Advertising Roadside Services using Vehicular Ad hoc Network (VANET) Opportunistic Capabilities

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***Abstract*—Vehicular Ad hoc Networks (VANETs) support a large number of Intelligent Transportation System (ITS) applications, ranging from safety to non-safety purposes. Non-safety applications encompass comfort, infotainment and marketing of services. In order to promote business, alongside roads and highways, and reach to maximum number of customers, the Business Managers (for instance: gas stations, restaurants, hotels, parking lots, coffee shops, supermarkets, etc.) would need a mechanism to advertise their services using a third party broker. Moreover, travellers (drivers, passengers) would need an efficient and cost effective way to discover these services, during their trips. However, the unique characteristics of VANETs (e.g., dynamic topology, high speed and densities, short inter-contact time, etc.) make the deployment of such applications a challenging task. This paper describes the use of the Opportunistic Service Discovery Protocol (OSDP) –a beaconing based protocol for roadside services discovery. We performed extensive simulation experiments to evaluate the performance of different phases of OSDP, under different traffic densities. The results concluded that: a) the number of advertisement packets, in a given region by different Road Side Units (RSUs), effect the success rate of receptions by moving vehicles; b) short inter-contact times (of around 1s) seem to be sufficient for a fast moving vehicle on a highway to receive at-least 70% of the advertisement packets from RSUs; c) the success rate of receiving response packets is highly affected by the density of neighbour vehicles; d) the model suggests that the system can be used to simulate several business models, including a number of advertisement points, their distances to the business's premises and duration that the packets are stored in the cache, etc.**

Keywords-Vehicular Ad hoc Networks; Opportunism; Services Advertisement; Roadside Services Discovery.

I. INTRODUCTION

Vehicular Ad hoc Networks (VANETs) play an important role in Intelligent Transportation System (ITS), by enabling Vehicles to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications. It has become an emerging field of research by gaining attention from different standardization organizations, government agencies, auto-mobile industry and research communities. The Federal Communications Commission (FCC) has already granted 75 MHz of bandwidth, in the 5.9 GHz band for exclusive use of VANETs. The allocated spectrum is called Dedicated Short Range Communication (DSRC), which enables high speed, short to medium range wireless communications (up to 1000m). The spectrum is divided into seven channels of 10 MHz each. The most important channel is the Control Channel (CCH), which is restricted for the use of safety applications and service announcements. The remaining channels are known as Service Channels (SCHs) [1][2]. VANET consists of many components. The most important components are: On Board Units (OBUs), mounted in vehicles, and Road Side Units (RSUs), installed at fixed locations alongside roads and highways [3].

The Institute of Electrical and Electronics Engineers (IEEE) has developed a system architecture for VANETs called Wireless Access in Vehicular Environments (WAVE). WAVE supports two different protocol stacks: Internet Protocol version six (IPv6) and WAVE Short Message Protocol (WSMP). For Physical (PHY) and Medium Access Control (MAC) layers, an amendment has been made to the 802.11a protocol, called IEEE 802.11p. Similarly, IEEE 1609.4 is standardized for coordination among multi-channel operations. Details about these protocols are provided in [4].

Apart from IEEE 802.11p –the de facto standard for VANET– the Long Term Evolution (LTE), developed by 3rd Generation Partnership Project (3GPP), is considered to be a competitor technology for V2I communications only. Its advantages include: high data rate, low latency, support for high mobility, large coverage area and support for Internet based applications (e.g., live streaming, Voice over IP, online gaming and cloud services etc.). However, the LTE does not support V2V communications. A detailed survey about the strength and weakness of LTE and LTE-Advanced (LTE-A), for V2I communications is presented in [5].

In addition to the standardization efforts from IEEE, the European Telecommunications Standards Institute (ETSI) also constitutes a technical committee for VANET communications. The standard developed by the committee is know as ETSI ITS-G5 [6]. Like the WAVE architecture, the lowest layers of ITS-G5 are based on IEEE 802.11p, with its own channel access and usage algorithms [7]. Unlike the WAVE standard, ITS-G5 has no support for WSMP; instead it uses multi-hop geographical routing. Moreover, the standard did not specify support for WAVE Service Advertisement (WSA), which is used for service announcements in WAVE architecture.

These standardization efforts have created a great deal of opportunities for the deployment of a large number of applications. Broadly speaking, these applications are divided into two categories: safety and non-safety applications. Safety applications would ensure safety of lives and properties on the roads, by reducing accidents. On the other hand, the non-safety applications would make the travelling experience, for both the drivers and passengers, more enjoyable, by providing access to a large number of services. In this paper, we tackle the challenge of near-by roadside services advertisement and means to discover them by the travelers.

The rest of this paper is organized as follows. Section II gives an overview of the related work. Section III presents our system model. A motivational scenario is provided in Section IV. The different phases of OSDP are briefly discussed in Section V. Experimental setup is explained in Section VI. Results and Discussions are presented in Section VII. Section VIII concludes this paper, with some future directions.

II. Related Work

In order to promote business and reach a maximum number of customers, the Business Managers (for instance: gas stations, restaurants, hotels, parking lots, bars, supermarkets, etc.) alongside the roads and highways would need a mechanism to advertise their services using a third party broker. Moreover, travellers (drivers, passengers) would need an efficient and cost effective way to discover those services during their trips. To address the issue, different studies regarding service discovery in VANETs have been conducted.

In [8], the authors studied the problem of providing information about the traffic and road conditions to the drivers. To address the problem, they offered an application layer, location based protocol called Vehicular Information Transfer Protocol (VITP). The vehicle requesting the service sends a query towards the target region using multi-hop transmission. Once the query is received by a vehicle inside the targeted area, it is resolved by the peers and the response is sent back towards the source region, where it is broadcast by the underlying network protocol. However, their protocol is not capable of dealing with dense traffic scenarios and large number of requests.

An Address Based Service Resolution Protocol (ABSRP) was proposed in [9]. The authors used IEEE 802.11a wireless interfaces for communication, and IP addresses for RSUs. The RSUs were interconnected using the Internet as a backbone. Vehicles need to be associated with a RSU each time they enter into its range. To locate a near-by service, the vehicle sends a query to its leader RSU (the one with which it is currently associated). If the service is not present at the current RSU, the request is forwarded to the next RSU using its IP addresses by Internet connection. The weakness of their solution is the time spent in the association process between the vehicle and the RSU, followed by granting access to the Internet, which make the communication ineffective.

An Internet-centric architecture for VANETs was suggested in [10]. The architecture consists of three main components: Roadside Gateways (RGs), Roadside Routers (RRs) and Road Vehicles (RVs). The RRs were connected using heterogeneous backbone network. A hybrid (proactive and reactive) service discovery protocol was proposed. There was no direct V2V communication for service discovery. Instead, the RRs collect and store advertisements from advertising vehicles, in the service information table. A vehicle requiring service sends a query to a near-by RR. If the service is present in the information table, the RR replies. Otherwise, the query is forwarded to the appropriate RR, using network layer routing. They also described a proof of concept, in order to verify the accuracy, completeness and correctness of the proposed algorithm. However, they left the simulations to validate the findings, for future work.

In [11], the authors presented two Location-based Vehicular Service Discovery Protocols (LocVSDP): election based-LocVSDP and naive-LocVSDP. Their scheme operates in four phases: advertisement of services, propagation of requests, election for the leader and service response. The driver sends a query to the neighbour Roadside Router (RR), in the Region of Interest (RI). The RR separates the service information from routing information, and sends the request to other RR, if required. A leader, inside each RI, is selected by using an election process, which is responsible for generating service reply and its propagation to the driver. The disadvantage of this approach is that the election phase is executed for each service query, which leads to high overhead and degrades the overall performance.

In a recent study in [12], the authors addressed the problem of providing location based service information to the travellers by proposing an Opportunistic Service Discovery Protocol (OSDP). Their solution is based on layer-2 and makes use of beacons for service advertisement and discovery. However, they did not performed simulation studies to evaluate the performance of their protocol; instead they carried out real experiments using five Access Points (APs), built with IEEE 802.11a interfaces.

The main objectives of this work are: a) to evaluate the performance of OSDP, presented in [12], by performing an extensive set of simulations; b) to extend the service discovery phase of OSDP. This study is different from the above mentioned proposals in numerous ways. First, we implemented our solution on top of WAVE protocol stack (i.e., IEEE 802.11p, 1609.4, and WSMP standards). Second, our solution does not rely on the Internet for resolving queries and responses. Like OSDP, we make use of beacons for service advertisements and discovery. Finally, we present the simulation scenario in a way that the results could be used by users for designing new business models. We performed simulation studies in order to evaluate the performance of OSDP under different traffic scenarios. For V2I communications, we increased the number of services, advertised by RSUs, while for V2V communications, we change the vehicle densities.

III. System Modelling

In this section, we discuss the main entities and messages of our system.

A. System Entities

Following are the main entities of our system.

1) Business Manager (BM)

Business Manager (BM) is an entity, e.g., restaurant, hotel, gas station, coffee shop, supermarket, etc., interested

 ISBN: 978-1-61208-434-3

in advertising its services to the travellers. The offered services would include: food menu, price list, special offers, discount on products and available facilities.

2) *The Broker*

The broker is a third party entity, which would be in charge of feeding one or more RSUs in the neighbourhood of the BM premises, accordingly with a Service Level Agreement (SLA). The SLA would include: number of RSUs to broadcast the advertisement packet, frequency of advertisement packet, distance of the premises from which the packets will be advertised, time and day of the week etc. The BM would register their services with the broker, using Internet connections.

3) *Road Side Unit (RSU)*

RSUs are fixed entities, which are installed at fixed locations along the roads and highways. These RSUs would be administered by the brokers, eventually in association with the roads or highways managers. In order to reach a maximum number of customers, the RSU broadcast the registered services –as per SLA details– using push-based strategy.

4) *On Board Unit (OBU)*

The OBU is an important entity, installed in each vehicle, with storage and processing capabilities. When a vehicle enters in the coverage area of RSU, it starts receiving service advertisement packets, using V2I communications. Those packets are cached for a specific amount of time or a certain distance. BM could make special agreement, such as promotions and incentives, in order to stimulate the vehicles to carry their advertisement packets in their caches and, hence, to be able to transmit to other cars opportunistically. Additionally, the OBUs would send and receive query/response messages in V2V communications, using IEEE 802.11p based wireless interface.

B. *System Messages*

In this subsection, we discuss the messages of our proposed system.

1) *Advertisement Packets*

Advertisement is a well known marketing strategy for announcing products and services to the customers. In our system, the BM would register their services with a broker, via Internet for advertising them to the travellers. The registration process is out of the scope of this work. The RSU(s) would then broadcast advertisement packets for the nearby passing vehicles.

2) *Query Packets*

To discover a desired service, the vehicle would broadcast a query message to the neighbour vehicle(s) using a pull-based strategy. The query is said to be successful, if the querying vehicle receives a response from neighbour vehicles. Otherwise, it is unsuccessful. In our experiments, the vehicle repeats sending the query packet every 20s. Additionally, we use single-hop strategy to broadcast the query packet.

3) *Response Packets*

When a vehicle receive a query packet, it will search its local cache for the required service. If one or more services are found, the vehicle would broadcast the response message. For this work, we assumed that all neighbour vehicles –receiving queries– already have the requested services inside their caches.

IV. MOTIVATIONAL SCENARIO

In this section, we explain our system model by assuming a motivational highway scenario with two lanes on each side. The scenario is depicted in Figure 1. Vehicles enter into the scenario from two different origins. Four RSUs are deployed, on both sides of the roads. RSUs are interconnected using Internet as a backbone. We assume that all RSUs and vehicles are equipped with WAVE devices and IEEE 802.11p based wireless interfaces. Additionally, each vehicle has a built-in Global Positioning System (GPS) device and an OBU, with storage and processing capabilities. Each RSU will broadcast advertisement packets on a regular interval, using beacons, and vehicles would start receiving these advertisements packets, as soon as they enter into the coverage area of an RSU.

Consider a vehicle *v1*, which has received advertisement packets from RSU1 (gas station, coffee shop), RSU2 (hotel, restaurant, shopping mall), RSU3 (hotel, restaurant, shopping mall) and RSU4 (coffee shop, gas station) respectively. *v1* will store and carry all these services information and will opportunistically forward them to other vehicles, upon receiving a query packet. Now suppose that vehicle *v9* is interested in finding information about a near-by gas station. First, *v9* will check its own local cache. If no such information exists, it will broadcast a query packet towards its neighbour vehicles. In this case, only vehicle *v1* will receive the query packet.

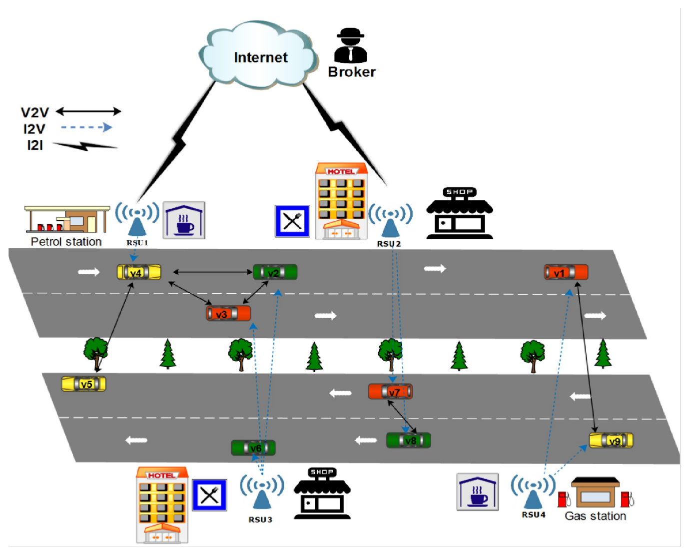

Figure 1. Motivational scenario: services advertisement and discovery.

To resolve this query, vehicle *v1* will search its own cache for gas station information. Since *v1* has information about a single gas station, it will broadcast this information in a V2V communications, using response packet. However, for some reasons, if *v9* does not receive any response packet, it will re-send the query packet, after some time or distance. OSDP protocol uses the unicast approach for sending back responses to the vehicles. We modified the unicast approach, by allowing vehicles to broadcast the response packet. This mechanism would allow other neighbour vehicles to receive advertisement packets without making queries for them.

V. OSDP PHASES

In this section, we emphasize the main points of OSDP phases. For a detailed description about phases, its operations and message formats, we refer the readers to [12]. It is important to note, that we use single hop communication mechanism in this work for the implementation of all the phases.

A. Advertisement Phase

This phase refers to the periodical broadcast of advertisements by RSUs, at regular intervals, in a V2I communication scenario. These advertisements contain necessary information about the services (for example: location, name of the service and its descriptions etc.). In our work, we utilize the SCH (Channel No. 174) of IEEE 802.11p protocol, for broadcasting our packets.

B. Caching Phase

In this phase, the vehicle stores the received advertisements packets in its cache. However, if the service is already present in the cache, it is simply ignored by the vehicle. The main objective behind caching approach is to forward advertisements information, opportunistically, to the querying vehicles, upon requests. We used store-carry-forward mechanism for this phase.

C. Querying Phase

The purpose of this phase is to discover the services by querying the near-by vehicles in a V2V communication scenario. The vehicle interested in finding a service sends a query message towards the neighbour vehicles. Upon receiving the query, the vehicles check their local caches and if at-least one service is found, it will send towards the requesting vehicle, using broadcast.

VI. SIMULATION SETUP

The aim of this section is to present the simulation tools and parameters selected for this work.

A. Simulation Tools

The main purpose of this work is to evaluate the performance of OSDP and elaborate its capabilities, under different traffic densities. To achieve this goal, we carried out extensive experiments with different set of parameters. Nowadays, a large number of simulation tools –ranging from open source to commercial products– are available, therefore, an important aspect of performing VANET simulations is to be cautious in the selection of the appropriate simulator tool. A comprehensive survey about current simulators, their capabilities and approaches is provided in [13].

The first step required to perform VANET simulations, is to use a realistic mobility simulator. Mobility simulator is responsible for defining road networks and generate traffic flows. We used Simulation of Urban Mobility (SUMO) [14], a well known microscopic and open source mobility simulator. After defining road network and traffic flows, the next important step is to enable the vehicles to talk to each other and road side infrastructure. This is achieved by using a network simulator. We used an object-oriented modular discrete event network simulation framework called Objective Modular Network Testbed in C++ (OMNET++) [15]. OMNET++ represents each vehicle as a node inside the network and allows communication among these nodes. Finally, in order to bridge the gap between the two worlds (SUMO and OMENT++), we used an open source bi-directional simulation framework called Vehicles in Network Simulation (Veins) [16]. Veins couples SUMO with OMNET++ using Traffic Control Interface (TraCI) [17]. Veins already implements WAVE protocol stacks. It is mostly noticeable for IEEE 802.11p, IEEE 1609.4 multi-channel operation and comprehensive MAC and PHY layers models. We implemented the OSDP protocol on top of WSMP and IEEE 802.11p.

B. Simulation Parameters

We defined the traffic parameters inside SUMO. One of the most important parameter is vehicle velocity. In our experiments, we used constant velocity of 120km/h for all vehicles. We performed our experiments using a highway of 140km, with multiple lanes on both sides. Additionally, we deployed a maximum of 7 RSUs (Section-VII A for details) along roadsides, for advertising the services. Vehicles were injected into the scenario from two different origins, with a fixed interval of 1.6s for the first experiment and 40s for the second experiment.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Wireless medium	IEEE 802.11p
Transmission rate	6 Mbps
Transmission power	33 dBm
Message type	WSMP data
Channel bandwidth	10 MHz
Beacon generation rate	1 Hz
Frequency band	5.9 GHz
Radio propagation model	Simple path loss model [18]
Simulation Time	Experiment 1: 250 s Experiment 2: 4200 s

The parameters we used for our network simulator, are summarized in the Table 1.

VII. RESULTS AND DISCUSSIONS

This section discusses the results we obtained from our simulations. Based on the OSDP phases (Section-V), we divided our experiments into two parts.

A. *Evaluation of Advertisement Packets*

In this experiment, we tested the first two phases (advertisement and caching) of OSDP in a V2I communication scenario (see Figure 2). We measured the success rate of advertisements packets received by vehicles, in a given inter-contact time. Success rate refers to the total number of received advertisement packets by the total number of delivered packets. An inter-contact time refers to the duration in which a vehicle continues to receive advertisement packets from an RSU, inside its coverage area. As soon as the inter-contact time expires, the vehicle stops receiving advertisements. We considered the same inter-contact times (ranging from 0.2s to 2.0s) used by OSDP. We control the inter-contact time by simTime() function of OMNET++. Similar to OSDP, we increased the density of RSUs, offering the services, from 1 RSU to 7 RSUs.

Each RSU broadcasts a single advertisement packet per second. In OSDP, all APs (which emulate RSUs) were deployed in the same location, therefore, we followed the same setup for the deployment of RSUs in our experiment. To achieve more reliable results, we calculated the average of samples collected from 100 vehicles, for each inter-contact time.

Figure 3 shows the success rate of advertisement packets received by vehicle in relation with inter-contact time. In general, the success rate increases as the inter-contact time increases. In case of a single service offered by an RSU, inter-contact time of 1s seems to be sufficient, for a vehicle to successfully receive the advertisement packets. It could also be observed that inter-contact time of 0.8s is enough for a vehicle to receive at-least 50% of the offered services, by at-most 7 RSUs. Moreover, the success rate decrease as the number of offered services increase. The reason of this performance degradation is likely due to packet collision at the MAC layer.

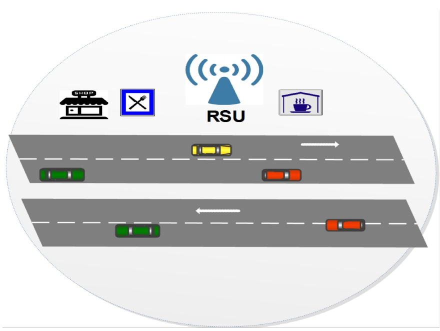

Figure 2. RSU broadcasting service advertisements .

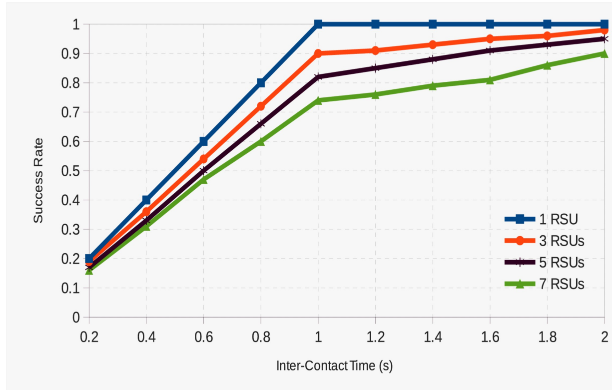

Figure 3. Success rate of service advertisements received by vehicles from RSUs (ranging from 1 to 7), under different inter-contact times.

B. *Evaluation of Query and Response Packets*

In this experiment, we tested the third phase (service discovery) of OSDP, using V2V communications among vehicles (see Figure 4). We divided our experiment into two sub-categories. In the first experiment, we evaluated the performance of service discovery by changing the number of vehicles responding to the query packet. While in the second experiment, we changed the number of vehicles querying for services.

i) Evaluation of Response Packets

In this experiment, a single vehicle would query its neighbour vehicles for a required service. We increased the density of neighbour vehicles responding to the query packet, from 1 vehicle to 21 vehicles. Like OSDP, we assumed that all neighbour vehicles have already received and stored the required service in their local caches. Success rate in this case, refers to the total number of received response packets by the total number of neighbour vehicles in that region. Vehicle density means, total number of neighbour vehicles inside the coverage range of querying vehicle.

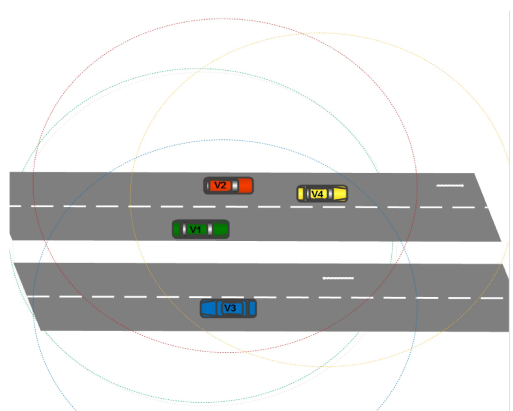

Figure 4. Vehicles querying for/responding to services.

To achieve more reliable results, we calculated the average of samples collected from 100 vehicles for each density. In OSDP, neighbour vehicle send back the response message in a unicast manner. We amended the unicast mode and permitted vehicles to broadcast the response packets.

An important conclusion of OSDP was that inter-contact time does not effect the success rate. Therefore, we consider constant inter-contact time of 0.2s, for all vehicle densities.

Figure 5 depicts that the success rate of response packets is highly dependent on the vehicle density, in a V2V communication scenario. It could be observed that, the success rate is 100%, for traffic densities of up-to 9 vehicles. However, the performance degrades to 50%, as soon as the traffic density reaches 21 vehicles. The reason behind this degradation in performance is due to the attempt made by vehicles to access the channel at the same time.

ii) Evaluation of Query Packets

In this experiment, we extend the OSDP by increasing the traffic density, querying for services from 1 vehicle to 21 vehicles. We consider only a single neighbour vehicle to respond to those query packets. We made the assumption that, all the vehicles are interested to search for the same service. The performance evaluation is depicted in Figure 6. It could be observed that, it is difficult to achieve 100% success rate, even in case of small traffic density (e.g., 3 vehicles). The success rate is 50% up-to traffic density of 7 vehicles. Performance further decreases, as the number of vehicles asking for services increases, and it reaches 10% for traffic density of 21 vehicles. We observed a speedy performance degradation in this experiment (as compared to the previous one), because in this case, only a single vehicle is trying to resolve the query packets of different vehicles.

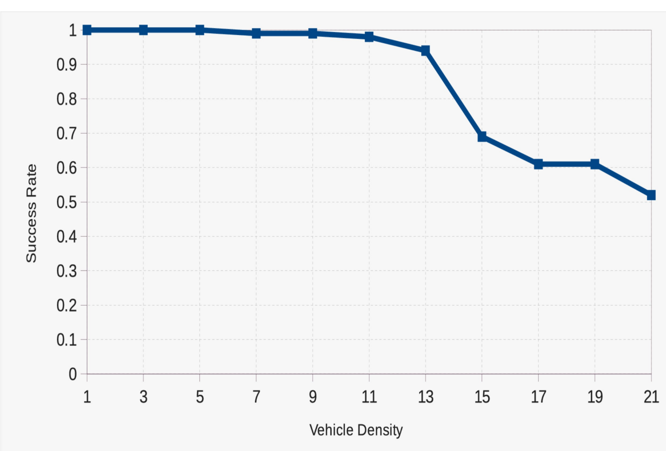

Figure 5. Success rate of received messages with varying number of responding vehicles.

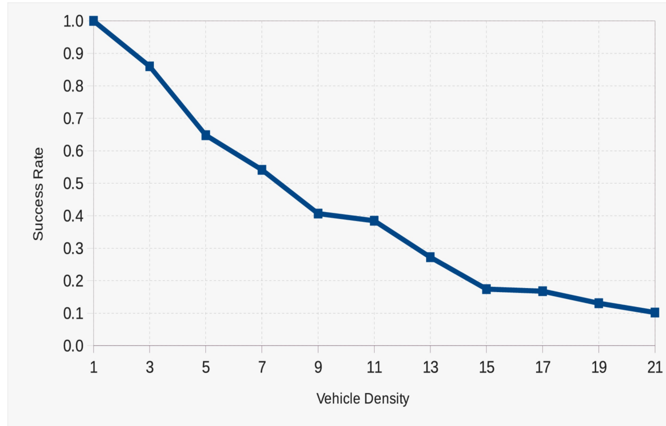

Figure 6. Success rate of received messages with varying number of querying vehicles.

VIII. CONCLUSION AND FUTURE WORK

In this paper, we addressed the problem of roadside services advertisement and discovery in VANET, by implementing OSDP –a recent beaconing based opportunistic service discovery protocol– on top of IEEE 802.11p and WSMP standards, and performed extensive simulations using SUMO, OMNET++ and Veins simulators. To evaluate the performance, we conducted two different set of experiments, under different traffic densities and inter-contact time. In the first experiment, we evaluated the performance of advertisement packets by RSUs in V2I communication scenario. In the second set of experiments, we evaluated the performance of service discovery in V2V communication scenario. We also extended OSDP, by changing the number of vehicles, querying for services. The results conclude that the success rate of service advertisements decreases as the number of offered services, by an RSU, increases. Moreover, success rate of response packets is highly dependent on vehicle densities. The model suggests that the system can be used to simulate several business models, including number of advertisement points, their distances to the business's premises, duration that the packets are stored in the cache, etc.

Presently, we are evaluating the performance of OSDP using more sophisticated path loss models (e.g., Obstacle Shadowing, Two Ray Interference) and Quality of service (QoS) parameters, for more realistic and congested traffic scenarios. As a future work, we would study the security and privacy aspects of OSDP. We also intend to implement OSDP using Named Data Networking (NDN, aka Content-Centric Networking - CCN), for interest based service discovery. We would like to extend OSDP operations to Vehicular Social Network (VSN).

ACKNOWLEDGEMENT

The authors are thankful to the world academy of sciences (TWAS), Italy and to the national council for scientific and technological development (CNPq), Brazil for providing financial support under the grant number 190275/2011-1.

REFERENCES

[1] D. Jiang and L. Delgrossi, “IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments,” in Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE , May 2008 , pp. 2036–2040.

[2] Y. Li, “An Overview of the DSRC/WAVE Technology,” in Quality, Reliability, Security and Robustness in Heterogeneous Networks (X. Zhang and D. Qiao, eds.), vol. 74 of Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Springer Berlin Heidelberg, 2012, pp. 544–558.

[3] S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, and H. Zedan, “A Comprehensive Survey on Vehicular Ad Hoc Network,” Journal of Network and Computer Applications, vol. 37, no. 0, 2014, pp. 380 – 392.

[4] R. Uzcategui and G. Acosta-Marum, “WAVE: A Tutorial,” Communications Magazine, IEEE, vol. 47, May 2009, pp. 126–133.

[5] G. Araniti, C. Campolo, M. Condoluci, A. Iera, and A. Molinaro, “LTE for Vehicular Networking: A Survey,” Communications Magazine, IEEE, vol. 51, May 2013, pp. 148–157.

[6] ETSI ES 202 663, ”Intelligent Transport Systems; European profile standard on the physical and medium access layer of 5 GHz ITS”, Draft Version 0.0.6, October 2009.

[7] D. Eckhoff, N. Sofra, and R. German, “A Performance Study of Cooperative Awareness in ETSI ITS G5 and IEEE WAVE,” in Wireless On-demand Network Systems and Services (WONS), 2013 10th Annual Conference on, March 2013, pp. 196–200.

[8] M. Dikaiakos, A. Florides, T. Nadeem, and L. Iftode, “Location-aware Services over Vehicular Ad-Hoc Networks using car-to-car Communication,” Selected Areas in Communications, IEEE Journal on, vol. 25, Oct 2007, pp. 1590–1602.

[9] B. Mohandas, A. Nayak, K. Naik, and N. Goel, “ABSRP- A Service Discovery Approach for Vehicular Ad Hoc Networks,” in Asia-Pacific Services Computing Conference, 2008. APSCC ’08. IEEE, Dec 2008, pp. 1590–1594.

[10] A. Boukerche and K. Abrougui, “A Service Discovery Protocol for Vehicular Ad Hoc Networks: A Proof of Correctness,” in Parallel Distributed Processing, 2009. IPDPS 2009. IEEE International Symposium on , May 2009, pp. 1–8.

[11] K. Abrougui, R. Pazzi, and A. Boukerche, “Performance Evaluation of Location-Based Service Discovery Protocols for Vehicular Networks,” in Communications (ICC), 2010 IEEE International Conference on , May 2010, pp. 1–5.

[12] R. Yokoyama, B. Kimura, L. Jaimes, and E. Moreira, “A Beaconing-Based Opportunistic Service Discovery Protocol for Vehicular Networks,” in Advanced Information Networking and Applications Workshops (WAINA), 2014 28th International Conference on , May 2014 , pp. 498–503.

[13] F. J. Martinez, C. K. Toh, J.-C. Cano, C. T. Calafate, and P. Manzoni, “A Survey and Comparative Study of Simulators for Vehicular Ad Hoc Networks (VANETs),” Wireless Communications and Mobile Computing, vol. 11, no. 7, 2011, pp. 813–828.

[14] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, “SUMO-Simulation of Urban MObility-an Overview,” in SIMUL 2011, The Third International Conference on Advances in System Simulation , 2011, pp. 55–60.

[15] A. Varga and R. Hornig, “An Overview of the OMNET++ Simulation Environment,” in Proceedings of the 1st International Conference on Simulation Tools and Techniques for Communications, Networks and Systems & Workshops, Simutools ’08, (ICST, Brussels, Belgium), ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2008, pp. 60:1–60:10.

[16] C. Sommer, R. German, and F. Dressler, “Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis,” Mobile Computing, IEEE Transactions on , vol. 10, Jan 2011, pp. 3–15.

[17] A. Wegener, M. Pi orkowski, M. Raya, H. Hellbr uck, S. Fischer, and J.-P. Hubaux, “TraCI: An Interface for Coupling Road Traffic and Network Simulators,” in Proceedings of the 11th Communications and Networking Simulation Symposium , CNS ’08, (New York, NY, USA), ACM, 2008, pp. 155–163.

[18] K. Wessel, M. Swigulski, A. Kopke, and D. Willkomm, “MiXiM: The Physical Layer An Architecture Overview,” in Proceedings of the 2nd International Conference on Simulation Tools and Techniques, Simutools ’09, (ICST, Brussels, Belgium), ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2009, pp. 78:1–78:8.