

Improving the Throughput in Vehicular Networks

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Abstract---Vehicular communication networks have emerged as a promising platform for the deployment of safety and infotainment applications. The stack of protocols for vehicular networks will potentially include Network Mobility Basic Support (NEMO BS) to enable IP mobility for infotainment and Internet-based applications. However, the protocol has performance limitations in highly dynamic scenarios, and several route optimization mechanisms have been proposed to overcome these limitations. This article addresses the problem of IP mobility and its specific requirements in vehicular scenarios. A qualitative comparison among the existent IP mobility solutions that optimize NEMO BS in vehicular networks is provided. Their improvements with respect to the current standard, their weaknesses, and their fulfillment of the specific requirements are also identified. In addition, the article describes some of the open research challenges related to IP mobility in vehicular scenarios. This paper studies the 802.11p/WAVE standard and its limitations for the support of infrastructure-based IP applications, and proposes the Vehicular IP in WAVE (VIP-WAVE) framework. VIP-WAVE defines the IP configuration for extended and non-extended IP services and a mobility management scheme supported by Proxy Mobile IPv6 over WAVE. Extensive simulations are performed to demonstrate the accuracy of our analytical model and the effectiveness of VIP-WAVE in making feasible the deployment of IP applications in the vehicular network.

Key words: Internet protocol (IP), multi-hop networks, Proxy Mobile IPv6 (PMIP), vehicle to infrastructure (V2I), vehicular networks, Wireless Access in Vehicular Environments (WAVE), 802.11p.

I. INTRODUCTION

The technologies and standards that allow for interoperable and seamless communication systems in the automotive industry have been intensively developed over the last decade. Such communication systems are meant to enable the deployment of safety and emergency services, as well as informational and entertainment applications. In addition, communications in the vehicular network are to be established. Under this perspective, existent radio access networks such as cellular (e.g., GSM/GPRS and UMTS) and Wi-Fi may be employed to enable vehicular communications.

Moreover, commercial products are already venturing in the transportation market with solutions that enable drive-thru Internet access over existent networks. However, the strict latency requirement for safety-oriented and emergency communications has resulted in the definition of the IEEE 802.11p and the Wireless Access in Vehicular Environments (WAVE) technologies and standards, which together define a

low-latency alternative network for vehicular communications.

Although the main focus of WAVE has been the effective, secure, and timely delivery of safety related information, the deployment of infotainment applications certainly would help accelerate the market penetration and leverage the deployment costs of the vehicular network. Thus, in order to support infotainment traffic, WAVE also includes IPv6 and transport protocols such as TCP and UDP. By supporting IP-based communications, the vehicular network may use well-known IP-based technologies and readily be connected to other IP-based networks. With many open operational aspects of IPv6, providing access to infrastructure-based IP applications, such as assisted parking, route management, and eventually Internet access, becomes a challenging task in 802.11p/WAVE networks. Previous works evaluate the performance of IP-based applications in I2V vehicular environments, but they often employ traditional 802.11 b/g technologies that do not resemble the intricacies of 802.11p/WAVE for IP communications. The limitations of the operation of IPv6 in 802.11p/WAVE have also been identified, but they can only be used as guidelines regarding the incompatibilities of the two technologies.

Therefore, we address the problem of I2V/V2I IP-based communications in 802.11p/WAVE networks by providing the Vehicular IP in WAVE (VIP-WAVE) framework. Our main contributions are summarized as follows:

- 1) To design an efficient mechanism for the assignment, maintenance, and duplicate detection of IPv6 global addresses in WAVE devices, which is customized according to the type of user service;
- 2) To design a relay detection and routing mechanism for the delivery of IP packets through one-hop and two-hop communications in 802.11p/WAVE networks.

II. RELATED WORK

In this section, we present the main concepts described in 802.11p/WAVE standards that is relevant for the transmission of data frames and for the operation of IP-based services. We also describe previous works dedicated to the support of IP-based communications in 802.11p/WAVE networks.

The 802.11p technology works in the 5.9-GHz frequency band and employs orthogonal frequency-division multiplexing modulation. It also employs carrier sense multiple access with collision avoidance (CSMA/CA) as the fundamental access method to the wireless media. The MAC layer of 802.11p includes the 802.11e enhanced distributed channel access (EDCA) function to manage access categories and priorities.

On the other hand, the WAVE standards,

1609.4-2010 and 1609.3-2010, define the medium- access channel capabilities for multichannel operation, and the management and data delivery services between WAVE devices. In, the WAVE frequency spectrum is divided into one control channel (CCH) and six service channels (SCHs), each with 10 MHz bandwidth. In addition, each channel has its own set of access categories and its own instance of the 802.11p MAC layer.

A. VIP-wave architecture

As denoted in Section II-A, one of the 802.11p/WAVE’s biggest issues, in terms of IP operation, is the announcement of a per-WSA IP prefix, which forces WAVE users of all IP services announced in a specific WSA (up to 32 services per WSA) to belong to the same IP network. This causes not only a necessity for often having to detect duplicate addresses throughout the network and other SCHs, but contradicts one of the main assumptions IPv6 has for the link-layer model as well. This assumption says that all nodes belonging to the same IP prefix are able to communicate directly with each other, which does not hold when there are WAVE users that are scattered along different locations or along different SCHs.

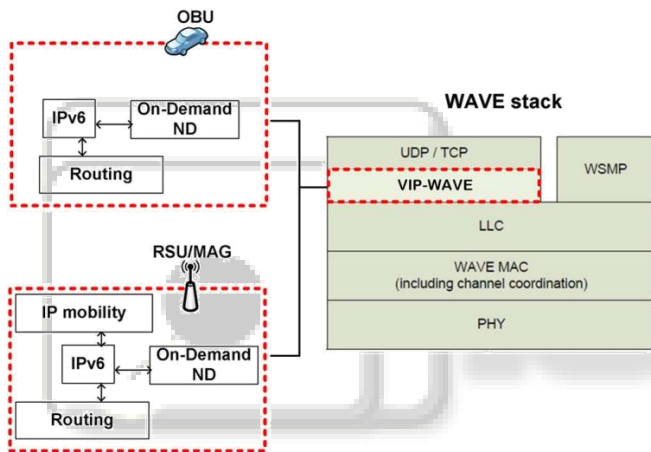


Fig.1: VIP-WAVE architecture

Additionally, there is a shortage in differentiating extended from non-extended services, and no IP mobility support is indicated to provide seamless communications in the case of extended services. Last, but not least, multihop communications are not exploited in the 802.11p/WAVE network, although they could boost the network’s performance and increase the IP service availability. An OBU transitions through the RSU service areas at vehicular speeds. Therefore, we introduce a handover mechanism that allows for seamless communications of extended IP services in the 802.11p/WAVE network. When an OBU is consuming an extended service, it continues monitoring the CCH while roaming toward a new RSU. Consequently, the reception of a WSA that announces the same extended service, but from a different WAVE provider, serves as a movement detection hint. This is detected thanks to the WAVE provider field in Service Info, which should include a different MAC address. The movement is then notified by the MAC layer to the VIP-WAVE layer in the OBU. Upon the movement notification, the on-demand ND module triggers the sending of an RS message, which is transmitted over the SCH in which the service is being provided.

B. Routing Through a Relay: Depending on the direction of traffic, the routing protocol works in the following way for multi-hop communications.

1) Traffic from hosting server to user OBU:

Once the packet arrives at the RSU, the IPv6 module queries the routing module about the next hop to reach the user OBU. The routing module selects the relay OBU MAC address as the MAC layer frame destination, as per configured by the relay setup procedure. The packet is then forwarded to the relay OBU.

2) Traffic from user OBU to hosting server:

Once the data packet is generated at the user OBU, the IP layer determines if the hosting server belongs to an external network; thus, it then decides that the packet should be sent toward the default gateway, which in this case is the RSU. The IPv6 module then queries the routing module about the next hop to reach the RSU. As configured by the relay setup procedure, the route to reach the RSU indicates the relay OBU as the next hop; therefore, the relay OBU MAC address is selected as the MAC layer frame destination. The packet is then forwarded to the relay OBU.

If at any moment during the two-hop communications the user OBU receives the WSA directly from the RSU with a signal level above the RCPI threshold, the user OBU will send an RS to reestablish direct communications with the RSU. In such a case, the RA response message sent by the RSU is overheard and employed by the relay OBU for terminating the relay service.

C. Handover of Extended IP Services

The procedure of two-hop handover to a different service area is illustrated in Fig.2

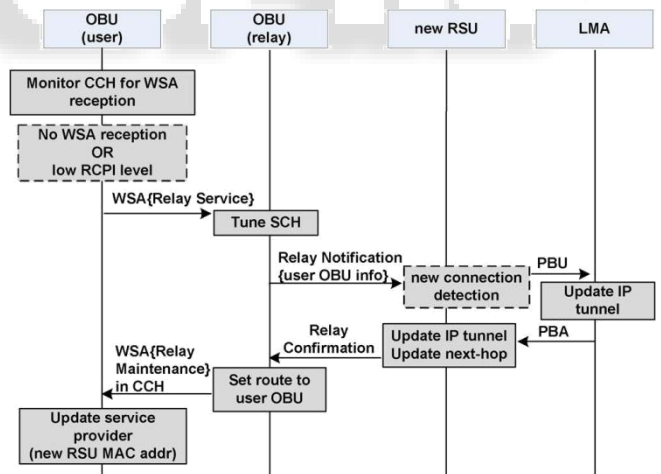


Fig. 2: Handover of Extended IP Services through a Relay in VIP-WAVE.

In this scenario, the handover may be triggered by the conditions and therefore, the relay detection procedure is started. However, given that the relay is connected to a different service area, when the RSU receives the relay notification message, it does not have an active tunnel configured for the user OBU. Therefore, the RSU uses the relay notification message as a hint for connection detection and triggers the PBU/PBA signaling toward the LMA. Once the PMIP signaling is completed, the RSU continues with the sending of relay confirmation to the relay OBU.

This message serves for triggering the relay maintenance announcements from relay OBU to user OBU, after which bidirectional communications are resumed.

Handover of IP Services: An OBU transitions through the RSU service areas at vehicular speeds. Therefore, we introduce a handover mechanism that allows for seamless communications of extended IP services in the 802.11p/WAVE network. When an OBU is consuming an extended service, it continues monitoring the CCH while roaming toward a new RSU. Consequently, the reception of a WSA that announces the same extended service, but from a different WAVE provider, serves as a movement detection hint. This is detected thanks to the WAVE provider field in Service Info, which should include a different MAC address. The movement is then notified by the MAC layer to the VIP-WAVE layer in the OBU. Upon the movement notification, the on-demand ND module triggers the sending of an RS message, which is transmitted over the SCH in which the service is being provided

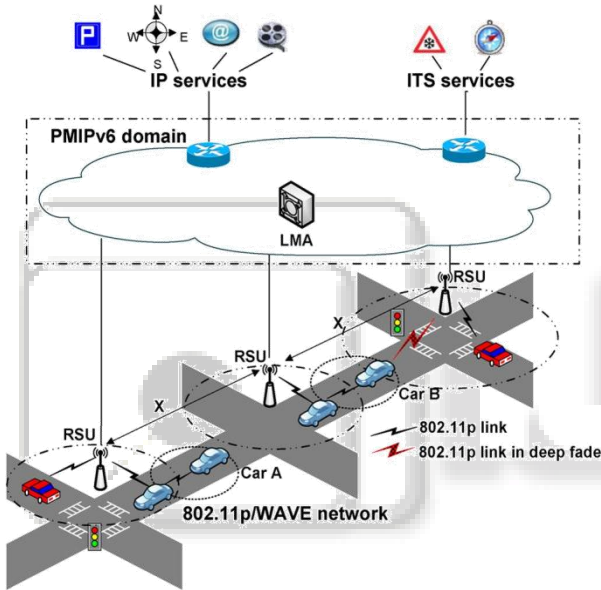


Fig. 3: IP-Enabled 802.11p/WAVE Network Model

III. STIMULATION SETTINGS

Extensive simulation results have been obtained based on the discrete event simulator Omnet++. RSUs and OBUs are equipped with two wireless interfaces transmitting in different channels. In this way, we emulate the multi-PHY capabilities with simultaneous transmissions over CCH and SCH. Each radio implements the Inetmanet 802.11p PHY and MAC model, and parameters are set according to the recommended values in. Connectivity among nodes is initially determined by a unit disk model. However, signals are attenuated following a log-normal propagation model with path loss exponent of 2.4. We have also modified the Inetmanet package so that it delivers the OBU's received power to the network layer; thus, we can employ the RCPI threshold to determine connectivity between OBU and RSU. An Internet-located application server for the downloading of data traffic is connected to the 802.11p/WAVE network with an RTT of 40 ms. RSUs are uniformly distributed along the road segment with distance X . A one-way lane is simulated, where vehicles are moving at a constant average velocity v . We employ randomly generated

topologies and a different tagged vehicle per topology. Topologies have, in average, a number ρX of vehicles per sub network in $[0, X]$. Only application layer packets, sent from the application server and received at the user OBU, are considered for the throughput calculation in each simulation run. The results

IV. PERFORMANCE EVALUATION

Impact of Vehicle Density

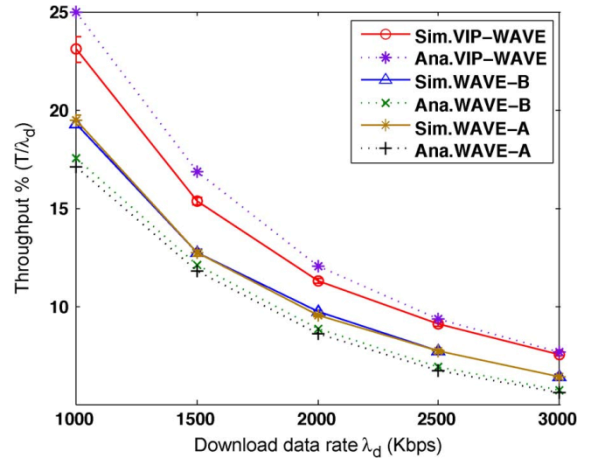


Fig.4: Nodal downstream throughput under saturated conditions for highly demanding IP applications, RSU interdistance $X = 1500$ m

The trends of the throughput can be observed in terms of vehicle density when the percentage of available relays decreases from 100% to 70% and 40%. For both WAVE-A and WAVE-B, the throughput decreases almost linearly when the vehicle density increases, regardless of the values of p_r . This is the result of an increase in congestion when there are more nodes in the vehicular network. Instead, in the case of VIP- WAVE, since it supports multihop communications, a greater p_r value directly translates into an increase of throughput and a better performance than that obtained by the standard WAVE in all three cases. However, it can also be observed that VIP- WAVE's throughput increases up to the maximal value, but thereafter it starts decreasing with the increase of vehicle density. The reason of the throughput increase before the maximum point is due to a greater number of available relays when the vehicle density increases. After the maximum point, the throughput decreases because as there are more vehicles on the road, the congestion of communications is dominant over the benefit from the increase of available relays.

A. Impact of Download Data Rates

An evaluation of how data rate demanding IP applications (i.e., $\lambda_d > 1$ Mbps) affect the overall performance of the nodal throughput is illustrated in Fig. 13. In the experiment, we calculate the throughput of VIP-WAVE and WAVE standards under saturated conditions for a vehicular network with low-level presence of infrastructure are plotted with a 95% confidence interval.

In all three cases, simulation and analytical results are configured to allow for 60% of the nodes around the tagged vehicles to be actively transmitting in the same SCH. Since every active vehicle intends to transmit at a larger data

rate, the congestion of communications becomes more and more severe, and thus, the performance of throughput degrades when the data rate increases. At the same time, a larger amount of data packets are lost when the OBU is experiencing a handover.

We can also observe that the improvement obtained by VIP-WAVE compared to the standard WAVE tends to be reduced due to the congestion of communications becoming dominant

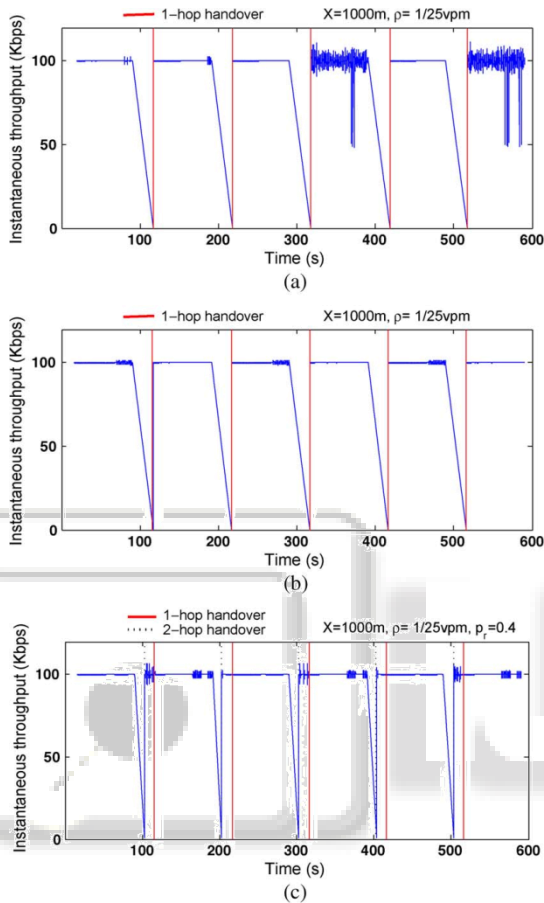


Fig.5: Instantaneous throughput and handover delay for different WAVE schemes. (a) WAVE-A. (b) WAVE-B. (c) VIP-WAVE.

For larger data rates. However, these throughput measurements may actually be better in real life scenarios, since the MAC layer in 802.11p/WAVE allows for prioritization of traffic by means of the EDCA mechanism (for simplicity, our simulation employs a single access category queue). Furthermore, access control and quality of service policies could be imposed in order to guarantee the minimum level of quality to the OBUs that are consuming the IP service.

B. Instantaneous Throughput and Delay

In order to evaluate the throughput behavior during a given session time, we show in Fig.6 the instantaneous throughput for the different schemes. In all three schemes, 60% of the nodes around the tagged vehicles are subscribed to the same service, which means that there are other nodes that are actively transmitting in the same SCH. In the case of VIP-WAVE, this condition translates to having a 40% probability of finding an available relay among the neighboring vehicles.

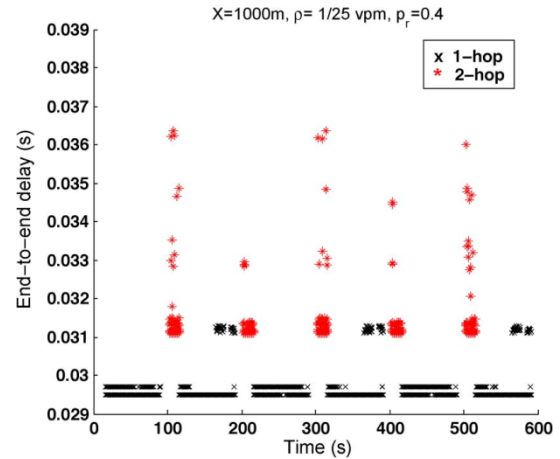


Fig.6: Data packet end-to-end delay in VIP-WAVE.

Comparing WAVE-A [see Fig. 5(a)] with WAVE-B [see Fig. 5(b)]. Moreover, although the region between RSUs is fully covered when $X = 1000$ m, the handover delay in WAVE-A and WAVE-B is longer than that experienced in VIP-WAVE. This is because the OBU needs to reestablish the connection with the new RSU, and given that $r < R$, it takes some time until the RSU is able to receive the location update in the form of an RS or a RESET message from the OBU. Such reception is only possible when $x < R$ or $x > X - R$, where x is the OBU's location. This phenomenon has a smaller impact in VIP-WAVE, since the framework allows for two-hop communications toward the RSU when the OBU is unable to communicate directly. Thus, the total handover delay in VIP-WAVE is reduced, and a smaller number of packet losses are perceived by the IP application

V. CONCLUSION

In this paper, we have proposed a novel framework for the support of IP communications in 802.11p/WAVE networks. In particular, we have studied the 802.11p/WAVE standard for the operation and differentiation of IP applications, and have proposed the VIP-WAVE framework to address such limitations. VIP-WAVE has demonstrated to notably improve the performance of IP applications even when a low presence of infrastructure results in large gaps between areas of coverage. Moreover, the protocols and mechanisms proposed in VIP-WAVE for IP addressing, mobility management, and multi-hop communications have been all designed according to the intricacies and special characteristics of 802.11p/WAVE networks. We conclude by reinforcing our observation that the individual downloading data rate perceived by an OBU is highly dependent on the road density and the interdistance of the RSUs. Our results suggest that it is beneficial for 802.11p/WAVE networks to put in place multi-hop communications, which extend the area of coverage and help to make smoother the transitions during handovers. As a next step, we plan to further improve the relay selection mechanism to incorporate policies of selection that choose the best relay based on different parameters, such as relay reliability and link duration.

REFERENCES

- [1] VIP-WAVE: On The Feasibility Of IP Communications In 802.11p Vehicular Networks Sandra Céspedes, Student Member, IEEE, Ning Lu, Student Member, IEEE, And Xuemin (Sherman) Shen, Fellow, IEEE.,2013
- [2] T. H. Luan, X. Ling, and X. Shen, "MAC in Motion: Impact of Mobility on the MAC of Drive-Thru Internet," *IEEE Trans. Mobile Comput.* Vol. 11, No. 2, Pp. 305–319, Feb. 2012.
- [3] Autonet Mobile. [Online]. Available: [Http://Www.Autonetmobile.Com/](http://www.autonetmobile.com/)
- [4] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment: Wireless Access in Vehicular Environments, IEEE Std. P802.11p, Jul. 15, 2010.
- [5] IEEE Standard for Wireless Access in Vehicular Environments (WAVE) Multi-Channel Operation, IEEE Std. 1609.4-2010, Feb. 7, 2011 (Rev. IEEE Std. 1609.4-2006).
- [6] E. Perera, V. Sivaraman, and A. Seneviratne, "Survey on Network Mobility Support," *SIGMOBILE Mob. Comp. Commun. Rev.*, Vol. 8, No. 2, 2004, Pp. 7–19.
- [7] M. Fiore and J. Härri, "The Networking Shape of Vehicular Mobility," *Proc. Mobihoc '08*, ACM, 2008, Pp. 261–72.
- [8] M. Watari Et Al., "Optimal Path Establishment For Next-Ed Mobile Networks," *IEEE VTC 2005-Fall*, Vol. 4, Pp. 2302–06.
- [9] K. Okada, R. Wakikawa, And J. Murai, "MANET And NEMO Converged Communication," *Technologies For Advanced Heterogeneous Networks II*, LNCS, Springer, 2006, Vol. 4311, Pp. 235–51
- [10] C. J. Bernardos Et Al., "VARON: Vehicular Ad Hoc Route Optimisation for NEMO," *Comp. Commun.*, Vol. 30, No. 8, 2007, Pp. 1765–84.
- [11] S. Thomson, T. Narten, and T. Jinmei, "Ipv6 Stateless Address Auto- Configuration," *RFC 4862 (Draft Standard)*, Sept. 2007.
- [12] R. Baldessari, A. Festag, W. Zhang, And L. Le, "A MANET-Centric Solution For The Application Of NEMO In VANET Using Geographic Routing," *In Proc Of Tridentcom*, Innsbruck, Austria, March 2008, 7 Pages.
- [13] R. Draves, "Default Address Selection For Internet Protocol Version 6 (Ipv6)," *RFC 3484 (Proposed Standard)*, Feb. 2003.
- [14] R. Draves And D. Thaler, "Default Router Preferences And More-Specific Routes," *RFC 4191 (Proposed Standard)*, Nov. 2005.