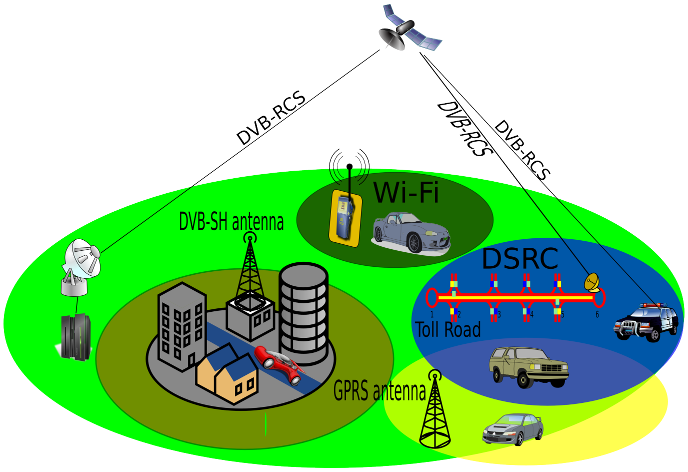

Figure 1. Extended WAVE Architecture

Several types of communications are involved in this architecture. Vehicle-to-vehicle (V2V) communications are performed with the protocol 802.11p. At high speed, vehicle-to-infrastructure (V2I) communications will also use 802.11p. When vehicles are stopped or when their speed is low, we use 802.11 a/b/g. For non-delay sensitive applications, satellite network can also be considered. When interaction is needed, we can also use cellular networks (GPRS, UMTS), which can also be used, when there are important data to transfer (for example for safety applications when an accident occurs far from an RSU) or when others technologies are unavailable.

802.11p technology works is suitable for safety applications in V2V and V2I, but the available bandwidth can be used for non-safety applications such as entertainment, Internet on board, File sharing, etc. The study [1] shows that this technique should be quite restricted especially in dense areas due to the performance constraints of safety applications.

For instance, in France, highway information boards are deployed every 15km([b]). This distance will be considered in the present paper between consecutive RSU. Dimensioning techniques should be further performed to derive accurate value of this parameter.

A. The technologies

WiFi technology can be used when the vehicle is parked, above all in service areas. On the roadways in France there is one service area every 15km. WiFi can be used to provide various services to clients such as a new type of advertisement presenting the list of available services (menus of the restaurants, shops, multicast television ...).

In this architecture, the satellite can be used for multimedia broadcast applications (radio, TV) where there is no need of return channel, and also for applications that are not related to multimedia, such as updates, which benefits from the great coverage of satellites. Map updates or software updates need to perform mass updates. To run interactive application with the satellite we need an up-link channel. GPRS or UMTS can be used. A return channel by satellite can also by considered specially for emergency vehicles because of its cost and the size of the antenna.

Cellular networks such as GPRS or UMTS, can be used as the upstream channel for a satellite network, when other technologies are not available. The amount of data transmitted on these networks should be controlled because of their cost even if their coverage is large (99% in France).

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[a] Defined in the the standard specification for IEEE 802.11p

[b] http://www.autoroutes.fr

B. The extensions

To use the WAVE architecture with the various proposed technologies, several changes must be considered. One of them is to add functions to the WME layer, which allows the selection of the technology that will be used. The transmission depends on several parameters: the type of application, the cost of transmission, the availability of technology, the signal level, and so on.

C. The gateway

The idea is that each client (RSU) acts as a gateway and can send important data through other available technologies. For example, let us consider the case of a damaged vehicle which is only equipped with 802.11p and that is isolated. When it enters in the coverage radius of a vehicle that can both access to GPRS and 802.11p, the damage vehicles can send it subsequent messages. If data is time constrained, it forwards data through its GPRS interface to help center.

In fact, the aim is to provide reliable communications regardless the technologies used. Multimedia data can not be treated in the same way because of the additional cost which would be charged to other vehicles.

III. Proposition

We will focus on map synchronization application. We will assume that the provider needs periodic updates a global map. This map is used by a large number of clients disseminated within a large area. The maps are used by a very large number of applications in the vehicle. There are actually two main issues: the size of the maps and the frequency of their updates, because of the number of vehicles. The first problem can be solved by performing a first download of the maps from a CD. However, in the case of updates, this technique is not feasible. A better solution is to use a wireless connection according to the possibilities of the vehicle. There are several alternatives such as: 802.11p, WiFi, cellular networks and networks via Satellite, each option has advantages and drawbacks.

- **Type of communication:** From the application's point of view, it a one way communication. The map center may send maps when there is a new map update, as shown in figure 2.
- **Coverage** A large coverage is expected. Updates should reach all the vehicles at the same time. Broadcast technologies can be used for this purpose.
- **Latency** Weak time constraints. The delay is acceptable if it is between a few seconds and several days. It may depend on the application that uses the map.
- **Rate download** It has to be quite important due to the amount of transferred data.

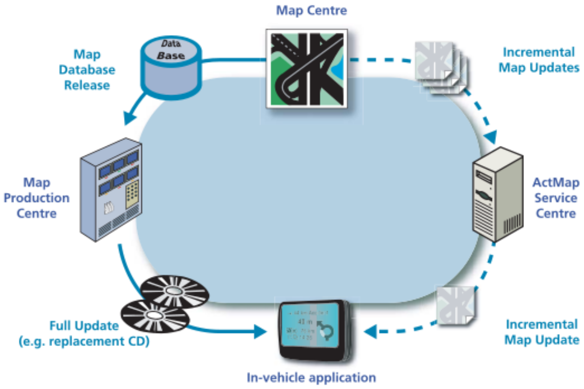

Figure 2. Map Updates [2, p. 4]

IV. Evaluation

A. The update application with 802.11p

Many solutions were proposed to evaluate and improve its performance, for instance [3], [4], [5] and [6].

Their advantages are its low connection cost and its high throughput with regard to other technologies such as GPRS, UMTS or DVB-SH. However, this technology can not cover the entire road. RSU unit can cover approximately a mile (see figure 3).

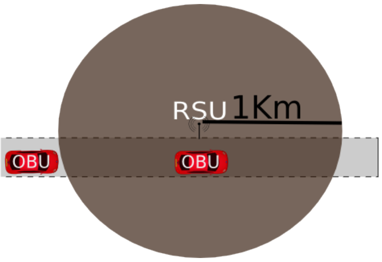

Figure 3. Coverage of 802.11p

The deployment of a RSU every mile is too expensive and will lead to a waste of resource. The highway information boards are placed every 15km in France. We propose to locate the RSUs with them. Their coverage area is 2km (theoretically). The uncovered area is the distance between RSUs least the distance of direct coverage, see figure 4. Communication between vehicles is considered in this area, as shown in figure 5.

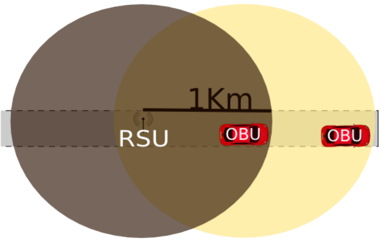

Figure 4. Access the RSU through an OBU

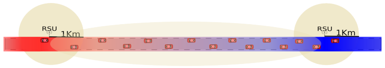

Figure 5. Access the RSU closer through several OBUs

A vehicle traveling at a speed of 130kmph can communicate during 55 seconds with the RSU (direct communication). During the following 360s, communications can only occur through OBUs (indirect communication). Theoretically if the OBU is connected during this period and if 10% of the bandwidth is dedicated to applications that are not safe (over all in dense areas), we can download 148Mbits (with a bit rate of 27Mbps). Considering the document produced by the Project SISTER, the maximum data size to download is 1,000,000 bytes (8Mbits) and latency is given in hours. 802.11p can easily fulfill this task (of course, it may depend on the traffic density). Moreover, a vehicle may have the opportunity to use several RSUs along highways.

This short-range technology (1 km radius) offers the opportunity to update local[c] temporary maps (for example, speed warnings may fluctuate due to road conditions, weather, etc.). Temporary maps contain local information that is only useful for vehicles located in the area. However, it has no overall scaling (to a region or a country). If we intend to update the entire vehicle population[d], the optimal solution will involve

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[c] The update also included maps of road signs

[d] In France there are 595 cars per 1000 inhabitants and there were 63,195,000 inhabitants (2006 statistics), so there are more than 37 million cars (previous site http://www.statistiques-mondiales.com/france.htm)

a technology that is scalable.

If we consider applications such as FeedMap[e], we can use 802.11p technology, because, it provides an up-link channel without cost to the user. The update FeedMap has no time constraint and does not need a high speed.

B. The update application with WiFi

WiFi technology leads to the best performance when the mobile unit is parked. Service areas on motorways (every 15 km[f]) can offer this access. Cars will be parked at least during five minutes. It leaves enough time to update maps. Theoretically, there may download up to (54 Mbit / s * 300s) = 16200 Mbits. It is sufficient to update a map.

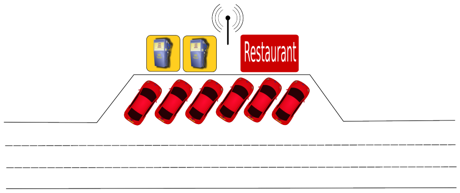

Figure 6. WiFi access in service stations

There is however a drawback, since it will operate in unicast. Thus, for each vehicle that enters the service area and that does not have the latest update, the download process should be done. Moreover WiFi is not scalable. For example, the bandwidth will be shared among all the vehicles. Consequently, it seems preferable to use this technology for local data such as maps of service area, services, advertising, etc.

The document [7] shows that, with 802.11a, we can operate at low speeds between 7kmph and 45kmph, with a coverage radius of 500m radius. With a speed of 45kmph we have a connection time of 40 seconds to deliver the advertising of the area.

In a VANET environment, WiFi can be used within a service area where lots of vehicles are parked or move at low speed. On the other hand, 802.11p ensures good performance even for high speed vehicles. The satellite can help to build a scalable ITS architecture when we need to disseminate a single set of data (like a map) to hundreds of customers. Finally cellular networks have a large coverage that could be used when there is no coverage achieved by the aforementioned technologies but also as upstream channel for interactive satellite connections.

C. The update application with Satellite Network

This technology has a great advantage: it is scalable. Regardless the number of vehicles, it continues to operate in the same way [8] because it broadcast messages. Thus, client can receive and decode data. The disadvantage is that data may not be received. Even if a correction mechanism such as MPE-FEC is implemented, the receiver may either be in a white areas[g] or inactive.

In such a context, document [9] proposes to implement a mechanism of repetition. We propose to apply a more aggressive approach using unicast if the map is not updated after a certain delay.

Consequently, we could reach vehicles that did not receive the information. Unicast transmission can also be used to download previous versions if we know that lack one or more versions between the last and the new update (see figure 7). There are other ways to detect the absence of a version such as questioning neighbors through 802.11p technology (we could use this technology to the update) or a server via GPRS or UMTS, or through the wireless network if the vehicle is parked.

This technology is excellent for the maps update application ActMap, since it can send updates to all vehicles with minimal use of bandwidth.

Document [9] presents different aspects of ITS Applications using this technology, such as the applications covered (Map updates, Customized Point of Interest updates and Traffic Information), the system architecture, the critical factors and the bandwidth estimation.

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[e] FeedMap is used to update a map of “service center” of “ActMAP System” when an abnormality detected by a vehicle

[f] http://www.autoroutes.fr

[g] zone where there is no signal from either satellite or terrestrial repeaters, such as underground garage

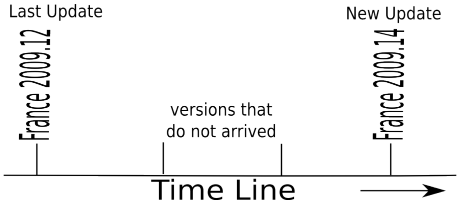

Figure 7. An example of map updates

D. The update application with the Cellular Network

The use of this technology in the context of our application has many drawbacks. The most important one is its cost due to the amount of data involved. Moreover, it is mainly a unicast technology. Each customer (37 million of cars) must periodically ask the server for the availability of an update. As communications are unicast, a connection will be provided to each vehicle. It will saturate both the network and the file server, because of the amount of customers. The great advantage is that operators have high GPRS coverage. Consequently, vehicles are able to receive updates wherever they are. This could be used for high priority updates.

V. Simulation Scenario

Using NS3 framework, we will estimate the amount of data that could be sent with 802.11p, using a TCP connection under different traffic densities. We will simulate the system with and without Nakagami Propagation Loss Model (Fading loss) and Three Log Distance Propagation Model (Path Loss). To provide confidence intervals, we simulated 20 replications of 600 seconds each.

A. Simulation parameters

The following values of the parameters have been considered. The vehicle density varies between 20000 and 100000 CUD (car unit per day). The data rate is equal to 3mbps with a threshold of -85 dbm. We use a simple mobility model, with a straight line of 900m and a single RSU (see figure 8). Vehicle speed is uniformly distributed between 20mps (72kmph) and 36mps(130kmph). Vehicle traffic is supposed to constitute a Poisson process. We used the constant speed propagation delay model, the three log distance propagation loss and the Nakagami propagation loss model.

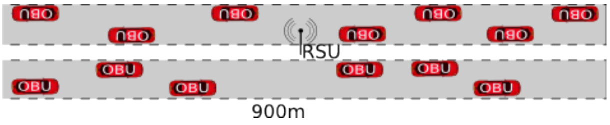

Figure 8. Simulation scenario

B. Propagation Loss Model

1. *Three Log Distance*

For the Three Log Distance Propagation Model the following parameters have been considered:

Parameter	Distance 0	Distance 1	Distance 2	Exponent 0	Exponent 1	Exponent 2	Reference Loss
Value	1m	200m	500m	1.9	3.8	3.8	47.8588

The Reference Loss is calculated with Friis propagation model at 1m with 5.9 GHz.

2. Nakagami

Parameter	Distance 1	Distance 2	m0	m1	m2
Value	80m	200m	1.5	0.75	0.75

C. Simulation results

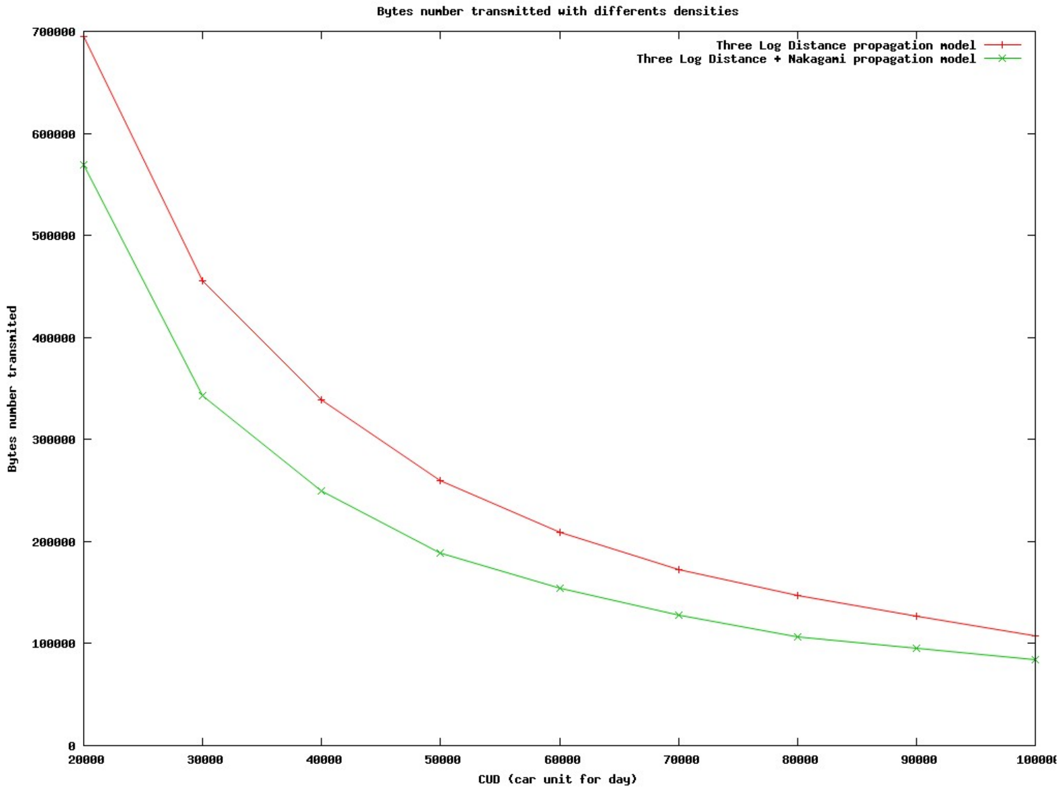

Figure 9. Simulation: Results

With a traffic intensity of 20000 CUD, the mean number of vehicles within the area is equal to 8. If we suppose that we download an incremental map of 1MB (through satellite) and that 10% of packets are lost, this technology can be used to download and complete the map update. Even with a traffic density of 100000 CUD (40 vehicles at the same time), we get the same result.

VI. Conclusion

In this paper, we proposed an extension to the WAVE reference model in order to allow several communication system according to application constraints, coverage, traffic density... for ITS. It has been shown that the map update application can benefit from the satellite environment with the help of its great coverage, and its ability to perform mass updates (map updates, software updates). Vehicles could also use a satellite link for interactive applications, with the help of an up-link channel, through GPRS, UMTS, or RCS+M (return channel satellite).

Several scenarios have been considered in this work. It is shown that satellite broadcast has a good performance results for this type of applications. Satellite communications also help other technologies such as 802.11p or WiFi to alleviate overloads due to the downloading of map updates with TCP and unicast. Moreover these technologies can help the satellite to download the chunks of a map which can not be downloaded by satellite because of white areas or bad receiver conditions.

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