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July 8, 2016

Transmission of IPv6 Packets over IEEE 802.11-OCB Networks
draft-ernst-its-ipv6-over-80211ocb-00.txt

Abstract

In this document the mapping of multicast IPv6 addresses to MAC addresses of 802.11-OCB is proposed.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on January 9, 2017.

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1. Introduction

In this document the mapping of link-scoped multicast IPv6 addresses to MAC addresses of 802.11-OCB is proposed.

IPv6 protocols often make use of IPv6 multicast addresses in the destination field of IPv6 headers. For example, an ICMPv6 link-scoped Neighbor Advertisement is sent to the IPv6 address ff02::1 denoted "all-nodes" address. When transmitting these packets on 802.11-OCB links it is necessary to map the IPv6 address to a MAC address.

The same mapping requirement applies to the link-scoped multicast addresses of other IPv6 protocols as well. In DHCPv6, the "All_DHCP_Servers" IPv6 multicast address ff02::1:2, and in OSPF the "All_SPF_Routers" IPv6 multicast address ff02::5, need to be mapped on a multicast MAC address.

Other than link-scope addressing, it may be possible to conceive other IPv6 multicast addresses for specific use in vehicular communication scenarios. For example, certain vehicle types (or road infrastructure equipment) in a zone can be denoted by an IPv6 multicast address: "all-yellow-taxis-in-street", or "all-uber-cars". This helps sending a message to these particular types of vehicles, instead of sending to all vehicles in that same street. The protocols SDP and LLDP could further be used in managing this as a service.

It may be possible to map parts of other-than-link-scope IPv6 multicast address (e.g. parts of a global-scope IPv6 multicast address) into parts of a 802.11-OCB MAC address. This may help certain IPv6 operations.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

OCB - Outside the Context of a Basic-Service Set ID (BSSID).

802.11-OCB - IEEE 802.11-2012 text flagged by "dot11OCBActivated". This means: IEEE 802.11e for quality of service; 802.11j-2004 for half-clocked operations; and 802.11p for operation in the 5.9 GHz band and in mode OCB.

3. Maximum Transmission Unit

MTU is

4. Frame Format

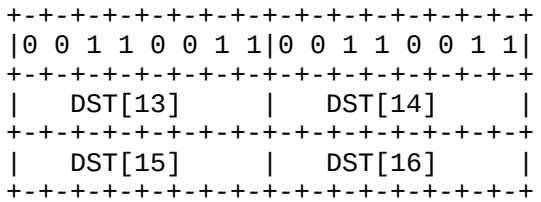
5. Stateless Autoconfiguration

6. Link-Local Addresses

7. Address Mapping -- Unicast

8. Address Mapping -- Multicast

An IPv6 packet with a multicast destination address DST, consisting of the sixteen octets DST[1] through DST[16], is transmitted to the IEEE 802.11-OCB MAC multicast address whose first two octets are the value 0x3333 and whose last four octets are the last four octets of DST.



A Group ID TBD of length 112bits may be requested from IANA; this Group ID signifies "All 80211OCB Interfaces Address". Only the least 32 significant bits of this "All 80211OCB Interfaces Address" will be mapped to and from a MAC multicast address.

Alternatively, instead of 0x3333 address other addresses reserved at IEEE can be considered. The Group MAC addresses reserved at IEEE are listed at https://standards.ieee.org/develop/regauth/grpmac/public.html (address browsed in July 2016).

9. Security Considerations

the security section

10. IANA Considerations

The Group ID for "All 80211OCB Interfaces Address" is TBD.

11. Acknowledgements

The authors would like to acknowledge Owen DeLong, Joe Touch, Jen Linkova, Erik Kline and participants to discussions in network working groups.

12. References

12.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

12.2. Informative References

[ieee802.11p-2010] "IEEE Std 802.11p(TM)-2010, IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 6: Wireless Access in Vehicular Environments; document freely available at URL http://standards.ieee.org/getieee802/download/802.11p-2010.pdf retrieved on September 20th, 2013.".

Appendix A. ChangeLog

The changes are listed in reverse chronological order, most recent changes appearing at the top of the list.

From -00.txt to -00.txt:

- first version.

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Transmission of IPv6 Packets over IEEE 802.11-OCB Networks
draft-haerri-ipv6-over-80211ocb-00.txt

Abstract

This document describes the mechanisms required by IPv6 to be transmitted on IEEE 802.11 OCB networks.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This document describes the transmission of IPv6 packets on IEEE 802.11 OCB networks.

2. Terminology

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3. Design Considerations

The networks defined by 802.11-OCB are in many ways similar to other networks of the 802.11 family. In theory, the encapsulation of IPv6 over 802.11-OCB could be very similar to the operation of IPv6 over other networks of the 802.11 family. However, the high mobility, strong link asymetry and very short connection makes the 802.11-OCB link significantly different from that of other 802.11 networks. Also, the automotive applications have specific requirements for reliability, security and privacy, which further add to the particularity of the 802.11-OCB link.

This section does not address safety-related applications, which are done on non-IP communications. However, this section will consider the transmission of such non IP communication in the design specification of IPv6 over IEEE 802.11-OCB.

3.1. Vehicle ID

Automotive networks require the unique representation of each of their node. Accordingly, a vehicle must be identified by at least one unique ID. The current specification at ETSI and at IEEE 1609 identifies a vehicle by its MAC address uniquely obtained from the 802.11-OCB NIC.

A MAC address uniquely obtained from a IEEE 802.11-OCB NIC implicitely generates multiple vehicle IDs in case of multiple 802.11-OCB NICs. A mechanims to uniquely identify a vehicle irrespectivey to the different NICs and/or technologies is required.

3.2. Non IP Communications

In IEEE 1609 and ETSI ITS, safety-related communications CANNOT be used with IP datagrams. For example, Basic Safety Message (BSM, an IEEE 1609 datagram) and Cooperative Awareness Message (CAM, an ETSI ITS-G5 datagram), are each transmitted as payload of 802.11 messages, without an IP header.

Each vehicle taking part of traffic (i.e. having its engine turned on and being located on a road) MUST use Non IP communication to periodically broadcast its status information (ID, GPS position, speed,..) in its immediate neighborhood. According to this mechanisms, vehicles become ’aware’ of the presence of other vehicles in their immediate vincinity. Accordingly, IP communication being transmitted by vehicles taking part of traffic MUST co-exist with Non IP communication and SHOULD NOT break any Non IP mechanism, including ’harmful’ interference on the channel.

The ID of the vehicle transmitting Non IP communication is transmitted in the src MAC address of the IEEE 1609 / ETSI Geonet datagrams. Accordingly, Non IP communications expose the ID of each vehicle, which may be considered as a privacy breach.

IEEE 802.11-OCB bypasses the authentication mechanisms of IEEE 802.11 networks, in order for non IP communications to be transmitted without any delay. This may be considered as a security breach.

IEEE 1609 and ETSI ITS provided strong security and privacy mechanisms for Non IP Communications. Security (authentication, encryption) is done by asymetric cryptography, where each vehicle attaches its public key and its certificate to all of its non IP messages. Privacy is enforced through the use of Pseudonymes. Each vehicle will be pre-loaded with a large (>1000s) of pseudonymes generated by a PKI, which will uniquely assign a pseudonyme to a certificate (and thus to a public/private key pair).

Non IP Communication being developped for safety-critical applications, complex mechanisms have been provided for their support. These mechanisms are OPTIONAL for IP Communication, but SHOULD be used whenever possible.

3.3. Reliability Requirements

The dynamically changing topology, short connectivity, mobile transmitter and receivers, different antenna heights, and many-to-many communication types, make IEEE 802.11-OCB links significantly different to other IEEE 802.11 links. Any IPv6 mechanism operating on IEEE 802.11-OCB link MUST support strong link asymetry, spatio-temporal link quality, fast address resolution and transmission.

IEEE 802.11-OCB strongly differs from other 802.11 systems to operate outside of the context of a Basic Service Set. This means in practice that IEEE 802.11-OCB does not rely on a Base Station for all Basic Service Set management. In particular, IEEE 802.11-OCB SHALL NOT use beacons. Any IPv6 mechanism requiring L2 services from IEEE 802.11 beacons MUST support an alternative service.

Channel scanning being disabled, IPv6 over IEEE 802.11-OCB MUST implement a mechanism for transmitter and receiver to converge to a common channel.

Authentication being not possible, IPv6 over IEEE 802.11-OCB MUST implement an distributed mechanism to authenticate transmitters and receivers without the support of a DHCP server.

Time synchronization being not available, IPv6 over IEEE 802.11-OCB MUST implement a higher layer mechanism for time synchroniation between transmitters and receivers without the support of a NTP server.

The IEEE 802.11-OCB link being asymetic, IPv6 over IEEE 802.11-OCB MUST disable management mechanisms requesting acknowledgements or replies.

The IEEE 802.11-OCB link having a short duration time, IPv6 over IEEE 802.11-OCB MUST implement fast IPv6 mobility management mechanisms.

3.4. Privacy requirements

Vehicles will move. As they move, each vehicle needs to regularly announce its network interface and reconfigure its local and global view of its network. L2 mechanisms of IEEE 802.11-OCB MAY be employed to assist IPv6 in discovering new network interfaces. L3 mechanisms over IEEE 802.11-OCB SHOULD be used to assist IPv6 in discovering new network interfaces.

The headers of the L2 mechanisms of IEEE 802.11-OCB and L3 management mechanisms of IPv6 are not encrypted, and as such expose at least the src MAC address of the sender. In the absence of mitigations, adversaries could monitor the L2 or L3 management headers, track the MAC Addresses, and through that track the position of vehicles over time; in some cases, it is possible to deduce the vehicle manufacturer name from the OUI of the MAC address of the interface (with help of additional databases). It is important that sniffers along roads not be able to easily identify private information of automobiles passing by.

Similary to Non IP safety-critical communications, the obvious mitigation is to use some form of MAC Address Randomization. We can assume that there will be "renumbering events" causing the MAC Addresses to change. Clearly, a change of MAC Address should induce a simultaneous change of IPv6 Addresses, to prevent linkage of the old and new MAC Addresses through continuous use of the same IP Addresses.

The change of an IPv6 address also implies the change of the network prefix. Prefix delegation mechanisms should be available to vehicles to obtain new prefices during "renumbering events".

Changing MAC and IPv6 addresses will disrupt communications, which goes against the reliability requirements expressed in [TS103097]. We will assume that the renumbering events happen only during "safe" periods, e.g. when the vehicle has come to a full stop. The

determination of such safe periods is the responsibility of implementors. In automobile settings it is common to decide that certain operations (e.g. software update, or map update) must happen only during safe periods.

MAC Address randomization will not prevent tracking if the addresses stay constant for long intervals. Suppose for example that a vehicle only renumbers the addresses of its interface when leaving the vehicle owner's garage in the morning. It would be trivial to observe the "number of the day" at the known garage location, and to associate that with the vehicle's identity. There is clearly a tension there. If renumbering events are too infrequent, they will not protect privacy, but if their are too frequent they will affect reliability. We expect that implementors will eventually find the right balance.

3.5. Authentication requirements

IEEE 802.11-OCB does not have L2 authentication mechanisms. Accordingly, a vehicle receiving a IPv6 over IEEE 802.11-OCB packet cannot check or be sure the legitimacy of the src MAC (and associated ID). This is a significant breach of security.

Similarly to Non IP safety-critical communications, IPv6 over 802.11-OCB packets must contain a certificate, including at least the public key of the sender, that will allow the receiver to authenticate the packet, and guarantee its legitimacy.

To satisfy the privacy requiremrents of Section 3.4, the certificate SHALL be changed at each 'renumbering event'.

3.6. Multiple interfaces

There are considerations of 2 or more IEEE 802.11-OCB interface cards per vehicle. For each vehicle taking part of road traffic, one IEEE 802.11-OCB interface card MUST be fully allocated for Non IP safety-critical communication. Any other IEEE 802.11-OCB may be used for other type of traffic.

The mode of operation of these other wireless interfaces is not clearly defined yet. One possibility is consider each card as an independent network interface, with a specific MAC Address and a set of IPv6 addresses. Another possibility is to consider the set of these wireless interfaces as a single network interface (not including the IEEE 802.11-OCB interface used by Non IP safety critical communications). This will require specific logic to ensure, for example, that packets meant for a vehicle in front are actually sent by the radio in the front, or that multiple copies of

the the same packet received by multiple interfaces are treated as a single packet. Treating each wireless interface as a separate network interface pushes such issues to the application layer.

The privacy requirements of Section 3.4 imply that if these multiple interfaces are represented by many network interface, a single renumbering event SHALL cause renumbering of all these interfaces. If one MAC changed and another stayed constant, external observers would be able to correlate old and new values, and the privacy benefits of randomization would be lost.

The privacy requirements of Non IP safety-critical communications imply that if a change of pseudonyme occurs, renumbering of all other interfaces SHALL also occur.

3.7. MAC Address Generation

When designing the IPv6 over 802.11-OCB address mapping, we will assume that the MAC Addresses will change during well defined "renumbering events". The 48 bits randomized MAC addresses will have the following characteristics:

- Bit "Local/Global" set to "locally admninistered".
- Bit "Unicast/Multicast" set to "Unicast".
- 46 remaining bits set to a random value, using a random number generator that meets the requirements of [RFC4086].

One possible way to meet the randomization requirements is to retain 46 bits from the output of a strong HASH function, such as SHA256, taking as input a 256 bit local secret, the "nominal" MAC Address of the interface, and a representation of the date and time of the renumbering event.

3.8. Security Certificate Generation

When designing the IPv6 over 802.11-OCB address mapping, we will assume that the MAC Addresses will change during well defined "renumbering events". So MUST also the Security Certificates. Unless unavailable, the Security Certificate Generation mechanisms SHOULD follow the specification in IEEE 1609.2 [ieee16094] or ETSI TS 103 097 [TS103097]. These security mechanisms have the following characteristics:

- Authentication - Elliptic Curve Digital Signature Algorithm (ECDSA) - A Secured Hash Function (SHA-256) will sign the message with the public key of the sender.

- Encryption - Elliptic Curve Integrated Encryption Scheme (ECIES) - A Key Derivation Function (KDF) between the sender's public key and the receiver's private key will generate a symetric key used to encrypt a packet.

If the mechanisms described in IEEE 1609.2 [ieee16094] or ETSI TS 103 097 [TS103097] are either not supported or not capable of running on the hardware, an alternative approach based on Pretty-Good-Privacy (PGP) MAY be used as an alternative.

4. Mapping IPv6 over 802.11-OCB

4.1. Maximum Transmission Unit

MTU is determined by the IEEE 802.11-2012 specification [ieee802.11-2012].

4.2. Frame Format

4.3. Stateless Autoconfiguration

4.4. Link-Local Addresses

4.5. Address Mapping -- Unicast

4.6. Address Mapping -- Multicast

5. Security Considerations

The source MAC address can be generated by the following random-number generation algorithm:

```
f = ... 48bits.
The output must not collide with existing allocations.
```

For one 802.11-OCB interface multiple random MAC addresses MAY be generated.

For each MAC address there is an associated certificate.

6. IANA Considerations

7. Acknowledgements

The authors would like to acknowledge...

8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

[RFC2460] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, DOI 10.17487/RFC2460, December 1998, <http://www.rfc-editor.org/info/rfc2460>.

[RFC2464] Crawford, M., "Transmission of IPv6 Packets over Ethernet Networks", RFC 2464, DOI 10.17487/RFC2464, December 1998, <http://www.rfc-editor.org/info/rfc2464>.

[RFC4086] Eastlake 3rd, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", BCP 106, RFC 4086, DOI 10.17487/RFC4086, June 2005, <http://www.rfc-editor.org/info/rfc4086>.

8.2. Informative References

[I-D.petrescu-its-scenarios-reqs] Petrescu, A., Janneteau, C., Boc, M., and W. Klaudel, "Scenarios and Requirements for IP in Intelligent Transportation Systems", draft-petrescu-its-scenarios-reqs-03 (work in progress), October 2013.

[ieee16094] "1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments--Security Services for Applications and Management Messages; document freely available at URL https://standards.ieee.org/findstds/standard/1609.2-2016.html retrieved on July 08th, 2016.".

[ieee802.11-2012]
"IEEE Std 802.11-2012 - IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications; document freely available at URL http://standards.ieee.org/getieee802/download/802.11-2012.pdf retrieved on July 08th, 2016.".

[ieee802.11p-2010]
"IEEE Std 802.11p(TM)-2010, IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 6: Wireless Access in Vehicular Environments; document freely available at URL http://standards.ieee.org/getieee802/download/802.11p-2010.pdf retrieved on September 20th, 2013.".

[TS103097]
"Intelligent Transport Systems (ITS); Security; Security header and certificate formats; document freely available at URL http://www.etsi.org/deliver/etsi_ts/103000_103099/103097/01.01.01_60/ts_103097v010101p.pdf retrieved on July 08th, 2016.".

Appendix A. ChangeLog

The changes are listed in reverse chronological order, most recent changes appearing at the top of the list.

From -00.txt to -00.txt:

- first version.

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Survey on IP-based Vehicular Networking for Intelligent Transportation Systems
draft-jeong-its-vehicular-networking-survey-01

Abstract

This document surveys the IP-based vehicular networks, which are considered a key component of Intelligent Transportation Systems (ITS). The main topics of vehicular networking are vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-vehicle (I2V) networking. This document deals with some critical aspects in vehicular networking, such as IP address autoconfiguration, vehicular network architecture, routing, and mobility management. This document summarizes and analyzes the previous research activities that use IPv4 or IPv6 for vehicular networking.

This Internet-Draft will expire on January 19, 2017.

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1. Introduction

Nowadays vehicular networks have been focused on the driving safety, driving efficiency, and infotainment in road networks. For the driving safety, IEEE has standardized Wireless Access in Vehicular Environments (WAVE) standards, such as IEEE 802.11p, IEEE 1609.3, and IEEE 1609.4 [VIP-WAVE]. Along with these WAVE standards, IPv6 and Mobile IP protocols (e.g., MIPv4 and MIPv6) can be extended to vehicular networks.

This document surveys the IP-based vehicular networking for Intelligent Transportation Systems (ITS), such as IP address autoconfiguration, vehicular network architecture, vehicular network routing (for multi-hop V2V, V2I, and V2V), and mobility management. This document summarizes and analyzes the previous research activities using IPv4 or IPv6 for vehicular networking.

Based on the survey of this document, we can specify the requirements for vehicular networks for the intended purposes, such as the driving safety, driving efficiency, and infotainment. As a consequence, this will make it possible to design the network architecture and protocols for vehicular networking.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Terminology

This document defines the following new terms:

- Road-Side Unit (RSU): A node that has Dedicated Short-Range Communications (DSRC) device for wireless communications with vehicles and is connected to the Internet. An RSU is usually deployed at an intersection.

- Vehicle: A node that has DSRC device for wireless communications with vehicles and RSUs. A vehicle may also have a GPS-navigation system for efficient driving.

- Traffic Control Center (TCC): A node that maintains road infrastructure information (e.g., RSUs and traffic signals), vehicular traffic statistics (e.g., average vehicle speed and vehicle inter-arrival time per road segment), and vehicle information (e.g., a vehicle’s identifier, position, direction, speed, and trajectory as a navigation path). TCC is included in a

vehicular cloud for vehicular networks.

4. IP Address Autoconfiguration

This section surveys IP address autoconfiguration schemes for vehicular networks.

4.1. Automatic IP Address Configuration in VANETs

Fazio et al. proposed a vehicular address configuration called VAC for automatic IP address configuration in Vehicular Ad Hoc Networks (VANET) [Address-Autoconf]. VAC uses a distributed dynamic host configuration protocol (DHCP). This scheme uses a leader playing a role of a DHCP server within a cluster having connected vehicles within a VANET. In a connected VANET, vehicles are connected with each other with the communication range. In this VANET, VAC dynamically elects a leader-vehicle to quickly provide vehicles with unique IP addresses. The leader-vehicle maintains updated information on configured addressed in its connected VANET. It aims at the reduction of the frequency of IP address reconfiguration due to mobility.

VAC defines the concept of SCOPE as a delimited geographic area where IP addresses are guaranteed to be unique. When it is allocated an IP address from a leader-vehicle with a scope, a vehicle is guaranteed to have a unique IP address while moving within the scope of the leader-vehicle. If it moves out of the scope of the leader vehicle, it needs to ask for another IP address from another leader-vehicle so that its IP address can be unique within the scope of the new leader-vehicle. This approach may allow for less frequent change of an IP address than the address allocation from a fixed Internet gateway.

Thus, VAC can support a feasible address autoconfiguration for V2V scenarios, but the overhead to guarantee the uniqueness of IP addresses is not ignorable under high-speed mobility.

4.2. Routing and Address Assignment using Lane/Position Information in a Vehicular Ad-hoc Network

Kato et al. proposed an IPv6 address assignment scheme using lane and position information [Address-Assignment]. In this addressing scheme, each lane of a road segment has a unique IPv6 prefix. When it moves in a lane in a road segment, a vehicle autoconfigures its IPv6 address with its MAC address and the prefix assigned to the lane. A group of vehicles constructs a connected VANET within the same subnet such that their IPv6 addresses have the same prefix. Whenever it moves to another lane, a vehicle updates its IPv6 address with the prefix corresponding to the new lane and also joins the

group corresponding to the lane.

However, this address autoconfiguration scheme may have much overhead in the case where vehicles change their lanes frequently in highway.

4.3. GeoSAC: Scalable Address Autoconfiguration for VANET Using Geographic Networking Concepts

Baldessari et al. proposed an IPv6 scalable address autoconfiguration scheme called GeoSAC for vehicular networks [GeoSAC]. GeoSAC uses geographic networking concepts such that it combines the standard IPv6 ND and geographic routing functionality. It matches geographically-scoped network partitions to individual IPv6 multicast-capable links. In the standard IPv6, all nodes within the same link must communicate with each other, but due to the characteristics of wireless links, this concept of a link is not clear in vehicular networks. GeoSAC defines a link as a geographic area having a network partition. This geographic area can have a connected VANET. Thus, vehicles within the same VANET in a specific geographic area are regarded as staying in the same link, that is, an IPv6 multicast link.

This paper identifies four key requirements of IPv6 address autoconfiguration for vehicular networks: (i) the configuration of globally valid addresses, (ii) a low complexity for address autoconfiguration, (iii) a minimum signaling overhead of address autoconfiguration, (iv) the support of network mobility through movement detection, (v) an efficient gateway selection from multiple RSUs, (vi) a fully distributed address autoconfiguration for network security, (vii) the authentication and integrity of signaling messages, and (viii) the privacy protection of vehicles' users.

To support the proposed link concept, GeoSAC performs ad hoc routing for geographic networking in a sub-IP layer called Car-to-Car (C2C) NET. Vehicles within the same link can receive an IPv6 router advertisement (RA) message transmitted by an RSU as a router, so they can autoconfigure their IPv6 address based on the IPv6 prefix contained in the RA and perform the DAD to verify the uniqueness of the autoconfigured IP address by the help of the geographic routing within the link.

For location-based applications, to translate between a geographic area and an IPv6 prefix belonging to an RSU, this paper takes advantage of an extended DNS service, using GPS-based addressing and routing along with geographic IPv6 prefix format [GeoSAC].

Thus, GeoSAC can support the IPv6 link concept through geographic routing within a specific geographic area.

5. Vehicular Network Architecture

This section surveys vehicular network architectures based on IP along with various ratio technologies.

5.1. VIP-WAVE: On the Feasibility of IP Communications in 802.11p Vehicular Networks

Cespedes et al. proposed a vehicular IP in WAVE called VIP-WAVE for I2V and V2I networking [VIP-WAVE]. IEEE 1609.4 specified a WAVE stack of protocols and includes IPv6 as a network layer protocol in data plane. The standard WAVE does not support duplicate address detection (DAD), seamless communications for Internet services, and multi-hop communications between a vehicle and an infrastructure node (e.g., RSU). To overcome these limitations of the standard WAVE for IP-based networking, VIP-WAVE enhances the standard WAVE by the following three schemes: (i) an efficient mechanism for the IPv6 address assignment and DAD, (ii) on-demand IP mobility based on Proxy Mobile IPv6 (PMIPv6), and (iii) one-hop and two-hop communications for I2V and V2I networking.

In WAVE, IPv6 neighbor discovery (ND) protocol is not recommended due to the overhead of ND against the timely and prompt communications in vehicular networking. By WAVE service advertisement (WAS) management frame, an RSU can provide vehicles with IP configuration information (e.g., IPv6 prefix, prefix length, gateway, router lifetime, and DNS server) without using ND. However, WAVE devices may support readdressing to provide pseudonymity, so a MAC address of a vehicle may be changed or randomly generated. This update of the MAC address may lead to the collision of an IPv6 address based on a MAC address, so VIP-WAVE includes a light-weight, on-demand ND to perform DAD.

For IP-based Internet services, VIP-WAVE adopts PMIPv6 for network-based mobility management in vehicular networks. In VIP-WAVE, RSU plays a role of mobile anchor gateway (MAG) of PMIPv6, which performs the detection of a vehicle as a mobile node in a PMIPv6 domain and registers it into the PMIPv6 domain. For PMIPv6 operations, VIP-WAVE requires a central node called local mobility anchor (LMA), which assigns IPv6 prefixes to vehicles as mobile nodes and forwards data packets to the vehicles moving in the coverage of RSUs under its control through tunnels between MAGs and itself.

For two-hop communications between a vehicle and an RSU, VIP-WAVE allows an intermediate vehicle between the vehicle and the RSU to play a role of a packet relay for the vehicle. When it becomes out of the communication range of an RSU, a vehicle searches for another vehicle as a packet relay by sending a relay service announcement. When it receives this relay service announcement and is within the

communication range of an RSU, another vehicle registers itself into the RSU as a relay and notifies the relay-requester vehicle of a relay maintenance announcement.

Thus, VIP-WAVE is a good candidate for I2V and V2I networking, supporting an enhanced ND, handover, and two-hop communications through a relay.

5.2. IPv6 Operation for WAVE - Wireless Access in Vehicular Environments

Baccelli et al. provided an analysis of the operation of IPv6 as it has been described by the IEEE WAVE standards 1609 [IPv6-WAVE]. Although the main focus of WAVE has been the timely delivery of safety related information, the deployment of IP-based infotainment applications is also considered. Thus, in order to support infotainment traffic, WAVE supports IPv6 and transport protocols such as TCP and UDP.

In the analysis provided in [IPv6-WAVE], it is identified that the IEEE 1609.3 standard’s recommendations for IPv6 operation over WAVE are rather minimal. Protocols on which the operation of IPv6 relies for IP address configuration and IP-to-link-layer address translation (e.g., IPv6 NP protocol) are not recommended in the standard. Additionally, IPv6 works under certain assumptions for the link model that do not necessarily hold in WAVE. For instance, IPv6 assumes symmetry in the connectivity among neighboring interfaces. However, interference and different levels of transmission power may cause unidirectional links to appear in a WAVE link model. Also, in an IPv6 link, it is assumed that all interfaces which are configured with the same subnet prefix are on the same IP link. Hence, there is a relationship between link and prefix, besides the different scopes that are expected from the link-local and global types of IPv6 addresses. Such a relationship does not hold in a WAVE link model due to node mobility and highly dynamic topology.

Baccellii et al. concluded that the use of the standard IPv6 protocol stack, as the IEEE 1609 family of specifications stipulate, is not sufficient. Instead, the addressing assignment should follow considerations for ad-hoc link models, defined in [RFC5889], which are similar to the characteristics of the WAVE link model. In terms of the supporting protocols for IPv6, such as Neighbor Discovery, DHCP, or stateless auto-configuration, which rely largely on multicast, do not operate as expected in the case where the WAVE link model does not have the same behavior expected for multicast IPv6 traffic due to nodes’ mobility and link variability. Additional challenges such as the support of pseudonimity through MAC address change along with the suitability of traditional TCP applications are

discussed by the authors since they require the design of appropriate solutions.

5.3. A Framework for IP and non-IP Multicast Services for Vehicular Networks

Jemaa et al. presented a framework that enables deploying multicast services for vehicular networks in Infrastructure-based scenarios [Vehicular-Network-Framework]. This framework deals with two phases: (i) Initialization or bootstrapping phase that includes a geographic multicast auto-configuration process and a group membership building method and (ii) Multicast traffic dissemination phase that includes a network selecting mechanism on the transmission side and a receiver-based multicast delivery in the reception side. To this end, authors define a distributed mechanism that allows the vehicles to configure a common multicast address: Geographic Multicast Address Auto-configuration (GMAA), which allows a vehicle to configure its own address without signaling. A vehicle may also be able to change the multicast address to which it is subscribed when it changes its location.

This framework suggests a network selecting approach that allows IP and non-IP multicast data delivery in the sender side. Then, to meet the challenges of multicast address auto-configuration, the authors propose a distributed geographic multicast auto-addressing mechanism for multicast groups of vehicles, and a simple multicast data delivery scheme in hybrid networks from a server to the group of moving vehicles. However, this study lacks simulations related to performance assessment.

5.4. Joint IP Networking and Radio Architecture for Vehicular Networks

Petrescu et al. defined the joined IP networking and radio architecture for V2V and V2I communication in [Joint-IP-Networking]. The paper proposes to consider an IP topology in a similar way as a radio link topology, in the sense that an IP subnet would correspond to the range of 1-hop vehicular communication. The paper defines three types of nodes: the Leaf Nodes (LN), the Range Extension Nodes (REV), and the Internet Nodes (IV). The first class corresponds to the largest set of communicating vehicles (or network nodes within a vehicle), while the role of the second class is to build an IP relay between two IP-subnet and two sub-IP networks. Finally, the last class corresponds to vehicles being connected to Internet. Based on these three classes, the paper defines six types of IP topologies corresponding to V2V communication between two LNs in direct range, or two LNs over a range extended vehicle, or V2I communication again either directly via an IV, via another vehicles being IV, or via an REV connecting to an IV.

Considering a toy example of a vehicular train, where LN would be in-wagon communicating nodes, REV would be inter-wagon relays, and IV would be one node (e.g., train head) connected to Internet. Petrescu et al. defined the required mechanisms to build subnetworks, and evaluated the protocol time that is required to build such networks. Although no simulation-based evaluation is conducted, the initial analysis shows a long initial connection overhead, which should be alleviated once the multi-wagon remains stable. However, this approach does not describe what would happen in the case of a dynamic multi-hop vehicular network, where such overhead would end up being too high for V2V/V2I IP-based vehicular applications.

One other aspect described in this paper is to join the IP-layer relaying with radio-link channels. This paper suggests to separate different subnetworks in different WiFi/ITS-G5 channels, which could be advertised by the REV. Accordingly, the overall interference could be controlled within each subnetwork. This statement is similar to multi-channel topology management proposals in multi-hop sensor networks, yet adapted to an IP topology.

In conclusion, this paper proposes to classify an IP multi-hop vehicular network in three classes of nodes: Leaf Node (LN), Range Extension Vehicle (REV), and Internet Vehicle (IV). It suggests that the generally complex multi-hop IP vehicular topology could be represented by only six different topologies, which could be further analyzed and optimized. A prefix dissemination protocol is proposed for one of the topologies.

5.5. Mobile Internet Access in FleetNet

Bechler et al. described the FleetNet project approach to integrate Internet Access in future vehicular networks [FleetNet]. The paper is most probably one of the first paper to address this aspect, and in many ways, introduces concepts that will be later used in MIPv6 or other subsequent IP mobility management schemes. The paper describes a V2I architecture consisting of Vehicles, Internet Gateways (IGW), Proxy, and Corresponding Nodes (CN). Considering that vehicular networks are required to use IPv6 addresses and also the new wireless access technology ITS-G5 (new at that time), one of the challenges is to bridge the two different networks (i.e., VANET and IP4/IPv6 Internet). Accordingly, the paper introduces a Fleetnet Gateway (FGW), which allows vehicles in IPv6 to access the IPv4 Internet and to bridge two types of networks and radio access technologies. Another challenge is to keep the active addressing and flows while vehicles move between FGWs. Accordingly, the paper introduces a proxy node, a cranked-up MIP Home Agent, which can re-route flows to the new FGW as well as acting as a local IPv4-IPv6 NAT.

The authors from the paper mostly observed two issues that VANET brings into the traditional IP mobility. First, VANET vehicles must mostly be addressed from the Internet directly, and do not specifically have a Home Network. Accordingly, VANET vehicles require a globally (predefined) unique IPv6 address, while an IPv6 co-located care-of address (CCoA) is a newly allocated IPv6 address every time a vehicle would enter a new IGW radio range. Second, VANET links are known to be unreliable and short, and the extensive use of IP tunneling on-the-air was judged not efficient. Accordingly, the first major architecture innovation proposed in this paper is to re-introduce a foreign agent (FA) in MIP located at the IGW, so that the IP-tunneling would be kept in the back-end (between a Proxy and an IGW) and not on the air. Second, the proxy has been extended to build an IP tunnel and be connected to the right FA/IWG for an IP flow using a global IPv6 address.

This is a pioneer paper, which contributed to changing MIP and led to the new IPv6 architecture currently known as Proxy-MIP and the subsequent DMM-PMIP. Three key messages can be yet kept in mind. First, unlike the Internet, vehicles can be more prominently directly addressed than the Internet traffic, and do not have a Home Network in the traditional MIP sense. Second, IP tunneling should be avoided as much as possible over the air. Third, the protocol-based mobility (induced by the physical mobility) must be kept hidden to both the vehicle and the correspondent node (CN).

5.6. A Layered Architecture for Vehicular Delay-Tolerant Networks

Soares et al. addressed the case of delay tolerant vehicular network [Vehicular-DTN]. For delay tolerant or disruption tolerant networks, rather than building a complex VANET-IP multi-hop route, vehicles may also be used to carry packets closer to the destination or directly at the destination. The authors built the well-accepted DTN Buddle architecture and protocol to propose a VANET extension. They introduced three types of VANET nodes: (i) terminal nodes (requiring data), (ii) mobile nodes (carrying data along their routes), and (iii) relay nodes (storing data at cross-roads of mobile nodes as data hotspot).

The major innovation in this paper is to propose a DTN VANET architecture separating a Control plane and a Data plane. The authors claimed it to be designed to allow full freedom to select the most appropriate technology, as well as allow to use out-of-band communication for small Control plane packets and use DTN in-band for the Data plane. The paper then further describes the different layers from the Control and the Data planes. One interesting aspect is the positioning of the Bundle layer between L2 and L3, rather than above TCP/IP as for the DTN Bundle architecture. The authors claimed

this to be required first to keep bundle aggregation/disaggregation transparent to IP, as well as to allow bundle transmission over multiple access technologies (described as MAC/PHY layers in the paper).

Although the DTN architectures evolved since the paper has been written, this paper addresses IP mobility management from a different approach. The innovative aspect is an early proposal to separate the Control from the Data plane to allow a large flexibility in a Control plane to coordinate a heterogeneous radio access technology (RAT) Data plane.

6. Vehicular Network Routing

This section surveys routing in vehicular networks.

6.1. An IP Passing Protocol for Vehicular Ad Hoc Networks with Network Fragmentation

Chen et al. tackled the issue of network fragmentation in VANET environments [IP-Passing-Protocol]. The paper proposes a protocol that can postpone the time to release IP addresses to the DHCP server and select a faster way to get the vehicle's new IP address, when the vehicle density is low or the speeds of vehicles are varied. In such circumstances, the vehicle may not be able to communicate with the intended vehicle either directly or through multi-hop relays as a consequence of network fragmentation.

The paper claims that although the existing IP passing and mobility solutions may reduce handoff delay, but they cannot work properly on VANET especially with network fragmentation. This is due to the fact that messages cannot be transmitted to the intended vehicles. When network fragmentation occurs, it may incur longer handoff latency and higher packet loss rate. The main goal of this study is to improve existing works by proposing an IP passing protocol for VANET with network fragmentation.

The paper makes the assumption that on the highway, when a vehicle moves to a new subnet, the vehicle will receive broadcast packet from the target Base Station (BS), and then perform the handoff procedure. The handoff procedure includes two parts, such as the layer-2 handoff (new frequency channel) and the layer-3 handover (a new IP address). The handoff procedure contains movement detection, DAD procedure, and registration. In the case of IPv6, the DAD procedure is time consuming and may cause the link to be disconnected.

This paper proposes another handoff mechanism. The handoff procedure contains the following phases. The first is the information

collecting phase, where each mobile node (vehicle) will broadcast its own and its neighboring vehicles' locations, moving speeds, and directions periodically. The remaining phases are, the fast IP acquiring phase, the cooperation of vehicle phase, the make before break phase, and the route redirection phase.

Simulations results show that for the proposed protocol, network fragmentation ratio incurs less impact. Vehicle speed and density has great impact on the performance of the IP passing protocol because vehicle speed and vehicle density will affect network fragmentation ratio. A longer IP lifetime can provide a vehicle with more chances to acquire its IP address through IP passing. Simulation results show that the proposed scheme can reduce IP acquisition time and packet loss rate, so extend IP lifetime with extra message overhead.

6.2. Experimental Evaluation for IPv6 over VANET Geographic Routing

Tsukada et al. presented a work that aims at combining IPv6 networking and a Car-to-Car Network routing protocol (called C2CNet) proposed by the Car2Car Communication Consortium (C2C-CC), which is an architecture using a geographic routing protocol [VANET-Geo-Routing]. In C2C-CC architecture, C2CNet layer is located between IPv6 and link layers. Thus, an IPv6 packet is delivered with outer C2CNet header, which introduces the challenge of how to support the communication types defined in C2CNet in IPv6 layer.

The main goal of GeoNet is to enhance these specifications and create a prototype software implementation interfacing with IPv6. C2CNet is specified in C2C-CC as a geographic routing protocol.

In order to assess the performance of this protocol, the authors measured the network performance with UDP and ICMPv6 traffic using iperf and ping6. The test results show that IPv6 over C2CNet does not have too much delay (less than 4ms with a single hop) and is feasible for vehicle communication. In the outdoor testbed, they developed AnaVANET to enable hop-by-hop performance measurement and position trace of the vehicles.

The combination of IPv6 multicast and GeoBroadcast was implemented, however, the authors did not evaluate the performance with such a scenario. One of the reasons is that a sufficiently high number of receivers is necessary to properly evaluate multicast but experimental evaluation is limited in the number of vehicles (4 in this study).

7. Mobility Management in Vehicular Networks

This section surveys mobility management schemes in vehicular networks to support handover.

7.1. A Hybrid Centralized-Distributed Mobility Management for Supporting Highly Mobile Users

Nguyen et al. proposed a hybrid centralized-distributed mobility management called H-DMM to support highly mobile vehicles [H-DMM]. The legacy DMM is not suitable for high-speed scenarios because it requires additional registration delay proportional to the distance between a vehicle and its anchor network. H-DMM is designed to satisfy a set of requirements, such as service disruption time, end-to-end delay, packet delivery cost, and tunneling cost.

H-DMM adopts a central node called central mobility anchor (CMA), which plays the role of a local mobility anchor (LMA) in PMIPv6. When it enters a mobile access router (MAR) as an access router, a vehicle obtains a prefix from the MAR (called MAR-prefix) according to the legacy DMM protocol. In addition, it obtains another prefix from the CMA (called LMA-prefix) for a PMIPv6 domain. Whenever it performs a handover between the subnets for two adjacent MARs, a vehicle keeps the LMA-prefix while obtaining a new prefix from the new MAR. For a new data exchange with a new CN, the vehicle can select the MAR-prefix or the LMA-prefix for its own source IPv6 address. If the number of active prefixes is greater than a threshold, the vehicle uses the LMA-prefix-based IPv6 address as its source address. In addition, it can continue receiving data packets with the destination IPv6 addresses based on the previous prefixes through the legacy DMM protocol.

Thus, H-DMM can support an efficient tunneling for a high-speed vehicle that moves fast across the subnets of two adjacent MARs. However, when H-DMM asks a vehicle to perform DAD for the uniqueness test of its configured IPv6 address in the subnet of the next MAR, the activation of the configured IPv6 address for networking will take a delay. This indicates that a proactive DAD by a network component (i.e., MAR and LMA) can shorten the address configuration delay of the current DAD triggered by a vehicle.

7.2. A Hybrid Centralized-Distributed Mobility Management Architecture for Network Mobility

Nguyen et al. proposed H-NEMO, a hybrid centralized-distributed mobility management scheme to handle IP mobility of moving vehicles [H-NEMO]. The standard Network Mobility (NEMO) basic support, which is a centralized scheme for network mobility, provides IP mobility

for a group of users in a moving vehicle, but also inherits the drawbacks from Mobile IPv6, such as suboptimal routing and signaling overhead in nested scenarios as well as reliability and scalability issues. On the contrary, distributed schemes such as the recently proposed Distributed Mobility Management (DMM) locates the mobility anchor at the network edge and enables mobility support only to traffic flows that require such support. However, in high speed moving vehicles, DMM may suffer from high signaling cost and high handover latency.

The proposed H-NEMO architecture is not designed for a specific wireless technology. Instead, it defines a general architecture and signaling protocol so that a mobile node can obtain mobility from fixed locations or mobile platforms, and also allows the use of DMM or Proxy Mobile IPv6 (PMIPv6), depending on flow characteristics and mobility patterns of the node. For IP addressing allocation, a mobile router (MR) or the mobile node (MN) connected to an MR in a NEMO obtain two sets of prefixes: one from the central mobility anchor and one from the mobile access router (MAR). In this way, the MR/MN may choose a more stable prefix for long-lived flows to be routed via the central mobility anchor and the MAR-prefix for short-lived flows to be routed following the DMM concept. The multi-hop scenario is considered under the concept of a nested-NEMO.

Nguyen et al. did not provide simulation-based evaluations, but they provided an analytical evaluation that considered signaling and packet delivery costs, and showed that H-NEMO outperforms the previous proposals, which are either centralized or distributed ones with NEMO support. In particular cases, such as the signaling cost, H-NEMO is more costly than centralized schemes when the velocity of the node is increasing, but behaves better in terms of packet delivery cost and handover delay.

7.3. NEMO-Enabled Localized Mobility Support for Internet Access in Automotive Scenarios

In [NEMO-LMS], authors proposed an architecture to enable IP mobility for moving networks in a network-based mobility scheme based on PMIPv6. In PMIPv6, only mobile terminals are provided with IP mobility. Different from host-based mobility, PMIPv6 shifts the signaling to the network side, so that the mobile access gateway (MAG) is in charge of detecting connection/disconnection of the mobile node, upon which the signaling to the Local Mobility Anchor (LMA) is triggered to guarantee a stable IP addressing assignment when the mobile node performs handover to a new MAG.

Soto et al. proposed NEMO support in PMIPv6 (N-PMIP). In this scheme, the functionality of the MAG is extended to the mobile router

(MR), also called a mobile MAG (mMAG). The functionality of the mobile terminal remains unchanged, but it can receive an IPv6 prefix belonging to the PMIPv6 domain through the new functionality of the mMAG. Therefore, in N-PMIP, the mobile terminal connects to the MR as if it is connecting to a fixed MAG, and the MR connects to the fixed MAG with the standardized signaling of PMIPv6. When the mobile terminal roams to a new MAG or a new MR, the network forwards the packets through the LMA. Hence, N-PMIP defines an extended functionality in the LMA that enables a recursive lookup. First, it locates the binding entry corresponding to the mMAGr. Next, it locates the entry corresponding to the fixed MAG, after which the LMA can encapsulate packets to the mMAG to which the mobile terminal is currently connected.

The performance of N-PMIP was evaluated through simulations and compared to a NEMO+MIPv6+PMIPv6 scheme, with better results obtained in N-PMIP. The work did not consider the case of multi-hop connectivity in the vehicular scenario. In addition, since the MR should be a trusted entity in the PMIP domain, it requires specific security associations that were not addressed in [NEMO-LMS].

7.4. Network Mobility Protocol for Vehicular Ad Hoc Networks

Chen et al. proposed a network mobility protocol to reduce handoff delay and maintain Internet connectivity to moving vehicles in a highway [NEMO-VANET]. In this work, vehicles can acquire IP addresses from other vehicles through V2V communications. At the time the vehicle goes out of the coverage of the base station, another vehicle may assist the roaming car to acquire a new IP address. Also, cars on the same or opposite lane are entitled to assist the vehicle to perform a pre-handoff.

Authors assumed that the wireless connectivity is provided by WiFi and WiMAX access networks. Also, they considered scenarios in which a single vehicle, i.e., a bus, may need two mobile routers in order to have an effective pre-handoff procedure. Evaluations are performed through simulations and the comparison schemes are the standard NEMO Basic Support protocol and the fast NEMO Basic Support protocol. Authors did not mention applicability of the scheme in other scenarios such as in urban transport schemes.

7.5. Performance Analysis of PMIPv6-Based Network MObility for Intelligent Transportation Systems

Lee et al. proposed P-NEMO, which is an IP mobility management scheme to maintain the Internet connectivity at the vehicle as a mobile network, and provides a make-before-break mechanism when vehicles switch to a new access network [PMIPv6-NEMO-Analysis]. Since the

standard PMIPv6 only supports mobility for a single node, the solution in [PMIPv6-NEMO-Analysis] adapts the protocol to reduce the signaling when a local network is to be served by the in-vehicle mobile router. To achieve this, P-NEMO extends the binding update lists at both MAG and LMA, so that the mobile router (MR) can receive a home network prefix (HNP) and a mobile network prefix (MNP). The latter prefix enables mobility for the moving network, instead of a single node as in the standard PMIPv6.

An additional feature is proposed by Lee et al. named fast P-NEMO (FP-NEMO). It adopts the fast handover approach standardized for PMIPv6 in [RFC5949] with both predictive and reactive modes. The difference of the proposed feature with the standard version is that by using the extensions provided by P-NEMO, the predictive transferring of the context from the old MAG to the new MAG also includes information for the moving network, i.e., the MNP, so that mobility support can be achieved not only for the mobile router, but also for mobile nodes traveling with the vehicle.

The performance of P-NEMO and F-NEMO is only evaluated through an analytical model that is compared to the standard NEMO-BS. No comparison was provided to other schemes that enable network mobility in PMIPv6 domains, such as the one presented in [NEMO-LMS].

7.6. A Novel Mobility Management Scheme for Integration of Vehicular Ad Hoc Networks and Fixed IP Networks

Peng et al. proposed a novel mobility management scheme for integration of VANET and fixed IP networks [Vehicular-Network-MM]. The proposed scheme deals with mobility of vehicles based on a street layout instead of a general two dimensional ad hoc network. This scheme makes use of the information provided by vehicular networks to reduce mobility management overhead. It allows multiple base stations that are close to a destination vehicle to discover the connection to the vehicle simultaneously, which leads to an improvement of the connectivity and data delivery ratio without redundant messages. The performance was assessed by using a road traffic simulator called SUMO (Simulation of Urban Mobility).

7.7. SDN-based Distributed Mobility Management for 5G Networks

Nguyen et al. extended their previous works on a vehicular adapted DMM considering a Software-Defined Networking (SDN) architecture [SDN-DMM]. On one hand, in their previous work, Nguyen et al. proposed DMM-PMIP and DMM-MIP architectures for VANET. The major innovation behind DMM is to distribute the Mobility Functions (MF) through the network instead of concentrating them in one bottleneck MF, or in a hierarchically organized backbone of MF. Highly mobile

vehicular networks impose frequent IP route optimizations that lead to suboptimal routes (detours) between CN and vehicles. The suboptimality critically increases by nested or hierarchical MF nodes. Therefore, flattening the IP mobility architecture significantly reduces detours, as it is the role of the last MF to get the closest next MF (in most cases nearby). Yet, with an MF being distributed throughout the network, a Control plane becomes necessary in order to provide a solution for CN to address vehicles. The various solutions developed by Nguyen at al. not only showed the large benefit of a DMM approach for IPv6 mobility management, but also emphasized the critical role of an efficient Control plane.

One the other hand, SDN recently appeared and gained a big attention from the Internet Networking community due to its capacity to provide a significantly higher scalability of highly dynamic flows, which is required by future 5G dynamic networks. In particular, SDN also suggests a strict separation between a Control plane (SDN-Controller) and a Data plane (OpenFlow Switches) based on the OpenFlow standard. Such an architecture has two advantages that are critical for IP mobility management in VANET. First, unlike traditional routing mechanisms, OpenFlow focuses on flows rather than optimized routes. Accordingly, they can optimize routing based on flows (grouping multiple flows in one route, or allowing one flow to have different routes), and can detect broken flows much earlier than the traditional networking solutions. Second, SDN controllers may dynamically reprogram (reconfigure) OpenFlow Switches (OFS) to always keep an optimal route between CN and a vehicular node.

Nguyen et. al observed the mutual benefits IPv6 DMM could obtain from an SDN architecture, and then proposed an SDN-based DMM for VANET. In their proposed architecture, a PMIP-DMM is used, where MF is OFS for the Data plane, and one or more SDN controllers handle the Control plane. The evaluation and prototype in the paper prove that the proposed architecture can provide a higher scalability than the standard DMM.

This paper makes several observations leading to a strong suggestions that IP mobility management should be based on an SDN architecture. First, SDN will be integrated into future Internet and 5G in a near future. Second, after separating the Identity and Routing addressing, IP mobility management further requires to separate the Control from the Data plane if it needs to remain scalable for VANET. Finally, Flow-based routing (in particular OpenFlow standard) will be required in future heterogeneous vehicular networks (e.g., multi-RAT and multi-protocol) and the SDN coupled with DMM provides a double benefit of dynamic flow detection/reconfiguration and short(-er) route optimizations.

7.8. IP Mobility Management for Vehicular Communication Networks: Challenges and Solutions

Cespedes et al. provided a survey of the challenges for NEMO Basic Support for VANET [Vehicular-IP-MM]. NEMO allows the management of a group of nodes (a mobile network) rather than a single node. However, although a vehicle and even a platoon of vehicles could be seen as a group of nodes, NEMO has not been designed considering the particularities of VANET. For example, NEMO builds a tunnel between an MR (on board of a vehicle) and its HA, which in a VANET context is suboptimal, for instance due to over-the-air tunneling cost, the detour taken to pass by the MR's HA even if the CN is nearby, or the route optimization when the MR moves to a new AR.

Cespedes et al. first summarize the requirements of IP mobility management, such as reduced power at end-device, reduced handover event, reduced complexity, or reduced bandwidth consumption. VANET adds the following requirements, such as minimum signaling for route optimization (RO), per-flow separability, security and binding privacy protection, multi-homing, and switching HA. As observed, these provide several challenges to IP mobility and NEMO BS for VANET.

Cespedes et al. then describe various optimization schemes available for NEMO BS. Considering a single hop connection to CN, one major optimization direction is to avoid the HA detour and reach the CN directly. In that direction, a few optimizations are proposed, such as creating an IP tunnel between the MR and the CR directly, creating an IP tunnel between the MR and a CR (rather than the HA), a delegation mechanism allowing Visiting Nodes to use MIPv6 directly rather than NEMO or finally intra-NEMO optimization for a direct path within NEMO bypassing HAs.

Specific to VANET, multi-hop connection is possible to the fixed network. In that case, NEMO BS must be enhanced to avoid that the path to immediate neighbors must pass by the respective HAs instead of directly. More specifically, two approaches are proposed to rely on VANET sub-IP multi-hop routing to hide a NEMO complex topology (e.g., Nested NEMO) and provide a direct route between two VANET nodes. Generally, one major challenge is security and privacy when opening a multi-hop route between a VANET and a CN. Heterogeneous multi-hop in a VANET (e.g., relying on various access technologies) corresponds to another challenge for NEMO BS as well.

Cespedes et al. conclude their paper with an overview of critical research challenges, such as Anchor Point location, the optimized usage of geographic information at the subIP as well as at the IP level to improve NEMO BS, security and privacy, and the addressing

allocation schema for NEMO.

In summary, this paper illustrates that NEMO BS for VANET should avoid the HA detour as well as opening IP tunnels over the air. Also, NEMO BS could use geographic information for subIP routing when a direct link between vehicles is required to reach an AR, but also anticipate handovers and optimize ROs. From an addressing perspective, dynamic MNP assignments should be preferred, but should be secured in particular during binding update (BU).

8. Summary and Analysis

This document surveyed state-of-the-arts technologies for IP-based vehicular networks, such as IP address autoconfiguration, vehicular network architecture, vehicular network routing, and mobility management.

Through this survey, it is learned that IPv6-based vehicular networking can be well-aligned with IEEE WAVE standards for various vehicular network applications, such as driving safety, efficient driving, and infotainment. However, since the IEEE WAVE standards do not recommend to use the IPv6 neighbor discovery (ND) protocol for the communication efficiency under high-speed mobility, it is necessary to adapt the ND for vehicular networks with such high-speed mobility.

The concept of a link in IPv6 does not match that of a link in VANET because of the physical separation of communication ranges of vehicles in the connected VANET. That is, in a linear topology of three vehicles (Vehicle-1, Vehicle-2, and Vehicle-3), Vehicle-1 and Vehicle-2 can communicate directly with each other. Vehicle-2 and Vehicle-3 can communicate directly with each other. However, Vehicle-1 and Vehicle-3 cannot communicate directly with each other due to the out-of-communication range. For the link in IPv6, all of three vehicles are on a link, so they can communicate directly with each other. On the other hand, in VANET, this on-link communication concept is not valid in VANET. Thus, the IPv6 ND should be extended to support this multi-link subnet of a connected VANET through either ND proxy or VANET routing.

For IP-based networking, IP address autoconfiguration is a prerequisite function. Since vehicles can communicate intermittently with TCC via RSUs through V2I communications, TCC can play a role of a DHCP server to allocate unique IPv6 addresses to the vehicles. This centralized address allocation can remove the delay of the duplicate address detection procedure for testing the uniqueness of IPv6 addresses.

For routing and mobility management, most of vehicles are equipped with a GPS navigator as a dedicated navigation system or a smartphone App. With this GPS navigator, vehicles can share their current position and trajectory (i.e., navigation path) with TCC. TCC can predict the future positions of the vehicles with their mobility information (i.e., the current position, speed, direction, and trajectory). With the prediction of the vehicle mobility, TCC supports RSUs to perform data packet routing and handover proactively.

9. Security Considerations

Security and privacy are important aspects in vehicular networks. Only valid vehicles should be allowed to participate in vehicular networking. Vehicle Identification Number (VIN) and user certificate can be used to authenticate a vehicle and user through road infrastructure, such as Road-Side Unit (RSU) connected to an authentication server in Traffic Control Center (TCC).

Moustafa et al. proposed a security scheme providing authentication and access control in vehicular networks [Vehicular-Network-Security]. The secuirty and privacy should be supported for safe and reliable data services in vehicular networks.

10. Acknowledgements

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11. References

11.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC5889] Baccelli, E. and M. Townsley, "IP Addressing Model in Ad Hoc Networks",

RFC 5889, September 2010.

[RFC5949] Yokota, H., Chowdhury, K., Koodli, R., Patil, B., and F. Xia, "Fast Handovers for Proxy Mobile IPv6", RFC 5949, September 2010.

11.2. Informative References

[Address-Autoconf] Fazio, M., Palazzi, C., Das, S., and M. Gerla, "Automatic IP Address Configuration in VANETs", ACM International Workshop on Vehicular Inter-Networking, September 2016.

[Address-Assignment] Kato, T., Kadowaki, K., Koita, T., and K. Sato, "Routing and Address Assignment using Lane/Position Information in a Vehicular Ad-hoc Network", IEEE Asia-Pacific Services Computing Conference, December 2008.

[GeoSAC] Baldessari, R., Bernardos, C., and M. Calderon, "GeoSAC - Scalable Address Autoconfiguration for VANET Using Geographic Networking Concepts", IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, September 2008.

[VIP-WAVE] Cespedes, S., Lu, N., and X. Shen, "VIP-WAVE: On the Feasibility of IP Communications in 802.11p Vehicular Networks", IEEE Transactions on Intelligent Transportation Systems, March 2013.

[IPv6-WAVE] Baccelli, E., Clausen, T., and R. Wakikawa, "IPv6 Operation for WAVE - Wireless Access in Vehicular Environments", IEEE Vehicular Networking Conference, December 2010.

[Vehicular-Network-Framework] Jemaa, I., Shagdar, O., and T. Ernst, "A Framework for IP and non-IP Multicast Services for Vehicular Networks", Third International

Conference on the Network of the Future, November 2012.

[Joint-IP-Networking] Petrescu, A., Boc, M., and C. Ibars, "Joint IP Networking and Radio Architecture for Vehicular Networks", 11th International Conference on ITS Telecommunications, August 2011.

[FleetNet] Bechler, M., Franz, W., and L. Wolf, "Mobile Internet Access in FleetNet", 13th Fachtagung Kommunikation in verteilten Systemen, February 2001.

[Vehicular-DTN] Soares, V., Farahmand, F., and J. Rodrigues, "A Layered Architecture for Vehicular Delay-Tolerant Networks", IEEE Symposium on Computers and Communications, July 2009.

[IP-Passing-Protocol] Chen, Y., Hsu, C., and W. Yi, "An IP Passing Protocol for Vehicular Ad Hoc Networks with Network Fragmentation", Elsevier Computers & Mathematics with Applications, January 2012.

[VANET-Geo-Routing] Tsukada, M., Jemaa, I., Menouar, H., Zhang, W., Goleva, M., and T. Ernst, "Experimental Evaluation for IPv6 over VANET Geographic Routing", IEEE International Wireless Communications and Mobile Computing Conference, June 2010.

[H-DMM] Nguyen, T. and C. Bonnet, "A Hybrid Centralized-Distributed Mobility Management for Supporting Highly Mobile Users", IEEE International Conference on Communications, June 2015.

[H-NEMO] Nguyen, T. and C. Bonnet, "A Hybrid Centralized-Distributed Mobility Management Architecture for Network Mobility", IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, June 2015.

[NEMO-LMS] Soto, I., Bernardos, C., Calderon, M., Banchs, A., and A. Azcorra, "NEMO-Enabled Localized Mobility Support for Internet Access in Automotive Scenarios", IEEE Communications Magazine, May 2009.

[NEMO-VANET] Chen, Y., Hsu, C., and C. Cheng, "Network Mobility Protocol for Vehicular Ad Hoc Networks", Wiley International Journal of Communication Systems, November 2014.

[PMIPv6-NEMO-Analysis] Lee, J., Ernst, T., and N. Chilamkurti, "Performance Analysis of PMIPv6-Based Network MObility for Intelligent Transportation Systems", IEEE Transactions on Vehicular Technology, January 2012.

[Vehicular-Network-MM] Peng, Y. and J. Chang, "A Novel Mobility Management Scheme for Integration of Vehicular Ad Hoc Networks and Fixed IP Networks", Springer Mobile Networks and Applications, February 2010.

[SDN-DMM] Nguyen, T., Bonnet, C., and J. Harri, "SDN-based Distributed Mobility Management for 5G Networks", IEEE Wireless Communications and Networking Conference, April 2016.

[Vehicular-IP-MM] Cespedes, S., Shen, X., and C. Lazo, "IP Mobility Management for Vehicular Communication Networks: Challenges and Solutions", IEEE Communications Magazine, May 2011.

[Vehicular-Network-Security] Moustafa, H., Bourdon, G., and Y. Gourhant, "Providing Authentication and Access Control in Vehicular Network Environment", IFIP TC-11 International Information Security Conference, May 2006.

Appendix A. Changes from draft-jeong-its-vehicular-networking-survey-00

The following changes were made from draft-jeong-its-vehicular-networking-survey-00:

- The duplicate sentences or phrases are removed and editorial corrections are done.

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Transmission of IPv6 Packets over the IEEE 802.11p OCB Mode
draft-lee-its-ipv6-over-80211ocb-00.txt

Abstract

This document describes the transmission of IPv6 packets over the IEEE 802.11p OCB mode. In particular it sets the MTU parameter and describes two alternative frame formats.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

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This Internet-Draft will expire on January 9, 2017.

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Table of Contents

1. Introduction

In the IEEE 802.11p OCB mode, all nodes in the wireless range can directly communicate with each other without authentication/ association procedures, thus data exchange between nodes can be established in fractions of seconds. The IEEE 802.11p OCB mode has the following properties:

- Wildcard BSSID (i.e., all bits are set to 1) used by each node
- No beacons transmitted
- No authentication required
- No association needed
- No encryption provided
- dot11OCBActivated OID set to true

This document describes the transmission of IPv6 packets over the IEEE 802.11p OCB mode.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

OCB - Outside the Context of a BSS.

802.11-OCB - IEEE 802.11-2012 text flagged by "dot11OCBActivated". This means: IEEE 802.11e for quality of service; 802.11j-2004 for half-clocked operations; and 802.11p for operation in the 5.9 GHz band and in mode OCB.

3. Maximum Transmission Unit

The default MTU size for IPv6 packets on an 802.11-OCB link is 1500 octets. This size may be reduced by a Router Advertisement containing an MTU option which specifies a smaller MTU, or by manual (or DHCPv6) configuration of each node. If a Router Advertisement received on an 802.11-OCB interface has an MTU option specifying an MTU larger than 1500 octets, or larger than a manually configured value, that MTU option may be logged to system management but must be otherwise ignored.

Non-IPv6 packets such as WAVE Short Message Protocol (WSMP) can be delivered on 802.11-OCB links. Specifications of these packets are out of scope and do not impose any limit on the MTU size, allowing an arbitrary number of ’containers’.

4. Frame Format

IPv6 packets can be transmitted as "IEEE 802.11 Data" or alternatively as "IEEE 802.11 QoS Data".

IEEE 802.11 Data	IEEE 802.11 QoS Data
Logical-Link Control	Logical-Link Control
IPv6 Header	IPv6 Header

5. Stateless Autoconfiguration

6. Link-Local Addresses

7. Address Mapping -- Unicast

8. Address Mapping -- Multicast

9. Security Considerations

10. IANA Considerations

11. Acknowledgements

The authors would like to acknowledge...

12. References

12.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

[RFC2460] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, DOI 10.17487/RFC2460, December 1998, <http://www.rfc-editor.org/info/rfc2460>.

[RFC2464] Crawford, M., "Transmission of IPv6 Packets over Ethernet Networks", RFC 2464, DOI 10.17487/RFC2464, December 1998, <http://www.rfc-editor.org/info/rfc2464>.

12.2. Informative References

[I-D.petrescu-its-scenarios-reqs] Petrescu, A., Janneteau, C., Boc, M., and W. Klaudel, "Scenarios and Requirements for IP in Intelligent Transportation Systems", draft-petrescu-its-scenarios-reqs-03 (work in progress), October 2013.

[ieee802.11p-2010] "IEEE Std 802.11p(TM)-2010, IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 6: Wireless Access in Vehicular Environments; document freely available at URL http://standards.ieee.org/getieee802/download/802.11p-2010.pdf retrieved on September 20th, 2013.".

Appendix A. ChangeLog

The changes are listed in reverse chronological order, most recent changes appearing at the top of the list.

From -00.txt to -00.txt:

o first version.

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