IPWAVE Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 7, 2020

N. Benamar
Moulay Ismail University
J. Haerri
Eurecom
J. Lee
Sangmyung University
T. Ernst
YoGoKo

July 6, 2019

Basic Support for IPv6 over IEEE Std 802.11 Networks Operating Outside the Context of a Basic Service Set (IPv6-over-80211-OCB) draft-ietf-ipwave-ipv6-over-80211ocb-48

Abstract

This document provides methods and settings, and describes limitations, for using IPv6 to communicate among nodes in range of one another over a single IEEE 802.11-OCB link. This support does only require minimal changes to existing stacks. Optimizations and usage of IPv6 over more complex scenarios is not covered in this specification and is subject of future work.

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 https://datatracker.ietf.org/drafts/current/.

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 7, 2020.

Copyright Notice

Copyright (c) 2019 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents

(https://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction 3
2. Terminology 3
3. Communication Scenarios where IEEE 802.11-OCB Links are Used 4
4. IPv6 over 802.11-OCB 4
4.1. Maximum Transmission Unit (MTU) 4
4.2. Frame Format 5
4.3. Link-Local Addresses 5
4.4. Stateless Autoconfiguration 5
4.5. Address Mapping 6
4.5.1. Address Mapping -- Unicast 6
4.5.2. Address Mapping -- Multicast 6
4.6. Subnet Structure 7
5. Security Considerations 8
5.1. Privacy Considerations 8
5.1.1. Privacy Risks of Meaningful info in Interface IDs . . 9
5.2. MAC Address and Interface ID Generation 9
5.3. Pseudonym Handling 10
6. IANA Considerations 10
7. Contributors 10
8. Acknowledgements 11
9. References 11
9.1. Normative References 12
9.2. Informative References 15
Appendix A. 802.11p 16
Appendix B. Aspects introduced by the OCB mode to 802.11 16
Appendix C. Changes Needed on a software driver 802.11a to become a 802.11-OCB driver . . . 21
Appendix D. Protocol Layering 22
Appendix E. Design Considerations 23
Appendix F. IEEE 802.11 Messages Transmitted in OCB mode 23
Appendix G. Examples of Packet Formats 23
G.1. Capture in Monitor Mode 24
G.2. Capture in Normal Mode 27
Appendix H. Extra Terminology 29
Appendix I. Neighbor Discovery (ND) Potential Issues in Wireless Links 30
Authors' Addresses 32

1. Introduction

This document provides a baseline with limitations for using IPv6 to communicate among nodes in range of one another over a single IEEE 802.11-OCB link [IEEE-802.11-2016] (a.k.a., "802.11p" see Appendicies Appendix A, Appendix B and Appendix C) with minimal changes to existing stacks. Moreover, the document identifies limitations of such usage. Concretly, the document describes the layering of IPv6 networking on top of the IEEE Std 802.11 MAC layer or an IEEE Std 802.3 MAC layer with a frame translation underneath. The resulting stack inherits from IPv6 over Ethernet [RFC 2464], but operates over 802.11-OCB to provide at least P2P (Point to Point) connectivity using IPv6 ND and link-local addresses.

The IPv6 network layer operates on 802.11-OCB in the same manner as operating on Ethernet with following exceptions:

- Exceptions due to different operation of IPv6 network layer on 802.11 than on Ethernet. The operation of IP on Ethernet is described in [RFC1042], [RFC2464] .

- Exceptions due to the OCB nature of 802.11-OCB compared to 802.11. This has impacts on security, privacy, subnet structure and movement detection. Security and privacy recommendations are discussed in Section 5 and Section 4.4. The subnet structure is described in Section 4.6. The movement detection on OCB links is not described in this document. Likewise, ND Extensions and IPWAVE optimizations for vehicular communications are not in scope. The expectation is that further specifications will be edited to cover more complex vehicular networking scenarios.

The reader may refer to [I-D.ietf-ipwave-vehicular-networking] for an overview of problems related to running IPv6 over 802.11-OCB. It is out of scope of this document to reiterate those.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The document makes uses of the following terms: IP-OBU (Internet Protocol On-Board Unit): an IP-OBU denotes a computer situated in a vehicle such as a car, bicycle, or similar. It has at least one IP interface that runs in mode OCB of 802.11, and that has an "OBU"

transceiver. See the definition of the term "OBU" in section Appendix H.

IP-RSU (IP Road-Side Unit): an IP-RSU is situated along the road. It has at least two distinct IP-enabled interfaces. The wireless PHY/MAC layer of at least one of its IP-enabled interfaces is configured to operate in 802.11-OCB mode. An IP-RSU communicates with the IP-OBU in the vehicle over 802.11 wireless link operating in OCB mode. An IP-RSU is similar to an Access Network Router (ANR) defined in [RFC3753], and a Wireless Termination Point (WTP) defined in [RFC5415].

OCB (outside the context of a basic service set - BSS): is a mode of operation in which a STA is not a member of a BSS and does not utilize IEEE Std 802.11 authentication, association, or data confidentiality.

802.11-OCB: refers to the mode specified in IEEE Std 802.11-2016 when the MIB attribute dot11OCBActivited is 'true'. Note: compliance with standards and regulations set in different countries when using the 5.9GHz frequency band is required.

3. Communication Scenarios where IEEE 802.11-OCB Links are Used

The IEEE 802.11-OCB networks are used for vehicular communications, as 'Wireless Access in Vehicular Environments'. In particular, we refer the reader to [I-D.ietf-ipwave-vehicular-networking], that lists some scenarios and requirements for IP in Intelligent Transportation Systems (ITS).

The link model is the following: STA --- 802.11-OCB --- STA. In vehicular networks, STAs can be IP-RSUs and/or IP-OBUs. All links are assumed to be P2P and multiple links can be on one radio interface. While 802.11-OCB is clearly specified, and a legacy IPv6 stack can operate on such links, the use of the operating environment (vehicular networks) brings in new perspectives.

4. IPv6 over 802.11-OCB

4.1. Maximum Transmission Unit (MTU)

The default MTU for IP packets on 802.11-OCB is inherited from RFC2464 and is, as such, 1500 octets. This value of the MTU respects the recommendation that every link on the Internet must have a minimum MTU of 1280 octets (stated in [RFC8200], and the recommendations therein, especially with respect to fragmentation).

4.2. Frame Format

IP packets MUST be transmitted over 802.11-OCB media as QoS Data frames whose format is specified in IEEE 802.11 spec [IEEE-802.11-2016].

The IPv6 packet transmitted on 802.11-OCB are immediately preceded by a Logical Link Control (LLC) header and an 802.11 header. In the LLC header, and in accordance with the EtherType Protocol Discrimination (EPD, see Appendix D), the value of the Type field MUST be set to 0x86DD (IPv6). The mapping to the 802.11 data service MUST use a 'priority' value of 1, which specifies the use of QoS with a 'Background' user priority.

To simplify the Application Programming Interface (API) between the operating system and the 802.11-OCB media, device drivers MAY implement IPv6-over-Ethernet as per RFC 2464 and then a frame translation from 802.3 to 802.11 in order to minimize the code changes.

4.3. Link-Local Addresses

There are several types of IPv6 addresses [RFC4291], [RFC4193], that may be assigned to an 802.11-OCB interface. Among these types of addresses only the IPv6 link-local addresses can be formed using an EUI-64 identifier, in particular during transition time.

If the IPv6 link-local address is formed using an EUI-64 identifier, then the mechanism of forming that address is the same mechanism as used to form an IPv6 link-local address on Ethernet links. Moreover, whether or not the interface identifier is derived from the EUI-64 A identifier, its length is 64 bits as is the case for Ethernet [RFC2464].

4.4. Stateless Autoconfiguration

The steps a host takes in deciding how to autoconfigure its interfaces in IP6 are described in [RFC4862]. This section describes the formation of Interface Identifiers for IPv6 addresses of type 'Global' or 'Unique Local'. For Interface Identifiers for IPv6 address of type 'Link-Local' are discussed in Section 4.3.

The RECOMMENDED method for forming stable Interface Identifiers (IIDs) is described in [RFC8064]. The method of forming IIDs described in Section 4 of [RFC2464] MAY be used during transition time, in particular for IPv6 link-local addresses. Regardless of how to form the IID, its length is 64 bits, as is the case of the IPv6 over Ethernet [RFC2464].

The bits in the IID have no specific meaning and the identifier should be treated as an opaque value. The bits 'Universal' and 'Group' in the identifier of an 802.11-OCB interface are significant, as this is an IEEE link-layer address. The details of this significance are described in [RFC7136].

Semantically opaque IIDs, instead of meaningful IIs derived from a valid and meaningful MAC address ([RFC2464], Section 4), help avoid certain privacy risks (see the risks mentioned in Section 5.1.1). If semantically opaque IIDs are needed, they MAY be generated using the method for generating semantically opaque IIDs with IPv6 Stateless Address Autoconfiguration given in [RFC7217]. Typically, an opaque IID is formed starting from identifiers different than the MAC addresses, and from cryptographically strong material. Thus, privacy sensitive information is absent from Interface IDs, because it is impossible to calculate back the initial value from which the Interface ID was first generated.

Some applications that use IPv6 packets on 802.11-OCB links (among other link types) may benefit from IPv6 addresses whose IIDs don't change too often. It is RECOMMENDED to use the mechanisms described in RFC 7217 to permit the use of Stable IIDs that do not change within one subnet prefix. A possible source for the Net-Iface Parameter is a virtual interface name, or logical interface name, that is decided by a local administrator.

4.5. Address Mapping

Unicast and multicast address mapping MUST follow the procedures specified for Ethernet interfaces specified in Sections 6 and 7 of [RFC2464].

4.5.1. Address Mapping -- Unicast

This document is scoped for Address Resolution (AR) and Duplicate Address Detection (DAD) per RFC 4861 [RFC4861].

4.5.2. Address Mapping -- Multicast

The multicast address mapping is performed according to the method specified in section 7 of [RFC2464]. The meaning of the value "3333" mentioned in that section 7 of [RFC2464] is defined in section 2.3.1 of [RFC7042].

Transmitting IPv6 packets to multicast destinations over 802.11 links proved to have some performance issues [I-D.ietf-mboned-ieee802-mcast-problems]. These issues may be

exacerbated in OCB mode.A A future improvement to this specification should consider solutions for these problems.

4.6. Subnet Structure

A subnet may be formed over 802.11-OCB interfaces of vehicles that are in close range (not by their in-vehicle interfaces). A Prefix List conceptual data structure ([RFC4861] Section 5.1) is maintained for each 802.11-OCB interface.

An IPv6 subnet on which Neighbor Discovery protocol (ND) can be mapped on an OCB network if all nodes share a single broadcast Domain, which is generally the case for P2P OCB links; The extension to IPv6 ND operating on a subnet that covers multiple OCB links and not fully overlapping (NBMA) is not in scope.

The structure of this subnet is ephemeral, in that it is strongly influenced by the mobility of vehicles: the hidden terminal effects appear; the 802.11 networks in OCB mode may be considered as 'ad-hoc' networks with an addressing model as described in [RFC5889]. On another hand, the structure of the internal subnets in each vehicle is relatively stable.

As recommended in [RFC5889], when the timing requirements are very strict (e.g. fast drive through IP-RSU coverage), no on-link subnet prefix should be configured on an 802.11-OCB interface. In such cases, the exclusive use of IPv6 link-local addresses is RECOMMENDED.

Additionally, even if the timing requirements are not very strict (e.g., the moving subnet formed by two following vehicles is stable, a fixed IP-RSU is absent), the subnet is disconnected from the Internet (i.e., a default route is absent), and the addressing peers are equally qualified (that is, it is impossible to determine that some vehicle owns and distributes addresses to others) the use of link-local addresses is RECOMMENDED.

The baseline ND protocol [RFC4861] MUST be supported over 802.11-OCB links. Transmitting ND packets may prove to have some performance issues as mentioned in Section 4.5.2, and Appendix I. These issues may be exacerbated in OCB mode. Solutions for these problems should consider the OCB mode of operation. Future solutions to OCB should consider solutions for avoiding broadcast. The best of current knowledge indicates the kinds of issues that may arise with ND in OCB mode; they are described in Appendix I.

Protocols like Mobile IPv6 [RFC6275] , [RFC3963] and DNAv6 [RFC6059], which depend on a timely movement detection, might need additional

tuning work to handle the lack of link-layer notifications during handover. This is for further study.

5. Security Considerations

Any security mechanism at the IP layer or above that may be carried out for the general case of IPv6 may also be carried out for IPv6 operating over 802.11-OCB.

The OCB operation is stripped off of all existing 802.11 link-layer security mechanisms. There is no encryption applied below the network layer running on 802.11-OCB. At the application layer, the IEEE 1609.2 document [IEEE-1609.2] provides security services for certain applications to use; application-layer mechanisms are out-of-scope of this document. On another hand, a security mechanism provided at networking layer, such as IPsec [RFC4301], may provide data security protection to a wider range of applications.

802.11-OCB does not provide any cryptographic protection, because it operates outside the context of a BSS (no Association Request/ Response, no Challenge messages). Any attacker can therefore just sit in the near range of vehicles, sniff the network (just set the interface card's frequency to the proper range) and performs attacks without needing to physically break any wall. Such a link is less protected than commonly used links (wired link or protected 802.11).

The potential attack vectors are: MAC address spoofing, IP address and session hijacking, and privacy violation Section 5.1. A previous work at SAVI WG identifies some threats [RFC6959], while SeND presented in [RFC3971] and [RFC3972] is a solution against address theft but it is complex and not deployed.

More IETF protocols are available in the toolbox of the IP security protocol designer. Some ETSI protocols related to security protocols in ITS are described in [ETSI-sec-archi].

5.1. Privacy Considerations

As with all Ethernet and 802.11 interface identifiers ([RFC7721]), the identifier of an 802.11-OCB interface may involve privacy, MAC address spoofing and IP hijacking risks. A vehicle embarking an IP-OBU whose egress interface is 802.11-OCB may expose itself to eavesdropping and subsequent correlation of data; this may reveal data considered private by the vehicle owner; there is a risk of being tracked. In outdoors public environments, where vehicles typically circulate, the privacy risks are more important than in indoors settings. It is highly likely that attacker sniffers are deployed along routes which listen for IEEE frames, including IP

packets, of vehicles passing by. For this reason, in the 802.11-OCB deployments, there is a strong necessity to use protection tools such as dynamically changing MAC addresses Section 5.2, semantically opaque Interface Identifiers and stable Interface Identifiers Section 4.4. An example of change policy is to change the MAC address of the OCB interface each time the system boots up. This may help mitigate privacy risks to a certain level. Futhermore, for pricavy concerns ([RFC8065]) recommends using an address generation scheme rather than addresses generated from a fixed link-layer address.

5.1.1. Privacy Risks of Meaningful info in Interface IDs

The privacy risks of using MAC addresses displayed in Interface Identifiers are important. The IPv6 packets can be captured easily in the Internet and on-link in public roads. For this reason, an attacker may realize many attacks on privacy. One such attack on 802.11-OCB is to capture, store and correlate Company ID information present in MAC addresses of many cars (e.g. listen for Router Advertisements, or other IPv6 application data packets, and record the value of the source address in these packets). Further correlation of this information with other data captured by other means, or other visual information (car color, others) MAY constitute privacy risks.

5.2. MAC Address and Interface ID Generation

In 802.11-OCB networks, the MAC addresses MAY change during well defined renumbering events. In the moment the MAC address is changed on an 802.11-OCB interface all the Interface Identifiers of IPv6 addresses assigned to that interface MUST change.

The policy dictating when the MAC address is changed on the 802.11-OCB interface is to-be-determined. For more information on the motivation of this policy please refer to the privacy discussion in Appendix B.

A 'randomized' MAC address has the following characteristics:

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

To meet the randomization requirements for the 46 remaining bits, a hash function may be used. For example, the SHA256 hash function may

be used with 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.

A randomized Interface ID has the same characteristics of a randomized MAC address, except the length in bits. An Interface ID SHOULD be of length specified in other documents.

5.3. Pseudonym Handling

The demand for privacy protection of vehicles' and drivers' identities, which could be granted by using a pseudonym or alias identity at the same time, may hamper the required confidentiality of messages and trust between participants - especially in safety critical vehicular communication.

- Particular challenges arise when the pseudonymization mechanism used relies on (randomized) re-addressing.
- A proper pseudonymization tool operated by a trusted third party may be needed to ensure both aspects simultaneously (privacy protection on one hand and trust between participants on another hand).
- This is discussed in Section 4.4 and Section 5 of this document.
- Pseudonymity is also discussed in [I-D.ietf-ipwave-vehicular-networking] in its sections 4.2.4 and 5.1.2.

6. IANA Considerations

No request to IANA.

7. Contributors

Christian Huitema, Tony Li.

Romain Kuntz contributed extensively about IPv6 handovers between links running outside the context of a BSS (802.11-OCB links).

Tim Leinmueller contributed the idea of the use of IPv6 over 802.11-OCB for distribution of certificates.

Marios Makassikis, Jose Santa Lozano, Albin Severinson and Alexey Voronov provided significant feedback on the experience of using IP messages over 802.11-OCB in initial trials.

Michelle Wetterwald contributed extensively the MTU discussion, offered the ETSI ITS perspective, and reviewed other parts of the document.

8. Acknowledgements

The authors would like to thank Alexandre Petrescu for initiating this work and for being the lead author until the version 43 of this draft.

The authors would like to thank Pascal Thubert for reviewing, proofreading and suggesting modifications of this document.

The authors would like to thank Witold Klaudel, Ryuji Wakikawa, Emmanuel Baccelli, John Kenney, John Moring, Francois Simon, Dan Romascanu, Konstantin Khait, Ralph Droms, Richard 'Dick' Roy, Ray Hunter, Tom Kurihara, Michal Sojka, Jan de Jongh, Suresh Krishnan, Dino Farinacci, Vincent Park, Jaehoon Paul Jeong, Gloria Gwynne, Hans-Joachim Fischer, Russ Housley, Rex Buddenberg, Erik Nordmark, Bob Moskowitz, Andrew Dryden, Georg Mayer, Dorothy Stanley, Sandra Cespedes, Mariano Falcitelli, Sri Gundavelli, Abdussalam Baryun, Margaret Cullen, Erik Kline, Carlos Jesus Bernardos Cano, Ronald in 't Velt, Katrin Sjoberg, Roland Bless, Tijink Jasja, Kevin Smith, Brian Carpenter, Julian Reschke, Mikael Abrahamsson, Dirk von Hugo, Lorenzo Colitti, Pascal Thubert, Ole Troan, Jinmei Tatuya, Joel Halpern, Eric Gray and William Whyte. Their valuable comments clarified particular issues and generally helped to improve the document.

Pierre Pfister, Rostislav Lisovy, and others, wrote 802.11-OCB drivers for linux and described how.

For the multicast discussion, the authors would like to thank Owen DeLong, Joe Touch, Jen Linkova, Erik Kline, Brian Haberman and participants to discussions in network working groups.

The authors would like to thank participants to the Birds-of-a-Feather "Intelligent Transportation Systems" meetings held at IETF in 2016.

Human Rights Protocol Considerations review by Amelia Andersdotter.

9. References

9.1. Normative References

[RFC1042] Postel, J. and J. Reynolds, "Standard for the transmission of IP datagrams over IEEE 802 networks", STD 43, RFC 1042, DOI 10.17487/RFC1042, February 1988, <https://www.rfc-editor.org/info/rfc1042>.

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

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

[RFC2818] Rescorla, E., "HTTP Over TLS", RFC 2818, DOI 10.17487/RFC2818, May 2000, <https://www.rfc-editor.org/info/rfc2818>.

[RFC3753] Manner, J., Ed. and M. Kojo, Ed., "Mobility Related Terminology", RFC 3753, DOI 10.17487/RFC3753, June 2004, <https://www.rfc-editor.org/info/rfc3753>.

[RFC3963] Devarapalli, V., Wakikawa, R., Petrescu, A., and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol", RFC 3963, DOI 10.17487/RFC3963, January 2005, <https://www.rfc-editor.org/info/rfc3963>.

[RFC3971] Arkko, J., Ed., Kempf, J., Zill, B., and P. Nikander, "SEcure Neighbor Discovery (SEND)", RFC 3971, DOI 10.17487/RFC3971, March 2005, <https://www.rfc-editor.org/info/rfc3971>.

[RFC3972] Aura, T., "Cryptographically Generated Addresses (CGA)", RFC 3972, DOI 10.17487/RFC3972, March 2005, <https://www.rfc-editor.org/info/rfc3972>.

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

[RFC4193] Hinden, R. and B. Haberman, "Unique Local IPv6 Unicast Addresses", RFC 4193, DOI 10.17487/RFC4193, October 2005, <https://www.rfc-editor.org/info/rfc4193>.

[RFC4210] Adams, C., Farrell, S., Kause, T., and T. Mononen, "Internet X.509 Public Key Infrastructure Certificate Management Protocol (CMP)", RFC 4210, DOI 10.17487/RFC4210, September 2005, <https://www.rfc-editor.org/info/rfc4210>.

[RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", RFC 4291, DOI 10.17487/RFC4291, February 2006, <https://www.rfc-editor.org/info/rfc4291>.

[RFC4301] Kent, S. and K. Seo, "Security Architecture for the Internet Protocol", RFC 4301, DOI 10.17487/RFC4301, December 2005, <https://www.rfc-editor.org/info/rfc4301>.

[RFC4302] Kent, S., "IP Authentication Header", RFC 4302, DOI 10.17487/RFC4302, December 2005, <https://www.rfc-editor.org/info/rfc4302>.

[RFC4303] Kent, S., "IP Encapsulating Security Payload (ESP)", RFC 4303, DOI 10.17487/RFC4303, December 2005, <https://www.rfc-editor.org/info/rfc4303>.

[RFC4861] Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)", RFC 4861, DOI 10.17487/RFC4861, September 2007, <https://www.rfc-editor.org/info/rfc4861>.

[RFC4862] Thomson, S., Narten, T., and T. Jinmei, "IPv6 Stateless Address Autoconfiguration", RFC 4862, DOI 10.17487/RFC4862, September 2007, <https://www.rfc-editor.org/info/rfc4862>.

[RFC5374] Weis, B., Gross, G., and D. Ignjatic, "Multicast Extensions to the Security Architecture for the Internet Protocol", RFC 5374, DOI 10.17487/RFC5374, November 2008, <https://www.rfc-editor.org/info/rfc5374>.

[RFC5415] Calhoun, P., Ed., Montemurro, M., Ed., and D. Stanley, Ed., "Control And Provisioning of Wireless Access Points (CAPWAP) Protocol Specification", RFC 5415, DOI 10.17487/RFC5415, March 2009, <https://www.rfc-editor.org/info/rfc5415>.

[RFC5889] Baccelli, E., Ed. and M. Townsley, Ed., "IP Addressing Model in Ad Hoc Networks", RFC 5889, DOI 10.17487/RFC5889, September 2010, <https://www.rfc-editor.org/info/rfc5889>.

[RFC6059] Krishnan, S. and G. Daley, "Simple Procedures for Detecting Network Attachment in IPv6", RFC 6059, DOI 10.17487/RFC6059, November 2010, <https://www.rfc-editor.org/info/rfc6059>.

[RFC6275] Perkins, C., Ed., Johnson, D., and J. Arkko, "Mobility Support in IPv6", RFC 6275, DOI 10.17487/RFC6275, July 2011, <https://www.rfc-editor.org/info/rfc6275>.

[RFC6959] McPherson, D., Baker, F., and J. Halpern, "Source Address Validation Improvement (SAVI) Threat Scope", RFC 6959, DOI 10.17487/RFC6959, May 2013, <https://www.rfc-editor.org/info/rfc6959>.

[RFC7042] Eastlake 3rd, D. and J. Abley, "IANA Considerations and IETF Protocol and Documentation Usage for IEEE 802 Parameters", BCP 141, RFC 7042, DOI 10.17487/RFC7042, October 2013, <https://www.rfc-editor.org/info/rfc7042>.

[RFC7136] Carpenter, B. and S. Jiang, "Significance of IPv6 Interface Identifiers", RFC 7136, DOI 10.17487/RFC7136, February 2014, <https://www.rfc-editor.org/info/rfc7136>.

[RFC7217] Gont, F., "A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)", RFC 7217, DOI 10.17487/RFC7217, April 2014, <https://www.rfc-editor.org/info/rfc7217>.

[RFC7721] Cooper, A., Gont, F., and D. Thaler, "Security and Privacy Considerations for IPv6 Address Generation Mechanisms", RFC 7721, DOI 10.17487/RFC7721, March 2016, <https://www.rfc-editor.org/info/rfc7721>.

[RFC8064] Gont, F., Cooper, A., Thaler, D., and W. Liu, "Recommendation on Stable IPv6 Interface Identifiers", RFC 8064, DOI 10.17487/RFC8064, February 2017, <https://www.rfc-editor.org/info/rfc8064>.

[RFC8065] Thaler, D., "Privacy Considerations for IPv6 Adaptation-Layer Mechanisms", RFC 8065, DOI 10.17487/RFC8065, February 2017, <https://www.rfc-editor.org/info/rfc8065>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8200] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", STD 86, RFC 8200, DOI 10.17487/RFC8200, July 2017, <https://www.rfc-editor.org/info/rfc8200>.

9.2. Informative References

[ETSI-sec-archi]
"ETSI TS 102 940 V1.2.1 (2016-11), ETSI Technical Specification, Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management, November 2016. Downloaded on September 9th, 2017, freely available from ETSI website at URL http://www.etsi.org/deliver/etsi_ts/102900_102999/102940/01.02.01_60/ts_102940v010201p.pdf".

[I-D.ietf-ipwave-vehicular-networking]
Jeong, J., "IP Wireless Access in Vehicular Environments (IPWAVE): Problem Statement and Use Cases", draft-ietf-ipwave-vehicular-networking-09 (work in progress), May 2019.

[I-D.ietf-mboned-ieee802-mcast-problems]
Perkins, C., McBride, M., Stanley, D., Kumari, W., and J. Zuniga, "Multicast Considerations over IEEE 802 Wireless Media", draft-ietf-mboned-ieee802-mcast-problems-05 (work in progress), April 2019.

[IEEE-1609.2]
"IEEE SA - 1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Security Services for Applications and Management Messages. Example URL http://ieeexplore.ieee.org/document/7426684/ accessed on August 17th, 2017.".

[IEEE-1609.3]
"IEEE SA - 1609.3-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Networking Services. Example URL http://ieeexplore.ieee.org/document/7458115/ accessed on August 17th, 2017.".

[IEEE-1609.4]
"IEEE SA - 1609.4-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Multi-Channel Operation. Example URL http://ieeexplore.ieee.org/document/7435228/ accessed on August 17th, 2017.".

[IEEE-802.11-2016]
"IEEE Standard 802.11-2016 - 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. Status - Active Standard. Description retrieved freely; the document itself is also freely available, but with some difficulty (requires registration); description and document retrieved on April 8th, 2019, starting from URL https://standards.ieee.org/findstds/standard/802.11-2016.html".

[IEEE-802.11p-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. 802.11p

The term "802.11p" is an earlier definition. The behaviour of "802.11p" networks is rolled in the document IEEE Std 802.11-2016. In that document the term 802.11p disappears. Instead, each 802.11p feature is conditioned by the IEEE Management Information Base (MIB) attribute "OCBActivated" [IEEE-802.11-2016]. Whenever OCBActivated is set to true the IEEE Std 802.11-OCB state is activated. For example, an 802.11 STAtion operating outside the context of a basic service set has the OCBActivated flag set. Such a station, when it has the flag set, uses a BSS identifier equal to ff:ff:ff:ff:ff:ff.

Appendix B. Aspects introduced by the OCB mode to 802.11

In the IEEE 802.11-OCB mode, all nodes in the wireless range can directly communicate with each other without involving authentication or association procedures. In OCB mode, the manner in which channels are selected and used is simplified compared to when in BSS mode. Contrary to BSS mode, at link layer, it is necessary to set statically the same channel number (or frequency) on two stations that need to communicate with each other (in BSS mode this channel set operation is performed automatically during 'scanning'). The

manner in which stations set their channel number in OCB mode is not specified in this document. Stations STA1 and STA2 can exchange IP packets only if they are set on the same channel. At IP layer, they then discover each other by using the IPv6 Neighbor Discovery protocol. The allocation of a particular channel for a particular use is defined statically in standards authored by ETSI (in Europe), FCC in America, and similar organisations in South Korea, Japan and other parts of the world.

Briefly, the IEEE 802.11-OCB mode has the following properties:

- The use by each node of a 'wildcard' BSSID (i.e., each bit of the BSSID is set to 1)
- No IEEE 802.11 Beacon frames are transmitted
- No authentication is required in order to be able to communicate
- No association is needed in order to be able to communicate
- No encryption is provided in order to be able to communicate
- Flag dot11OCBActivated is set to true

All the nodes in the radio communication range (IP-OBU and IP-RSU) receive all the messages transmitted (IP-OBU and IP-RSU) within the radio communications range. The eventual conflict(s) are resolved by the MAC CDMA function.

The message exchange diagram in Figure 1 illustrates a comparison between traditional 802.11 and 802.11 in OCB mode. The 'Data' messages can be IP packets such as HTTP or others. Other 802.11 management and control frames (non IP) may be transmitted, as specified in the 802.11 standard. For information, the names of these messages as currently specified by the 802.11 standard are listed in Appendix F.

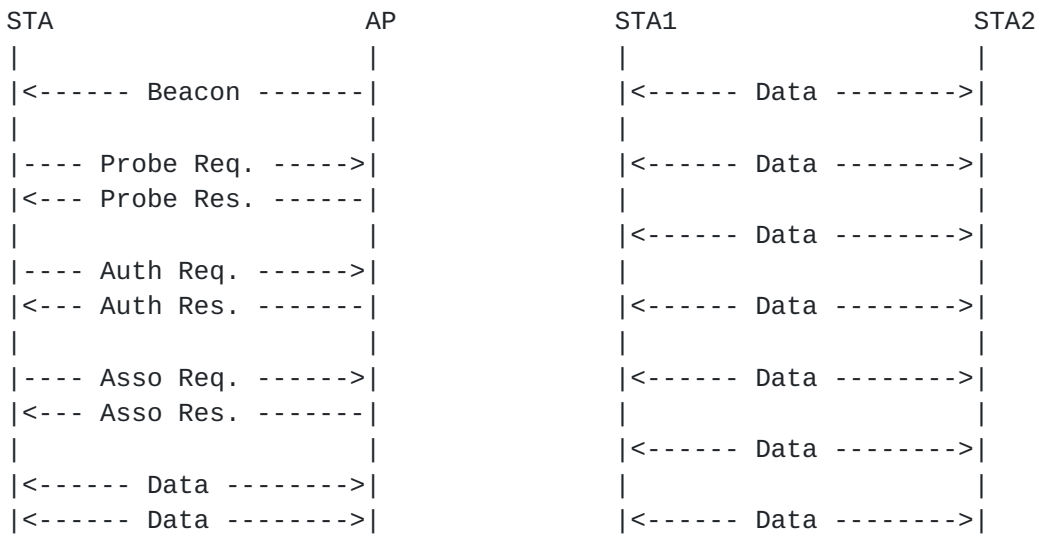


Figure 1: Difference between messages exchanged on 802.11 (left) and 802.11-OCB (right)

The interface 802.11-OCB was specified in IEEE Std 802.11p (TM) -2010 [IEEE-802.11p-2010] as an amendment to IEEE Std 802.11 (TM) -2007, titled "Amendment 6: Wireless Access in Vehicular Environments". Since then, this amendment has been integrated in IEEE 802.11(TM) -2012 and -2016 [IEEE-802.11-2016].

In document 802.11-2016, anything qualified specifically as "OCBActivated", or "outside the context of a basic service" set to be true, then it is actually referring to OCB aspects introduced to 802.11.

In order to delineate the aspects introduced by 802.11-OCB to 802.11, we refer to the earlier [IEEE-802.11p-2010]. The amendment is concerned with vehicular communications, where the wireless link is similar to that of Wireless LAN (using a PHY layer specified by 802.11a/b/g/n), but which needs to cope with the high mobility factor inherent in scenarios of communications between moving vehicles, and between vehicles and fixed infrastructure deployed along roads. While 'p' is a letter identifying the Ammendment, just like 'a, b, g' and 'n' are, 'p' is concerned more with MAC modifications, and a little with PHY modifications; the others are mainly about PHY modifications. It is possible in practice to combine a 'p' MAC with an 'a' PHY by operating outside the context of a BSS with OFDM at 5.4GHz and 5.9GHz.

The 802.11-OCB links are specified to be compatible as much as possible with the behaviour of 802.11a/b/g/n and future generation IEEE WLAN links. From the IP perspective, an 802.11-OCB MAC layer offers practically the same interface to IP as the 802.11a/b/g/n and 802.3. A packet sent by an IP-OBU may be received by one or multiple IP-RSUs. The link-layer resolution is performed by using the IPv6 Neighbor Discovery protocol.

To support this similarity statement (IPv6 is layered on top of LLC on top of 802.11-OCB, in the same way that IPv6 is layered on top of LLC on top of 802.11a/b/g/n (for WLAN) or layered on top of LLC on top of 802.3 (for Ethernet)) it is useful to analyze the differences between 802.11-OCB and 802.11 specifications. During this analysis, we note that whereas 802.11-OCB lists relatively complex and numerous changes to the MAC layer (and very little to the PHY layer), there are only a few characteristics which may be important for an implementation transmitting IPv6 packets on 802.11-OCB links.

The most important 802.11-OCB point which influences the IPv6 functioning is the OCB characteristic; an additional, less direct influence, is the maximum bandwidth afforded by the PHY modulation/ demodulation methods and channel access specified by 802.11-OCB. The maximum bandwidth theoretically possible in 802.11-OCB is 54 Mbit/s (when using, for example, the following parameters: 20 MHz channel; modulation 64-QAM; coding rate R is 3/4); in practice of IP-over-802.11-OCB a commonly observed figure is 12Mbit/s; this bandwidth allows the operation of a wide range of protocols relying on IPv6.

- Operation Outside the Context of a BSS (OCB): the (earlier 802.11p) 802.11-OCB links are operated without a Basic Service Set (BSS). This means that the frames IEEE 802.11 Beacon, Association Request/Response, Authentication Request/Response, and similar, are not used. The used identifier of BSS (BSSID) has a hexadecimal value always 0xffffffffffff (48 '1' bits, represented as MAC address ff:ff:ff:ff:ff:ff, or otherwise the 'wildcard' BSSID), as opposed to an arbitrary BSSID value set by administrator (e.g. 'My-Home-AccessPoint'). The OCB operation - namely the lack of beacon-based scanning and lack of authentication - should be taken into account when the Mobile IPv6 protocol [RFC6275] and the protocols for IP layer security [RFC4301] are used. The way these protocols adapt to OCB is not described in this document.

- Timing Advertisement: is a new message defined in 802.11-OCB, which does not exist in 802.11a/b/g/n. This message is used by stations to inform other stations about the value of time. It is similar to the time as delivered by a GNSS system (Galileo, GPS,

...) or by a cellular system. This message is optional for implementation.

- Frequency range: this is a characteristic of the PHY layer, with almost no impact on the interface between MAC and IP. However, it is worth considering that the frequency range is regulated by a regional authority (ARCEP, ECC/CEPT based on ENs from ETSI, FCC, etc.); as part of the regulation process, specific applications are associated with specific frequency ranges. In the case of 802.11-OCB, the regulator associates a set of frequency ranges, or slots within a band, to the use of applications of vehicular communications, in a band known as "5.9GHz". The 5.9GHz band is different from the 2.4GHz and 5GHz bands used by Wireless LAN. However, as with Wireless LAN, the operation of 802.11-OCB in "5.9GHz" bands is exempt from owning a license in EU (in US the 5.9GHz is a licensed band of spectrum; for the fixed infrastructure an explicit FCC authorization is required; for an on-board device a 'licensed-by-rule' concept applies: rule certification conformity is required.) Technical conditions are different than those of the bands "2.4GHz" or "5GHz". The allowed power levels, and implicitly the maximum allowed distance between vehicles, is of 33dBm for 802.11-OCB (in Europe), compared to 20 dBm for Wireless LAN 802.11a/b/g/n; this leads to a maximum distance of approximately 1km, compared to approximately 50m. Additionally, specific conditions related to congestion avoidance, jamming avoidance, and radar detection are imposed on the use of DSRC (in US) and on the use of frequencies for Intelligent Transportation Systems (in EU), compared to Wireless LAN (802.11a/b/g/n).

- 'Half-rate' encoding: as the frequency range, this parameter is related to PHY, and thus has not much impact on the interface between the IP layer and the MAC layer.

- In vehicular communications using 802.11-OCB links, there are strong privacy requirements with respect to addressing. While the 802.11-OCB standard does not specify anything in particular with respect to MAC addresses, in these settings there exists a strong need for dynamic change of these addresses (as opposed to the non-vehicular settings - real wall protection - where fixed MAC addresses do not currently pose some privacy risks). This is further described in Section 5. A relevant function is described in documents IEEE 1609.3-2016 [IEEE-1609.3] and IEEE 1609.4-2016 [IEEE-1609.4].

Appendix C. Changes Needed on a software driver 802.11a to become a 802.11-OCB driver

The 802.11p amendment modifies both the 802.11 stack's physical and MAC layers but all the induced modifications can be quite easily obtained by modifying an existing 802.11a ad-hoc stack.

Conditions for a 802.11a hardware to be 802.11-OCB compliant:

- The PHY entity shall be an orthogonal frequency division multiplexing (OFDM) system. It must support the frequency bands on which the regulator recommends the use of ITS communications, for example using IEEE 802.11-OCB layer, in France: 5875MHz to 5925MHz.

- The OFDM system must provide a "half-clocked" operation using 10 MHz channel spacings.

- The chip transmit spectrum mask must be compliant to the "Transmit spectrum mask" from the IEEE 802.11p amendment (but experimental environments tolerate otherwise).

- The chip should be able to transmit up to 44.8 dBm when used by the US government in the United States, and up to 33 dBm in Europe; other regional conditions apply.

Changes needed on the network stack in OCB mode:

- Physical layer:

  * The chip must use the Orthogonal Frequency Multiple Access (OFDM) encoding mode.

  * The chip must be set in half-mode rate mode (the internal clock frequency is divided by two).

  * The chip must use dedicated channels and should allow the use of higher emission powers. This may require modifications to the local computer file that describes regulatory domains rules, if used by the kernel to enforce local specific restrictions. Such modifications to the local computer file must respect the location-specific regulatory rules.

  MAC layer:

  * All management frames (beacons, join, leave, and others) emission and reception must be disabled except for frames of subtype Action and Timing Advertisement (defined below).

* No encryption key or method must be used.

* Packet emission and reception must be performed as in ad-hoc mode, using the wildcard BSSID (ff:ff:ff:ff:ff:ff).

* The functions related to joining a BSS (Association Request/ Response) and for authentication (Authentication Request/Reply, Challenge) are not called.

* The beacon interval is always set to 0 (zero).

* Timing Advertisement frames, defined in the amendment, should be supported. The upper layer should be able to trigger such frames emission and to retrieve information contained in received Timing Advertisements.

Appendix D. Protocol Layering

A more theoretical and detailed view of layer stacking, and interfaces between the IP layer and 802.11-OCB layers, is illustrated in Figure 2. The IP layer operates on top of the EtherType Protocol Discrimination (EPD); this Discrimination layer is described in IEEE Std 802.3-2012; the interface between IPv6 and EPD is the LLC_SAP (Link Layer Control Service Access Point).

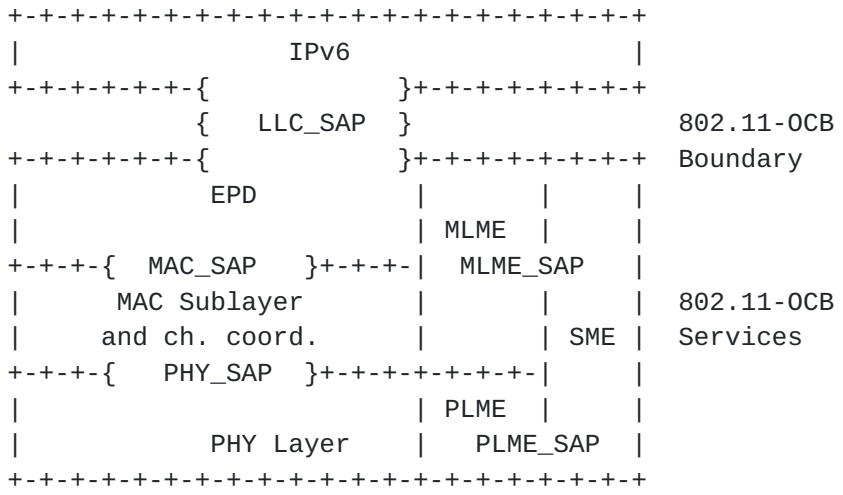


Figure 2: EtherType Protocol Discrimination

Appendix E. 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 transportation 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 asymmetry and very short connection makes the 802.11-OCB link significantly different from 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.

Appendix F. IEEE 802.11 Messages Transmitted in OCB mode

For information, at the time of writing, this is the list of IEEE 802.11 messages that may be transmitted in OCB mode, i.e. when dot11OCBActivated is true in a STA:

- The STA may send management frames of subtype Action and, if the STA maintains a TSF Timer, subtype Timing Advertisement;
- The STA may send control frames, except those of subtype PS-Poll, CF-End, and CF-End plus CFAck;
- The STA MUST send data frames of subtype QoS Data.

Appendix G. Examples of Packet Formats

This section describes an example of an IPv6 Packet captured over a IEEE 802.11-OCB link.

By way of example we show that there is no modification in the headers when transmitted over 802.11-OCB networks - they are transmitted like any other 802.11 and Ethernet packets.

We describe an experiment of capturing an IPv6 packet on an 802.11-OCB link. In topology depicted in Figure 3, the packet is an IPv6 Router Advertisement. This packet is emitted by a Router on its 802.11-OCB interface. The packet is captured on the Host, using a network protocol analyzer (e.g. Wireshark); the capture is performed in two different modes: direct mode and 'monitor' mode. The topology used during the capture is depicted below.

The packet is captured on the Host. The Host is an IP-OBU containing an 802.11 interface in format PCI express (an ITRI product). The kernel runs the ath5k software driver with modifications for OCB mode. The capture tool is Wireshark. The file format for save and

analyze is 'pcap'. The packet is generated by the Router. The Router is an IP-RSU (ITRI product).

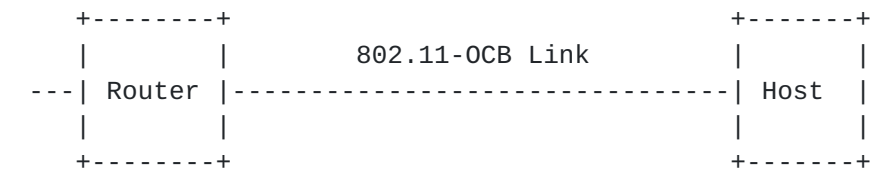


Figure 3: Topology for capturing IP packets on 802.11-OCB

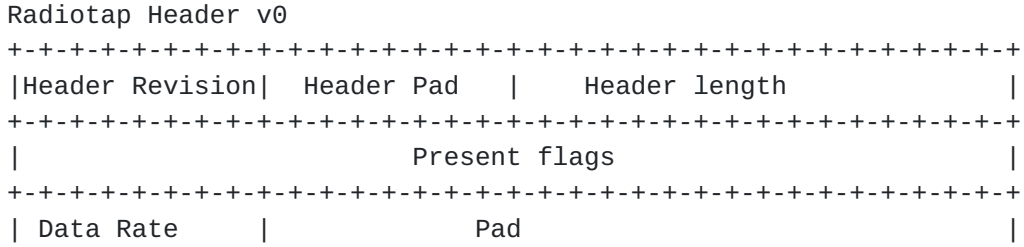
During several capture operations running from a few moments to several hours, no message relevant to the BSSID contexts were captured (no Association Request/Response, Authentication Req/Resp, Beacon). This shows that the operation of 802.11-OCB is outside the context of a BSSID.

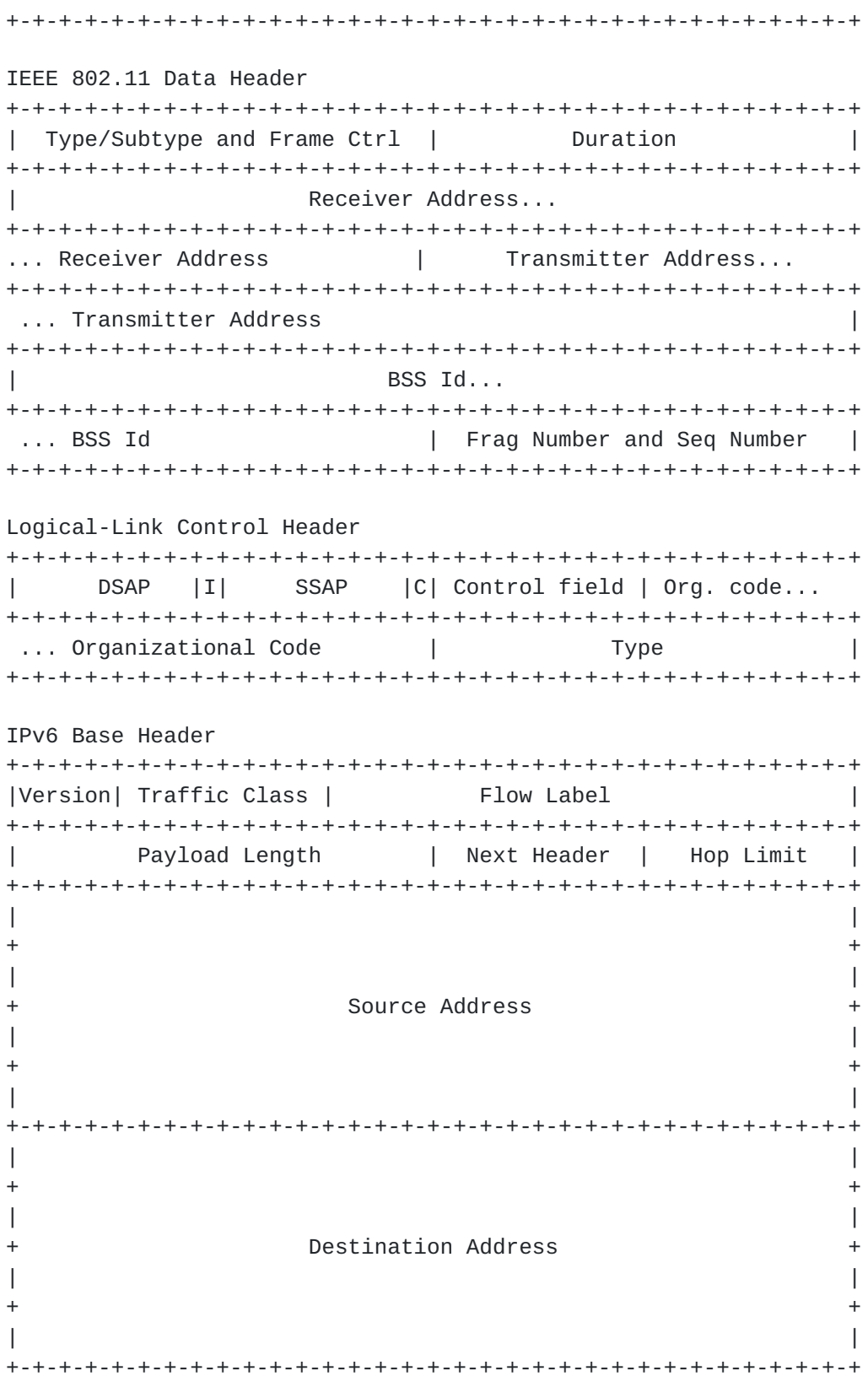
Overall, the captured message is identical with a capture of an IPv6 packet emitted on a 802.11b interface. The contents are precisely similar.

G.1. Capture in Monitor Mode

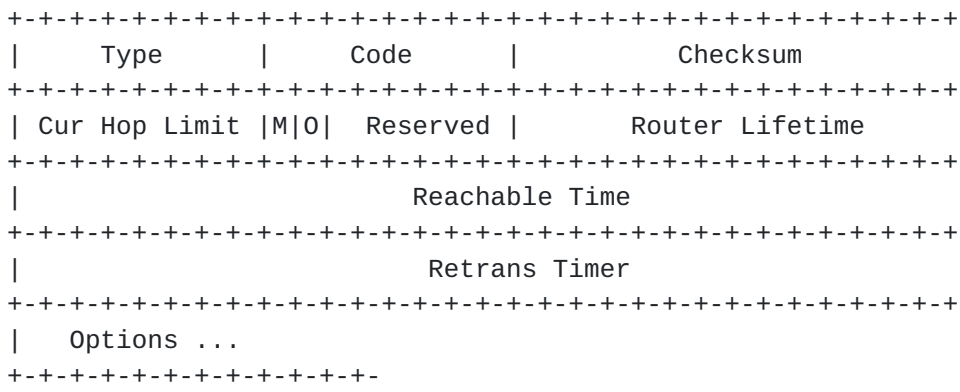
The IPv6 RA packet captured in monitor mode is illustrated below. The radio tap header provides more flexibility for reporting the characteristics of frames. The Radiotap Header is prepended by this particular stack and operating system on the Host machine to the RA packet received from the network (the Radiotap Header is not present on the air). The implementation-dependent Radiotap Header is useful for piggybacking PHY information from the chip's registers as data in a packet understandable by userland applications using Socket interfaces (the PHY interface can be, for example: power levels, data rate, ratio of signal to noise).

The packet present on the air is formed by IEEE 802.11 Data Header, Logical Link Control Header, IPv6 Base Header and ICMPv6 Header.





Router Advertisement



The value of the Data Rate field in the Radiotap header is set to 6 Mb/s. This indicates the rate at which this RA was received.

The value of the Transmitter address in the IEEE 802.11 Data Header is set to a 48bit value. The value of the destination address is 33:33:00:00:00:1 (all-nodes multicast address). The value of the BSS Id field is ff:ff:ff:ff:ff:ff, which is recognized by the network protocol analyzer as being "broadcast". The Fragment number and sequence number fields are together set to 0x90C6.

The value of the Organization Code field in the Logical-Link Control Header is set to 0x0, recognized as "Encapsulated Ethernet". The value of the Type field is 0x86DD (hexadecimal 86DD, or otherwise #86DD), recognized as "IPv6".

A Router Advertisement is periodically sent by the router to multicast group address ff02::1. It is an icmp packet type 134. The IPv6 Neighbor Discovery's Router Advertisement message contains an 8-bit field reserved for single-bit flags, as described in [RFC4861].

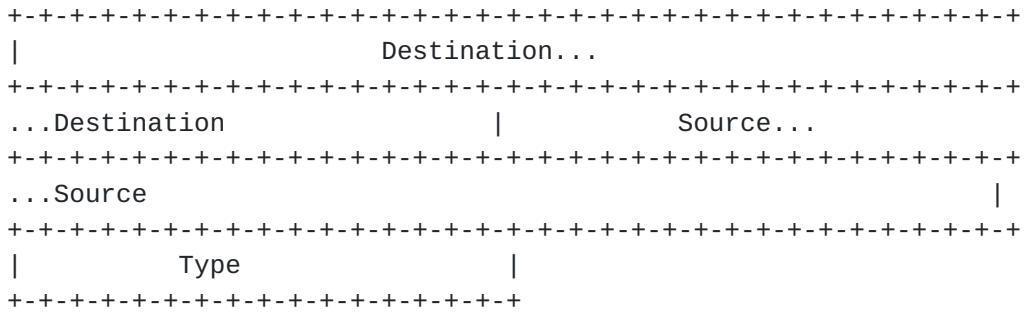
The IPv6 header contains the link local address of the router (source) configured via EUI-64 algorithm, and destination address set to ff02::1.

The Ethernet Type field in the logical-link control header is set to 0x86dd which indicates that the frame transports an IPv6 packet. In the IEEE 802.11 data, the destination address is 33:33:00:00:00:01 which is the corresponding multicast MAC address. The BSS id is a broadcast address of ff:ff:ff:ff:ff:ff. Due to the short link duration between vehicles and the roadside infrastructure, there is no need in IEEE 802.11-OCB to wait for the completion of association and authentication procedures before exchanging data. IEEE 802.11-OCB enabled nodes use the wildcard BSSID (a value of all 1s) and may start communicating as soon as they arrive on the communication channel.

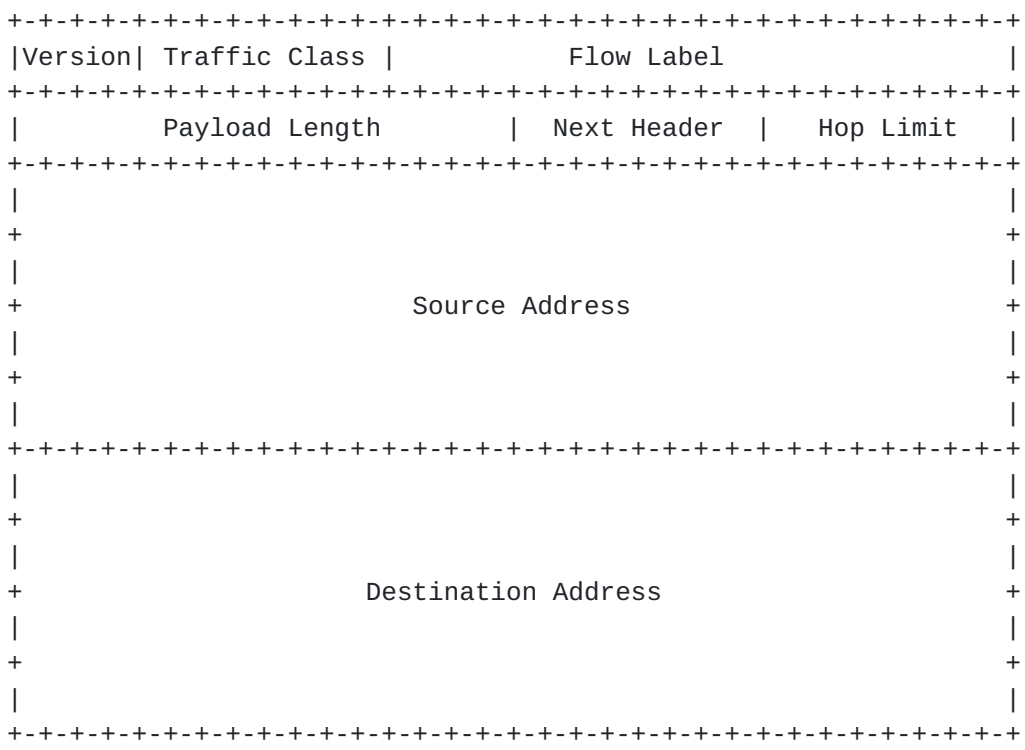
G.2. Capture in Normal Mode

The same IPv6 Router Advertisement packet described above (monitor mode) is captured on the Host, in the Normal mode, and depicted below.

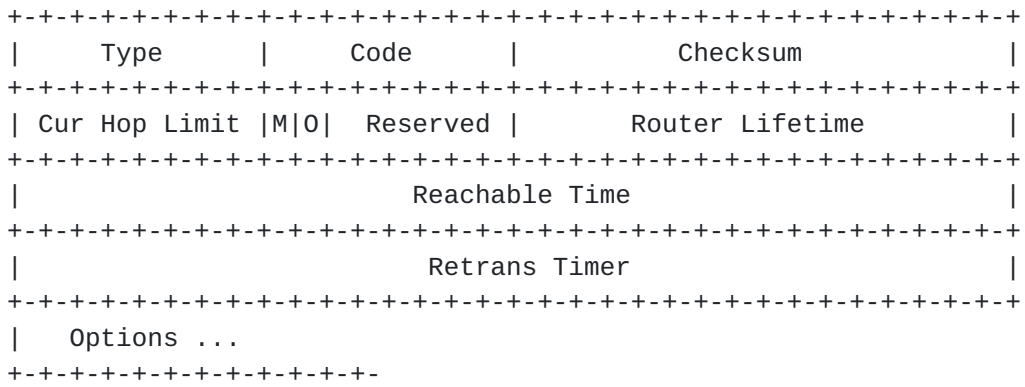
Ethernet II Header



IPv6 Base Header



Router Advertisement



One notices that the Radiotap Header, the IEEE 802.11 Data Header and the Logical-Link Control Headers are not present. On the other hand, a new header named Ethernet II Header is present.

The Destination and Source addresses in the Ethernet II header contain the same values as the fields Receiver Address and Transmitter Address present in the IEEE 802.11 Data Header in the "monitor" mode capture.

The value of the Type field in the Ethernet II header is 0x86DD (recognized as "IPv6"); this value is the same value as the value of the field Type in the Logical-Link Control Header in the "monitor" mode capture.

The knowledgeable experimenter will no doubt notice the similarity of this Ethernet II Header with a capture in normal mode on a pure Ethernet cable interface.

A frame translation is inserted on top of a pure IEEE 802.11 MAC layer, in order to adapt packets, before delivering the payload data to the applications. It adapts 802.11 LLC/MAC headers to Ethernet II headers. In further detail, this adaptation consists in the elimination of the Radiotap, 802.11 and LLC headers, and in the insertion of the Ethernet II header. In this way, IPv6 runs straight over LLC over the 802.11-OCB MAC layer; this is further confirmed by the use of the unique Type 0x86DD.

Appendix H. Extra Terminology

The following terms are defined outside the IETF. They are used to define the main terms in the main terminology section Section 2.

DSRC (Dedicated Short Range Communication): a term defined outside the IETF. The US Federal Communications Commission (FCC) Dedicated Short Range Communication (DSRC) is defined in the Code of Federal Regulations (CFR) 47, Parts 90 and 95. This Code is referred in the definitions below. At the time of the writing of this Internet Draft, the last update of this Code was dated October 1st, 2010.

DSRCS (Dedicated Short-Range Communications Services): a term defined outside the IETF. The use of radio techniques to transfer data over short distances between roadside and mobile units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety, and other intelligent transportation service applications in a variety of environments. DSRCS systems may also transmit status and instructional messages related to the units involve. [Ref. 47 CFR 90.7 - Definitions]

OBU (On-Board Unit): a term defined outside the IETF. An On-Board Unit is a DSRCS transceiver that is normally mounted in or on a vehicle, or which in some instances may be a portable unit. An OBU can be operational while a vehicle or person is either mobile or stationary. The OBUs receive and contend for time to transmit on one or more radio frequency (RF) channels. Except where specifically excluded, OBU operation is permitted wherever vehicle operation or human passage is permitted. The OBUs mounted in vehicles are licensed by rule under part 95 of the respective chapter and communicate with Roadside Units (RSUs) and other OBUs. Portable OBUs are also licensed by rule under part 95 of the respective chapter. OBU operations in the Unlicensed National Information Infrastructure (UNII) Bands follow the rules in those bands. - [CFR 90.7 - Definitions].

RSU (Road-Side Unit): a term defined outside of IETF. A Roadside Unit is a DSRC transceiver that is mounted along a road or pedestrian passageway. An RSU may also be mounted on a vehicle or is hand carried, but it may only operate when the vehicle or hand- carried unit is stationary. Furthermore, an RSU operating under the respectgive part is restricted to the location where it is licensed to operate. However, portable or hand-held RSUs are permitted to operate where they do not interfere with a site-licensed operation. A RSU broadcasts data to OBUs or exchanges data with OBUs in its communications zone. An RSU also provides channel assignments and operating instructions to OBUs in its communications zone, when required. - [CFR 90.7 - Definitions].

Appendix I. Neighbor Discovery (ND) Potential Issues in Wireless Links

IPv6 Neighbor Discovery (IPv6 ND) [RFC4861][RFC4862] was designed for point-to-point and transit links such as Ethernet, with the expectation of a cheap and reliable support for multicast from the lower layer. Section 3.2 of RFC 4861 indicates that the operation on Shared Media and on non-broadcast multi-access (NBMA) networks require additional support, e.g., for Address Resolution (AR) and duplicate address detection (DAD), which depend on multicast. An infrastructureless radio network such as OCB shares properties with both Shared Media and NBMA networks, and then adds its own complexity, e.g., from movement and interference that allow only transient and non-transitive reachability between any set of peers.

The uniqueness of an address within a scoped domain is a key pillar of IPv6 and the base for unicast IP communication. RFC 4861 details the DAD method to avoid that an address is duplicated. For a link local address, the scope is the link, whereas for a Globally Reachable address the scope is much larger. The underlying assumption for DAD to operate correctly is that the node that owns an

IPv6 address can reach any other node within the scope at the time it claims its address, which is done by sending a NS multicast message, and can hear any future claim for that address by another party within the scope for the duration of the address ownership.

In the case of OCB, there is a potentially a need to define a scope that is compatible with DAD, and that cannot be the set of nodes that a transmitter can reach at a particular time, because that set varies all the time and does not meet the DAD requirements for a link local address that could possibly be used anytime, anywhere. The generic expectation of a reliable multicast is not ensured, and the operation of DAD and AR (Address Resolution) as specificed by RFC 4861 cannot be guaranteed. Moreoever, multicast transmissions that rely on broadcast are not only unreliable but are also often detrimental to unicast traffic (see [draft-ietf-mboned-ieee802-mcast-problems]).

Early experience indicates that it should be possible to exchange IPv6 packets over OCB while relying on IPv6 ND alone for DAD and AR (Address Resolution) in good conditions. In the absence of a correct DAD operation, a node that relies only on IPv6 ND for AR and DAD over OCB should ensure that the addresses that it uses are unique by means others than DAD. It must be noted that deriving an IPv6 address from a globally unique MAC address has this property but may yield privacy issues.

RFC 8505 provides a more recent approach to IPv6 ND and in particular DAD. RFC 8505 is designed to fit wireless and otherwise constrained networks whereby multicast and/or continuous access to the medium may not be guaranteed. RFC 8505 Section 5.6 "Link-Local Addresses and Registration" indicates that the scope of uniqueness for a link local address is restricted to a pair of nodes that use it to communicate, and provides a method to assert the uniqueness and resolve the link-Layer address using a unicast exchange.

RFC 8505 also enables a router (acting as a 6LR) to own a prefix and act as a registrar (acting as a 6LBR) for addresses within the associated subnet. A peer host (acting as a 6LN) registers an address derived from that prefix and can use it for the lifetime of the registration. The prefix is advertised as not onlink, which means that the 6LN uses the 6LR to relay its packets within the subnet, and participation to the subnet is constrained to the time of reachability to the 6LR. Note that RSU that provides internet connectivity MAY announce a default router preference [RFC 4191], whereas a car that does not provide that connectivity MUST NOT do so. This operation presents similarities with that of an access point, but at Layer-3. This is why RFC 8505 well-suited for wireless in general.

Support of RFC 8505 may be implemented on OCB. OCB nodes that support RFC 8505 SHOULD support the 6LN operation in order to act as a host, and may support the 6LR and 6LBR operations in order to act as a router and in particular own a prefix that can be used by RFC 8505-compliant hosts for address autoconfiguration and registration.

Authors' Addresses

Nabil Benamar
Moulay Ismail University
Morocco

Phone: +212670832236
Email: n.benamar@est.umi.ac.ma

Jerome Haerri
Eurecom
Sophia-Antipolis 06904
France

Phone: +33493008134
Email: Jerome.Haerri@eurecom.fr

Jong-Hyouk Lee
Sangmyung University
31, Sangmyeongdae-gil, Dongnam-gu
Cheonan 31066
Republic of Korea

Email: jonghyouk@smu.ac.kr

Thierry Ernst
YoGoKo
France

Email: thierry.ernst@yogoko.fr