Map Update Application: Performance measurements on a Highway Scenario

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***Abstract*—Road maps are important for several applications in vehicular networks. As a consequence, an updated map is essential for a proper behavior of such applications. In this paper, we focus on a map update application based on an infrastructure-to-vehicle communication with a high mobility. In order to understand the application's behavior, we analyze different performance criteria: System Goodput, Packet Delivery Ratio, Delay, Fairness, and Fragmentation. We compare the application's QoS behavior with three different flow densities (overloaded system, maximum system capacity, and under saturated system) and determinate a trade off between bandwidth (spectrum efficiency) and performance.**

***Index Terms*—Wireless networks, VANET, unicast, System Goodput, Performance Analysis, Fragmentation.**

I. Introduction

Vehicular ad-hoc network (VANET) 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, ETSI allocated 30 MHz of spectrum in the 5.9 GHz band for DSRC, in 2008. DSRC has been integrated in an 802.11 working group and uses the IEEE 802.11p standard.

The National Highway Traffic Safety Administration (NHTSA) in USA, as well as ERTICO in Europe are involved in ITS. Their goal is to improve passengers safety and reduce fatalities through safety applications. We believe that ITS technologies can also be used for non safety applications.

A map is an important element for several applications, specially for some safety applications and the Advanced Driver Assistance Systems (ADAS). Thus, an up-to-date map is an essential requirement for decision making in those applications. ActMap [1] is a European project that develops and proposes mechanisms to deliver incremental map update. A map update application is a specific kind of content download application.

Content downloading is studied by [2] using infrastructure-to-vehicle (I2V) and vehicle-to-vehicle (V2V) communications. It defines the traffic as best-effort and considers a general case, where each downloader is not interested in the same content. This work has been focused on finding the maximum downloading performance achievable in a vehicular context, based on the number of Access Point (AP) deployed in an urban area of $20km^2$.

A preliminary work [3] analyzes a map update application on different technologies including 802.11p. It concludes that a satellite link is a useful communication mean for such application. 802.11p could be an alternative way to download the lost parts of a map. This study builds upon the concepts of this work.

The purpose of present paper is to determine in which conditions a large number of vehicles, spread among a highway section, cans download some missing map chunks. System efficiency and fairness metrics are used to determine the feasibility of 802.11p as a "second chance" delivery network.

The study examines the amount of data that a vehicle (OBU, On-Board Unit in WAVE terminology) could receive from a server application, under different circumstances using unicast. The objective is to achieve an optimum flow control and QoS adjusting certain parameters. A map update application will try to download the lost parts as fast as possible. Thereby, in a specific time every OBU generates queries (with the lost parts) to the server.

The rest of this paper is organized as follows: the architecture, scenarios and parameters are settled first in Section II. Theoretical and simulated evaluation of the System Goodput (SG) is then performed in Section III. Results are analyzed in Section IV. Section V concludes this paper and gives some outlooks on the future works.

II. Architecture, scenarios and parameters

A. Architecture

The architecture considered is shown in Figure 1. It encompasses the following elements: (1) an 802.11p wireless access network on a highway section covering the OBUs and RSUs, (2) an access network between the RSUs and an application server and finally (3) a content provider which hosts the available applications in application server, in this case, a map update service center. A Constant Bit Rate (CBR)/UDP based application is considered because of high mobility and short connectivity duration. UDP is used because its better performance on wireless medium[4].

B. Topology

Highway consists of two ways and two lanes per way. It is a straight line of length L. A single RSU is located in middle of

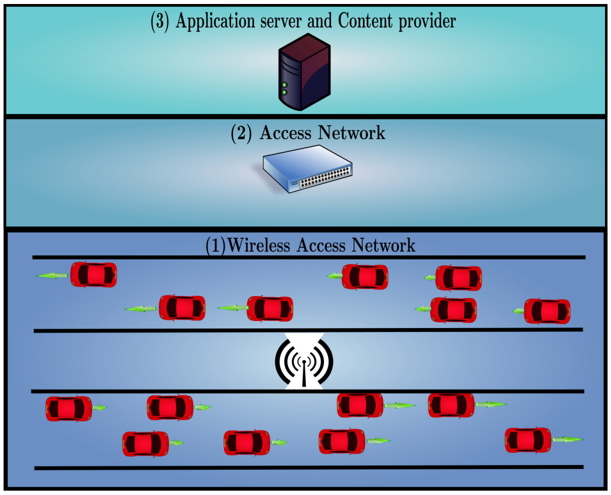

Fig. 1. WAVE architecture

highway. A basic mobility model is used, each vehicle enters the highway with a random speed s according to an Uniform distribution with mean $\bar{s}$. The inter-arrival time between OBUs is given by an exponential distribution with mean λ. Lane is selected conforming to an Uniform Distribution between 1 and the number of lanes l.

To calculate car flow rate q (The rate at which vehicles pass a fixed point, vehicles per hour) from density (per kilometer) d, the fundamental equation of traffic flow $q = \bar{s} * d$ [5] is used. The inter-arrival time λ is calculate from equation $\lambda = 1/q$. The values of parameters are presented on table I.

TABLE I
HIGHWAY PARAMETERS

L	$2000m$
l	4
$\bar{s}$	$36m/s$
s	$\mathcal{U}(32m/s, 40m/s)$
d	$10, 20, 30, 40veh/km$

$36m/s$ is approximately $130km/h$. It is the limit speed on highways in France.

C. Scenarios

The content provider supplies a map update application. It has been modeled as a CBR to improve fairness, QoS, and to simplify the model. Server sends data to OBUs through a single RSU. Transmission data rate on each flow is constant and equal to r. We thus assume that if C is the channel capacity, $r = \frac{C}{d}$. Study assumes that OBUs are only receivers, therefore there is one sender, which is the RSU. Three system scenarios has been implemented:

- First scenario is an overloaded system. Application transmits using the maximum data rate of wireless medium (C). This scenario is used as a reference for data delivery ratio.
- Second scenario uses maximum system capacity which is given by SG (see section III). The problem is that it depends on different parameters. This value can be obtained through analysis (section III-A) or simulation (from first scenario, see section III-B).
- Third scenario is an under-saturated system. The application does not take advantage of full system capacity. It evaluates the impact of congestion in second scenario.

D. Parameters

The parameters in table II are used in both: analysis and simulation.

TABLE II
PARAMETERS

Parameter	Value
PSDU	1088 bytes
Payload	1024 bytes
UDP header	8 bytes
IP header	20 bytes
MAC header	36 bytes
PHY header	3 bytes
PHY preamble	$32\mu s$
ACK & CTS	14 bytes + PHY header & preamble
RTS	20 bytes + PHY header & preamble
Symbol Duration	$8\mu s$
Channel Bit Rate	$C = 3Mbps$
Signal Reception Threshold	$-85dbm$
Modulation	OFDM BPSK
Coding Rate	1/2
Access Method	RTS/CTS
Output Power	28.8 dBm(Device Class D[6, I.2.2])
Antenna Gain	6dBi[6, I.2.2]
Propagation Delay (σ)	$< 4\mu s$
Slot Time	$16\mu s$
SIFS	$32\mu s$
DIFS	$64\mu s$

Three log distance propagation loss model and Nist error rate model are used [7]. No fading loss model is considered.

This work focuses on different QoS metrics: Packet Delivery Rate (PDR), delay, fairness (using Jain's fairness method [8]) and fragmentation (with a metric coming from percolation theory [9], [10]).

Those performance metrics are evaluated as a function of data rate at application layer. The three scenarios, mentioned above, are used to compare the proposed measure indicators.

III. System Goodput Evaluation

Goodput S is a criterion that helps to know the useful information delivered at application layer per time unit (payload data rate). It does not take into account retransmitted packets and overhead.

In an analytical model S is a relation between the payload and resources needed to transmit this (overhead from physical to network layer), System Goodput SG_a is equal to S.

On simulation, System Goodput SG_s is the average of set $\mathbb{SG}$. Each element of set $\mathbb{SG}$ represents an Aggregate Goodput or System Goodput (SG) at time t. Aggregate Goodput is the sum of Goodputs S of all OBUs that participate at the same time unit. Goodput S is a normalized value between data received at application layer and bandwidth used (C), see equation (1). SG_s gives a value between 0 and 1 that represents the percentage of bandwidth used by the payload.

$$SG_s = \frac{\sum_{i=1}^{t} \mathbb{SG}_t}{n} = \frac{\sum_{i=1}^{t} \left(\sum_{j=1}^{n} S_{nt} \right)}{n} = avg(\mathbb{SG}) \quad (1)$$

A. Analytical model

Many analytical models of 802.11 DCF have already been published [11], [12], [13], [14] and [15]. Many papers are extensions of the well known Bianchi's model [16]. These works try to give a better approximation of the reality. Our study is based on Bianchi analysis, which does not take into account an imperfect channel and the mobility of nodes, the number of nodes in the highway is not actually constant (nodes enter and leave the system). This model represents a saturated channel behavior through a Markov chain analysis. It is used with 802.11p parameters that are depicted in table II. Our objective is here, to calculate the Goodput values for each car density. Modifications were done to calculate SG instead of system throughput. The procedure shown in [17, section 17.3.5.3] was used to integrate OFDM (Orthogonal Frequency Division Multiplexing) instead of DSSS (Direct Sequence Spread Spectrum).

Hereafter, a little explanation of Bianchi' model is given. The model normalizes two values in time unit, based on the probability transmission success (P_s) and the probability that there is at least one transmission per slot time (P_{tr}): The first value is derived from the payload size ($E[P]$), expressed in time units, and both probabilities ($P_s * P_{tr} * E[P]$). The second value is the sum of three values: the first one is the probability of an empty time slot ($(1-P_{tr})\sigma$) where σ is the time slot size, the second one is the time taken by a successful transmission ($P_s * P_{tr} * T_s$) and the final value is the time taken by an unsuccessful transmission ($(1 - P_s) * P_{tr} * T_c$). A successful transmission using RTS/CTS includes RTS, CTS, data, and ACK PPDUs. An unsuccessful transmission only uses the RTS PPDU (The model takes only into account the errors due to collisions). The normalization gives us a relation between the proportion of time used by the payload, and the total time used by the access mechanism including overhead.

Bianchi analysis assumes that all clients (RSU or OBU) send and receive data (there is always a packet to transmit in the queue of each client). But, with the application proposed above, the only client that saturates the medium is the RSU. Thus, a SG_a value of 0.78 is given by equation (2).

$$S = \frac{P_s P_{tr} E[P]}{(1 - P_{tr}\sigma + P_{tr} P_s T_s + P_{tr}(1 - P_s) T_c)} \quad (2)$$

B. Simulated model

NS3 is used to do simulations. As already stated, first scenario is an overloaded system. It is used to estimate SG_s. The results of first scenario are compared with those of analytical model SG_a in order to tune second scenario.

First scenario gives a SG_s value of 0.66 (useful bandwidth at application layer), with a negligible impact of car density. There is a big difference $\mathcal{D}$ with regard to Bianchi's analysis. However, $max(\mathbb{SG})$ value is close to SG_a value.

The problem of vehicle density variation is the requirement of instantaneous information. That information helps to optimize the use of bandwidth, but is not taken into account on simulation. Data rate r is calculated at beginning of simulation using the desired car density. Thus, the target car density (d_d) and the instantaneous car density (d_i) are different.

There are three behaviors of the aggregated data rate: (1) when $d_i = d_d$ the OBUs uses the maximum data rate of medium, (2) when $d_i < d_d$, bandwidth is not totally used, and finally (3) when $d_i > d_d$, the maximum data rate is used but there are lost packets because the system is saturated (maximum values of $\mathbb{SG}$ set are presents). Consequently, SG_s is away of $max(\mathbb{SG})$. To achieve an optimal SG_s value, the flow data rate from the application server should be adapted to the instantaneous density. For this purpose, a scheduler system on application layer can be used.

To verify this hypothesis, a static scenario has been analyzed, and results compared with those of analytic model. Resulting on a difference of less than 1% at both: analytical SG and $max(\mathbb{SG})$. Later on, a scenario with constant speed and constant car flow rate (like a conveyor belt) has been evaluated. SG value is further from that obtained analytically but still different for less than 1%. Hence, there is no important difference between static and conveyor belt scenarios. It has been determined that difference $\mathcal{B}$ is due to the variation on vehicle density, which depends on vehicle's speed and car flow rate (q), and the scheduler used by application server.

The second scenario takes the result value SG_s from the first scenario (0.66), and the third scenario takes an arbitrary value less than last one (0.56). Thus, application layer sends respectively with 66% and 56% of wireless medium data rate.

IV. Results

This section describes some results obtained through simulation. We will focus on PDR IV-A, delay IV-B and fairness IV-C. We have also measured fragmentation IV-D. This metric is not relevant as far as a map update is considered, but it is an important result for initial whole map transfer, for example.

A. Packet Delivery Ratio (PDR)

It is obvious that when the system is overloaded, there are packets sent by the server that OBUs do not receive. Figure 2 illustrates the PDR impact on three scenarios. In first scenario is received a mean of 68% of packages which means a Packet Loss Rate (PLR) of 32%. The second scenario searches to minimize the PLR while maximizing the medium utilization. The results show this achievement, but anyway there is a PLR of 4%. The last scenario shows a PDR of 100%.

Appropriate congestion control mechanisms are essential to maintain the efficient operation of a network. Specific challenges need to be addressed in order to ensure congestion control within vehicular networks [18]. To improve communication, server application needs a continuous information feedback from the RSU, e.g. RSU sends the current number of vehicles to the server application. Once the application has received the information, it adapts the transmitted data rate. Other alternative is to use a scheduler application with a fairness criteria, this application needs the current available data rate at RSU. Then, RSU sends as a control information its available data rate, this could be measured taking into account the number of bytes sent per second and backoff information. However flow control falls outside the scope of this study.

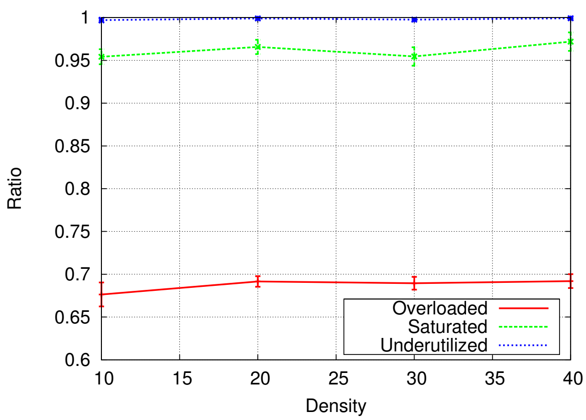

Fig. 2. Packet Delivery Ratio (PDR) vs Car Density

B. Delay

Figure 3 illustrates clearly the impact of *data traffic density* on the delay (each scenario has been chosen with a very specific density). It is thus important to find a maximum value of data traffic density; it allows exploit wireless medium with an affordable QoS, not necessarily the best. We can see that an overloaded system has a delay higher than 1 second. In fact, the delay depends on queue size (by default in our model the queue size is 500 packets). This parameter has an impact on real time applications but not in content download applications.

According to the results, there is not impact of car density on the delay for a given scenario. It is true when data rate is adapted in accordance with car density such as $r = C/d$. Of course, a constant non adaptive data rate would lead to a very different result.

C. Fairness

As shown in Figure 4, fairness is not impacted by car density and is fairly good. Anyway, it is more unfair when an overloaded system is used. The scheduler at application server sends packets with the same inter-arrival time to OBUs. The unfairness is introduced when the packets are drop from an overload queue at RSU.

The third scenario is not perfectly fair, even if it does not have drop packets. Unfairness, in this case, is the consequence of mobility. If an OBU goes faster, it has less time to download data. Therefore, fairness is affected by: mobility and packet losses.

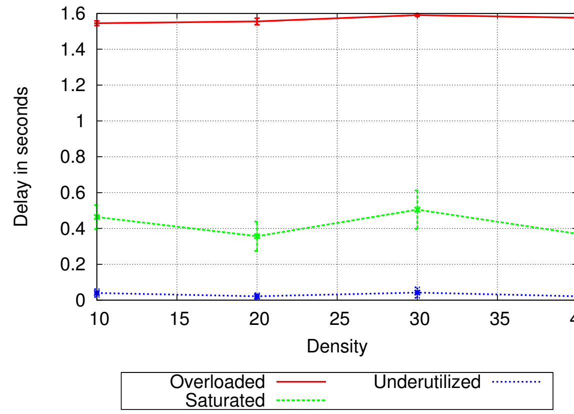

Fig. 3. Delay vs Car Density

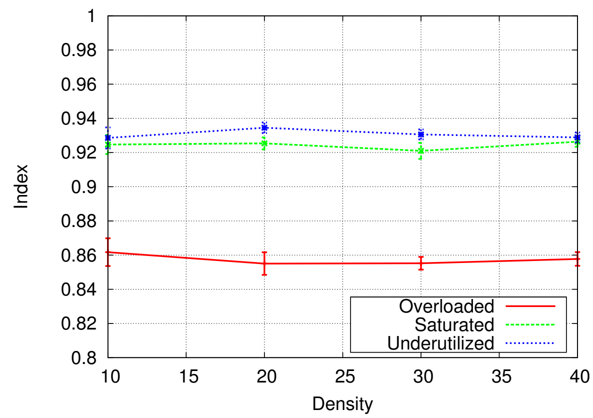

Fig. 4. Fairness vs Car Density

D. Fragmentation

Applications usually require an entire file to use it. Other applications like map update could use downloaded data to operate, however it requires a certain number of continuous data. The data fragmentation level is estimated through the fragmentation measure (1 is the best, not fragmented; 0 is the worst, very fragmented). Figure 5 shows the fragmentation measures for each scenario. It also shows the optimal curves; for which there is no fragmentation (all the received packets were in sequence, no gaps between them but all the last packets are lost). In this way we can have a better idea of the fragmentation taking into account the packet loss ratio. In this sense, we can see that this index is very affected by the *data traffic density*.

V. Conclusion and Future works

The four measures presented are important for a good perception of a WAVE system behavior. Indeed all the measures in an overloaded system are not acceptable, and these results demonstrate that a flow control is important to the communication, and the number of CBR application connections has to be restricted and managed by the RSU to keep an acceptable QoS in other applications.

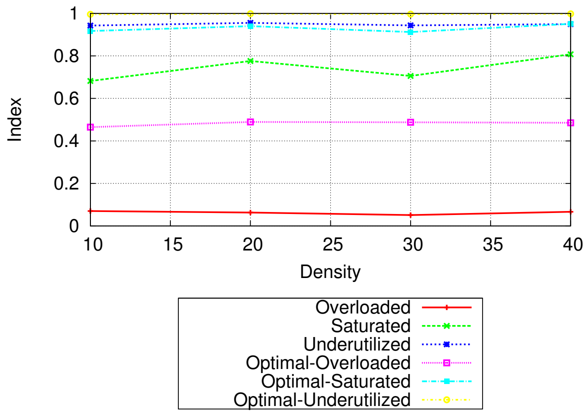

Fig. 5. Fragmentation vs Car Density

Most content download applications are best-effort applications. However a map update application has to add an extra element, this element is the fairness. Fairness could be managed by the RSU or the server application using a scheduler method to send the same amount of data to each vehicle. But this scheduler needs information from the RSU such as: the number of vehicles near the RSU and the available throughput for the application.

We have shown that a good quality of service (with a high fairness) could be achieved with the help of a basic congestion control mechanism. A simple feedback mechanism, based on information gathered by RSU, should give best results.

In this paper, we use Bianchi's model. It exhibits an overestimation of SG_a with respect to SG_s. It is due to the instantaneous density (mobility model) and the used scheduler. But, it shows a close estimation in regard to $max(\mathbb{SG})$, it means that the model is accurate in predicting the system goodput and with a better scheduler method we could improve SG_s.

In a future work we search improve the simulation method by adding a realistic mobility model like IDM/Model and compare the results with a simple mobility model. The implementation of IDM/model was presented in [19]. We analyze the implementation of module ns-3 TraCI[20] to communicate with Simulation of Urban MObility (SUMO[21]).

Another possible work is the impact study, on fragmentation, fairness and PDR, of fading. The goal is to study the improvement of a broadcast and an unicast application in a dissemination context, especially with regard to the fragmentation.

VI. Acknowledgements

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