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Transmission of IPv6 Packets over IEEE 802.11 Networks operating in mode
Outside the Context of a Basic Service Set (IPv6-over-80211-OCB)
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Abstract

In order to transmit IPv6 packets on IEEE 802.11 networks running outside the context of a basic service set (OCB, earlier "802.11p") there is a need to define a few parameters such as the supported Maximum Transmission Unit size on the 802.11-OCB link, the header format preceding the IPv6 header, the Type value within it, and others. This document describes these parameters for IPv6 and IEEE 802.11-OCB networks; it portrays the layering of IPv6 on 802.11-OCB similarly to other known 802.11 and Ethernet layers - by using an Ethernet Adaptation Layer.

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[1](#). Introduction

This document describes the transmission of IPv6 packets on IEEE Std 802.11-OCB networks [[IEEE-802.11-2016](#)] (a.k.a "802.11p" see [Appendix B](#), [Appendix C](#) and [Appendix D](#)). This involves the layering of IPv6 networking on top of the IEEE 802.11 MAC layer, with an LLC layer. Compared to running IPv6 over the Ethernet MAC layer, there is no modification expected to IEEE Std 802.11 MAC and Logical Link sublayers: IPv6 works fine directly over 802.11-OCB too, with an LLC layer.

The IPv6 network layer operates on 802.11-OCB in the same manner as operating on Ethernet, but there are two kinds of exceptions:

- o Exceptions due to different operation of IPv6 network layer on 802.11 than on Ethernet. To satisfy these exceptions, this document describes an Ethernet Adaptation Layer between Ethernet headers and 802.11 headers. The Ethernet Adaptation Layer is described [Section 4.2.1](#). The operation of IP on Ethernet is described in [[RFC1042](#)], [[RFC2464](#)] .
- o 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. For security and privacy recommendations see [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.

In the published literature, many documents describe aspects and problems related to running IPv6 over 802.11-OCB:
[\[I-D.ietf-ipwave-vehicular-networking\]](#).

[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.

IP-OBU (Internet Protocol On-Board Unit): an IP-OBU is a computer situated in a vehicle such as an automobile, 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 I](#).

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): 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: mode specified in IEEE Std 802.11-2016 when the MIB attribute dot11OCBActivated 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'. The IP communication scenarios for these environments have been described in several documents; 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.

The link model is the following: STA --- 802.11-OCB --- STA. In vehicular networks, STAs can be IP-RSUs and/or IP-OBUs. While 802.11-OCB is clearly specified, and the use of IPv6 over such link is not radically new, 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 MUST be 1500 octets. It is the same value as IPv6 packets on Ethernet links, as specified in [\[RFC2464\]](#). 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(TM) -2016 [[IEEE-802.11-2016](#)].

The IPv6 packet transmitted on 802.11-OCB MUST be 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 E](#)), the value of the Type field MUST be set to 0x86DD (IPv6). In the 802.11 header, the value of the Subtype sub-field in the Frame Control field MUST be set to 8 (i.e. 'QoS Data'); the value of the Traffic Identifier (TID) sub-field of the QoS Control field of the 802.11 header MUST be set to binary 001 (i.e. User Priority 'Background', QoS Access Category 'AC_BK').

To simplify the Application Programming Interface (API) between the operating system and the 802.11-OCB media, device drivers MAY implement an Ethernet Adaptation Layer that translates Ethernet II frames to the 802.11 format and vice versa. An Ethernet Adaptation Layer is described in [Section 4.2.1](#).

4.2.1. Ethernet Adaptation Layer

An 'adaptation' layer is inserted between a MAC layer and the Networking layer. This is used to transform some parameters between their form expected by the IP stack and the form provided by the MAC layer.

An Ethernet Adaptation Layer makes an 802.11 MAC look to IP Networking layer as a more traditional Ethernet layer. At reception, this layer takes as input the IEEE 802.11 header and the Logical-Link Layer Control Header and produces an Ethernet II Header. At sending, the reverse operation is performed.

The operation of the Ethernet Adaptation Layer is depicted by the double arrow in Figure 1.

(in the above figure, a 802.11 profile is represented; this is used also for 802.11-OCB profile.)

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 MAY 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. This mechanism is described in [section 5 of \[RFC2464\]](#).

4.4. Stateless Autoconfiguration

There are several types of IPv6 addresses [[RFC4291](#)], [[RFC4193](#)], that MAY be assigned to an 802.11-OCB interface. 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' see [Section 4.3](#).

The Interface Identifier for an 802.11-OCB interface is formed using the same rules as the Interface Identifier for an Ethernet interface; 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.

The bits in the Interface Identifier have no generic 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 Interface Identifiers, instead of meaningful Interface Identifiers 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 Interface Identifiers are needed, they MAY be generated using the method for generating semantically opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration given in [[RFC7217](#)]. Typically, an opaque Interface Identifier 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 (intuitively, it is as hard as mentally finding the square root of a number, and as impossible as trying to use computers to identify quickly whether a large number is prime).

Some applications that use IPv6 packets on 802.11-OCB links (among other link types) may benefit from IPv6 addresses whose Interface Identifiers don't change too often. It is RECOMMENDED to use the mechanisms described in [RFC 7217](#) to permit the use of Stable Interface Identifiers 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 in sections [6](#) and [7](#) of [[RFC2464](#)].

[4.5.1.](#) Address Mapping -- Unicast

The procedure for mapping IPv6 unicast addresses into Ethernet link-layer addresses is described in [[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. Solutions for these problems SHOULD consider the OCB mode of operation.

[4.6.](#) Subnet Structure

A subnet is formed by the external 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.

All nodes in the subnet MUST be able to communicate directly using their link-local unicast addresses.

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 car 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 (a default route is absent), and the addressing peers are equally qualified (impossible to determine that some vehicle owns and distributes addresses to others) the use of link-local addresses is RECOMMENDED.

The baseline Neighbor Discovery protocol (ND) [[RFC4861](#)] MUST be used over 802.11-OCB links. Transmitting ND packets may prove to have some performance issues. These issues may be exacerbated in OCB mode. Solutions for these problems SHOULD consider the OCB mode of operation. The best of current knowledge indicates the kinds of issues that may arise with ND in OCB mode; they are described in [Appendix J](#).

Protocols like Mobile IPv6 [[RFC6275](#)] and DNAV6 [[RFC6059](#)], which depend on 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 application layer, the IEEE 1609.2 document [[IEEE-1609.2](#)] does provide 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 perform 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](#).

Within the IPsec Security Architecture [[RFC4301](#)], the IPsec AH and ESP headers [[RFC4302](#)] and [[RFC4303](#)] respectively, its multicast extensions [[RFC5374](#)], HTTPS [[RFC2818](#)] and SeND [[RFC3971](#)] protocols can be used to protect communications. Further, the assistance of proper Public Key Infrastructure (PKI) protocols [[RFC4210](#)] is necessary to establish credentials. More IETF protocols are available in the toolbox of the IP security protocol designer. Certain ETSI protocols related to security protocols in Intelligent Transportation Systems 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 address 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](#). This may help mitigate privacy risks to a certain level.

[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 C](#).

A 'randomized' MAC address has the following characteristics:

- o Bit "Local/Global" set to "locally administered".
- o Bit "Unicast/Multicast" set to "Unicast".
- o 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. A MAC address SHOULD be of length 48 decimal. An Interface ID SHOULD be of length 64 decimal for all types of IPv6 addresses. In the particular case of IPv6 link-local addresses, the length of the Interface ID MAY be 118 decimal.

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.

- o Particular challenges arise when the pseudonymization mechanism used relies on (randomized) re-addressing.
- o 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).

- o This is discussed in [Section 4.4](#) and [Section 5](#) of this document.
- o 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.

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9.2. Informative References

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[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-08](#) (work in progress), March 2019.

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Perkins, C., McBride, M., Stanley, D., Kumari, W., and J. Zuniga, "Multicast Considerations over IEEE 802 Wireless Media", [draft-ietf-mboned-ieee802-mcast-problems-04](#) (work in progress), November 2018.

[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]

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[IEEE-802.11-2016]

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[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. ChangeLog

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

-41: updated a reference from [draft-ietf-ipwave-vehicular-networking-survey](#) to [draft-ietf-ipwave-vehicular-networking](#); clarified the link-local text by eliminating link-local addresses and prefixes altogether and referring to [RFC4861](#) which requires the prefixes; added a statement about the subnet being a not multi-link subnet.

-40: added a phrase in appendix to further described a condition where ND on OCB may not work; that phrase contains a placeholder; the placeholder is 'TBD' (To Be Defined).

-39: removed a reference to an expired draft trying to update the IPv6-over-Ethernet spec 'RFC2464bis'; added text in the subnet structure section saying nodes MUST be able to communicate directly using their link-local addresses.

-38: removed the word "fe80::/10".

-37: added a section about issues on ND wireless; added the qualifier 'baseline' to using ND on 802.11-OCB; improved the description of the reference to 802.11-2016 document, with a qualifier about the difficulty of accessing it, even though it is free.

-36: removed a phrase about the IID formation and MAC generation, but left in the [section 5.2](#) that describes how it happens.

-35: addressing the the intarea review: clarified a small apparent contradiction between two parts of text that use the old MAC-based IIDs (clarified by using qualifiers from each other: transition time, and ll addresses); sequenced closer the LL and Stateless Autoconf sections, instead of spacing them; shortened the paragraph of Opaque IIDs; moved the privacy risks of in-clear IIDs in the security section; removed a short phrase duplicating the idea of privacy risks; added third time a reference to the 802.11-2016 document; used 'the hidden terminal' text; updated the Terminology section with new [BCP-14](#) text 'MUST' to include [RFC8174](#).

-33: substituted 'movement detection' for 'handover behaviour' in introductory text; removed redundant phrase referring to Security Considerations section; removed the phrase about forming mechanisms being left out, as IP is not much concerned about L2 forming; moved the Pseudonym section from main section to end of Security Considerations section (and clarified 'concurrently'); capitalized SHOULD consider OCB in WiFi multicast problems, and referred to more recent I-D on topic; removed several phrases in a paragraph about oui.txt and MAC presence in IPv6 address, as they are well known info, but clarified the example of privacy risk of Company ID in MAC addresses in public roads; clarified that ND MUST be used over 802.11-OCB.

-32: significantly shortened the relevant ND/OCB paragraph. It now just states ND is used over OCB, w/o detailing.

-31: filled in the section titled "Pseudonym Handling"; removed a 'MAY NOT' phrase about possibility of having other prefix than the LL on the link between cars; shortened and improved the paragraph about Mobile IPv6, now with DNaV6; improved the ND text about ND retransmissions with relationship to packet loss; changed the title of an appendix from 'EPD' to 'Protocol Layering'; improved the 'Aspects introduced by OCB' appendix with a few phrases about the channel use and references.

-30: a clarification on the reliability of ND over OCB and over 802.11.

-29:

o

-28:

- o Created a new section 'Pseudonym Handling'.
- o removed the 'Vehicle ID' appendix.
- o improved the address generation from random MAC address.
- o shortened Term IP-RSU definition.
- o removed refs to two detail Clauses in IEEE documents, kept just these latter.

-27: part 1 of addressing Human Rights review from IRTF. Removed appendices F.2 and F.3. Shortened definition of IP-RSU. Removed reference to 1609.4. A few other small changes, see diff.

-26: moved text from SLAAC section and from Design Considerations appendix about privacy into a new Privacy Considerations subsection of the Security section; reformulated the SLAAC and IID sections to stress only LLs can use EUI-64; removed the "GeoIP" wireshark explanation; reformulated SLAAC and LL sections; added brief mention of need of use LLs; clarified text about MAC address changes; dropped pseudonym discussion; changed title of section describing examples of packet formats.

-25: added a reference to 'IEEE Management Information Base', instead of just 'Management Information Base'; added ref to further appendices in the introductory phrases; improved text for IID formation for SLAAC, inserting recommendation for [RFC8064](#) before [RFC2464](#).

From [draft-ietf-ipwave-ipv6-over-80211ocb-23](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-24](#)

- o Nit: wrote "IPWAVE Working Group" on the front page, instead of "Network Working Group".
- o Addressed the comments on 6MAN: replaced a sentence about ND problem with "is used over 802.11-OCB".

From [draft-ietf-ipwave-ipv6-over-80211ocb-22](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-23](#)

- o No content modifications, but check the entire draft chain on IPv6-only: xml2rfc, submission on tools.ietf.org and datatracker.

From [draft-ietf-ipwave-ipv6-over-80211ocb-21](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-22](#)

- o Corrected typo, use dash in "802.11-OCB" instead of space.
- o Improved the Frame Format section: MUST use QoSData, specify the values within; clarified the Ethernet Adaptation Layer text.

From [draft-ietf-ipwave-ipv6-over-80211ocb-20](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-21](#)

- o Corrected a few nits and added names in Acknowledgments section.
- o Removed unused reference to old Internet Draft tsvwg about QoS.

From [draft-ietf-ipwave-ipv6-over-80211ocb-19](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-20](#)

- o Reduced the definition of term "802.11-OCB".
- o Left out of this specification which 802.11 header to use to transmit IP packets in OCB mode (QoS Data header, Data header, or any other).
- o Added 'MUST' use an Ethernet Adaptation Layer, instead of 'is using' an Ethernet Adaptation Layer.

From [draft-ietf-ipwave-ipv6-over-80211ocb-18](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-19](#)

- o Removed the text about fragmentation.
- o Removed the mentioning of WSMP and GeoNetworking.
- o Removed the explanation of the binary representation of the EtherType.
- o Rendered normative the paragraph about unicast and multicast address mapping.
- o Removed paragraph about addressing model, subnet structure and easiness of using LLs.
- o Clarified the Type/Subtype field in the 802.11 Header.
- o Used RECOMMENDED instead of recommended, for the stable interface identifiers.

From [draft-ietf-ipwave-ipv6-over-80211ocb-17](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-18](#)

- o Improved the MTU and fragmentation paragraph.

From [draft-ietf-ipwave-ipv6-over-80211ocb-16](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-17](#)

- o Substituted "MUST be increased" to "is increased" in the MTU section, about fragmentation.

From [draft-ietf-ipwave-ipv6-over-80211ocb-15](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-16](#)

- o Removed the definition of the 'WiFi' term and its occurrences. Clarified a phrase that used it in [Appendix C](#) "Aspects introduced by the OCB mode to 802.11".
- o Added more normative words: MUST be 0x86DD, MUST fragment if size larger than MTU, Sequence number in 802.11 Data header MUST be increased.

From [draft-ietf-ipwave-ipv6-over-80211ocb-14](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-15](#)

- o Added normative term MUST in two places in section "Ethernet Adaptation Layer".

From [draft-ietf-ipwave-ipv6-over-80211ocb-13](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-14](#)

- o Created a new Appendix titled "Extra Terminology" that contains terms DSRC, DSRCs, OBU, RSU as defined outside IETF. Some of them are used in the main Terminology section.
- o Added two paragraphs explaining that ND and Mobile IPv6 have problems working over 802.11-OCB, yet their adaptations is not specified in this document.

From [draft-ietf-ipwave-ipv6-over-80211ocb-12](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-13](#)

- o Substituted "IP-OBUS" for "OBRU", and "IP-RSU" for "RSRU" throughout and improved OBU-related definitions in the Terminology section.

From [draft-ietf-ipwave-ipv6-over-80211ocb-11](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-12](#)

- o Improved the appendix about "MAC Address Generation" by expressing the technique to be an optional suggestion, not a mandatory mechanism.

From [draft-ietf-ipwave-ipv6-over-80211ocb-10](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-11](#)

- o Shortened the paragraph on forming/terminating 802.11-OCB links.
- o Moved the draft tsvwg-ieee-802-11 to Informative References.

From [draft-ietf-ipwave-ipv6-over-80211ocb-09](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-10](#)

- o Removed text requesting a new Group ID for multicast for OCB.
- o Added a clarification of the meaning of value "3333" in the section Address Mapping -- Multicast.
- o Added note clarifying that in Europe the regional authority is not ETSI, but "ECC/CEPT based on ENs from ETSI".
- o Added note stating that the manner in which two STATIONS set their communication channel is not described in this document.
- o Added a time qualifier to state that the "each node is represented uniquely at a certain point in time."
- o Removed text "This section may need to be moved" (the "Reliability Requirements" section). This section stays there at this time.
- o In the term definition "802.11-OCB" added a note stating that "any implementation should comply with standards and regulations set in the different countries for using that frequency band."
- o In the RSU term definition, added a sentence explaining the difference between RSU and RSRU: in terms of number of interfaces and IP forwarding.
- o Replaced "with at least two IP interfaces" with "with at least two real or virtual IP interfaces".
- o Added a term in the Terminology for "OBU". However the definition is left empty, as this term is defined outside IETF.
- o Added a clarification that it is an OBU or an OBRU in this phrase "A vehicle embarking an OBU or an OBRU".

- o Checked the entire document for a consistent use of terms OBU and OBRU.
- o Added note saying that "'p' is a letter identifying the Ammendment".
- o Substituted lower case for capitals SHALL or MUST in the Appendices.
- o Added reference to [RFC7042](#), helpful in the 3333 explanation. Removed reference to individual submission [draft-petrescu-its-scenario-reqs](#) and added reference to [draft-ietf-ipwave-vehicular-networking-survey](#).
- o Added figure captions, figure numbers, and references to figure numbers instead of 'below'. Replaced "section Section" with "section" throughout.
- o Minor typographical errors.

From [draft-ietf-ipwave-ipv6-over-80211ocb-08](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-09](#)

- o Significantly shortened the Address Mapping sections, by text copied from [RFC2464](#), and rather referring to it.
- o Moved the EPD description to an Appendix on its own.
- o Shortened the Introduction and the Abstract.
- o Moved the tutorial section of OCB mode introduced to .11, into an appendix.
- o Removed the statement that suggests that for routing purposes a prefix exchange mechanism could be needed.
- o Removed refs to [RFC3963](#), [RFC4429](#) and [RFC6775](#); these are about ND, MIP/NEMO and oDAD; they were referred in the handover discussion section, which is out.
- o Updated a reference from individual submission to now a WG item in IPWAVE: the survey document.
- o Added term definition for WiFi.
- o Updated the authorship and expanded the Contributors section.
- o Corrected typographical errors.

From [draft-ietf-ipwave-ipv6-over-80211ocb-07](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-08](#)

- o Removed the per-channel IPv6 prohibition text.
- o Corrected typographical errors.

From [draft-ietf-ipwave-ipv6-over-80211ocb-06](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-07](#)

- o Added new terms: OBRU and RSRU ('R' for Router). Refined the existing terms RSU and OBU, which are no longer used throughout the document.
- o Improved definition of term "802.11-OCB".
- o Clarified that OCB does not "strip" security, but that the operation in OCB mode is "stripped off of all .11 security".
- o Clarified that theoretical OCB bandwidth speed is 54mbits, but that a commonly observed bandwidth in IP-over-OCB is 12mbit/s.
- o Corrected typographical errors, and improved some phrasing.

From [draft-ietf-ipwave-ipv6-over-80211ocb-05](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-06](#)

- o Updated references of 802.11-OCB document from -2012 to the IEEE 802.11-2016.
- o In the LL address section, and in SLAAC section, added references to 7217 opaque IIDs and 8064 stable IIDs.

From [draft-ietf-ipwave-ipv6-over-80211ocb-04](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-05](#)

- o Lengthened the title and cleaned the abstract.
- o Added text suggesting LLs may be easy to use on OCB, rather than GUAs based on received prefix.
- o Added the risks of spoofing and hijacking.
- o Removed the text speculation on adoption of the TSA message.
- o Clarified that the ND protocol is used.
- o Clarified what it means "No association needed".

- o Added some text about how two STAs discover each other.
- o Added mention of external (OCB) and internal network (stable), in the subnet structure section.
- o Added phrase explaining that both .11 Data and .11 QoS Data headers are currently being used, and may be used in the future.
- o Moved the packet capture example into an [Appendix Implementation Status](#).
- o Suggested moving the reliability requirements appendix out into another document.
- o Added a IANA Considerations section, with content, requesting for a new multicast group "all OCB interfaces".
- o Added new OBU term, improved the RSU term definition, removed the ETTC term, replaced more occurrences of 802.11p, 802.11-OCB with 802.11-OCB.
- o References:
 - * Added an informational reference to ETSI's IPv6-over-GeoNetworking.
 - * Added more references to IETF and ETSI security protocols.
 - * Updated some references from I-D to RFC, and from old RFC to new RFC numbers.
 - * Added reference to multicast extensions to IPsec architecture RFC.
 - * Added a reference to 2464-bis.
 - * Removed FCC informative references, because not used.
- o Updated the affiliation of one author.
- o Reformulation of some phrases for better readability, and correction of typographical errors.

From [draft-ietf-ipwave-ipv6-over-80211ocb-03](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-04](#)

- o Removed a few informative references pointing to Dx draft IEEE 1609 documents.

- o Removed outdated informative references to ETSI documents.
- o Added citations to IEEE 1609.2, .3 and .4-2016.
- o Minor textual issues.

From [draft-ietf-ipwave-ipv6-over-80211ocb-02](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-03](#)

- o Keep the previous text on multiple addresses, so remove talk about MIP6, NEMOV6 and MCoA.
- o Clarified that a 'Beacon' is an IEEE 802.11 frame Beacon.
- o Clarified the figure showing Infrastructure mode and OCB mode side by side.
- o Added a reference to the IP Security Architecture RFC.
- o Detailed the IPv6-per-channel prohibition paragraph which reflects the discussion at the last IETF IPWAVE WG meeting.
- o Added section "Address Mapping -- Unicast".
- o Added the ".11 Trailer" to pictures of 802.11 frames.
- o Added text about SNAP carrying the Ethertype.
- o New RSU definition allowing for it be both a Router and not necessarily a Router some times.
- o Minor textual issues.

From [draft-ietf-ipwave-ipv6-over-80211ocb-01](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-02](#)

- o Replaced almost all occurrences of 802.11p with 802.11-OCB, leaving only when explanation of evolution was necessary.
- o Shortened by removing parameter details from a paragraph in the Introduction.
- o Moved a reference from Normative to Informative.
- o Added text in intro clarifying there is no handover spec at IEEE, and that 1609.2 does provide security services.

- o Named the contents the fields of the EthernetII header (including the Ethertype bitstring).
- o Improved relationship between two paragraphs describing the increase of the Sequence Number in 802.11 header upon IP fragmentation.
- o Added brief clarification of "tracking".

From [draft-ietf-ipwave-ipv6-over-80211ocb-00](#) to [draft-ietf-ipwave-ipv6-over-80211ocb-01](#)

- o Introduced message exchange diagram illustrating differences between 802.11 and 802.11 in OCB mode.
- o Introduced an appendix listing for information the set of 802.11 messages that may be transmitted in OCB mode.
- o Removed appendix sections "Privacy Requirements", "Authentication Requirements" and "Security Certificate Generation".
- o Removed appendix section "Non IP Communications".
- o Introductory phrase in the Security Considerations section.
- o Improved the definition of "OCB".
- o Introduced theoretical stacked layers about IPv6 and IEEE layers including EPD.
- o Removed the appendix describing the details of prohibiting IPv6 on certain channels relevant to 802.11-OCB.
- o Added a brief reference in the privacy text about a precise clause in IEEE 1609.3 and .4.
- o Clarified the definition of a Road Side Unit.
- o Removed the discussion about security of WSA (because is non-IP).
- o Removed mentioning of the GeoNetworking discussion.
- o Moved references to scientific articles to a separate 'overview' draft, and referred to it.

Appendix B. 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 C. 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:

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

All the nodes in the radio communication range (IP-OBUs and IP-RSUs) receive all the messages transmitted (IP-OBUs and IP-RSUs) within the

radio communications range. The eventual conflict(s) are resolved by the MAC CDMA function.

The message exchange diagram in Figure 3 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 G](#).

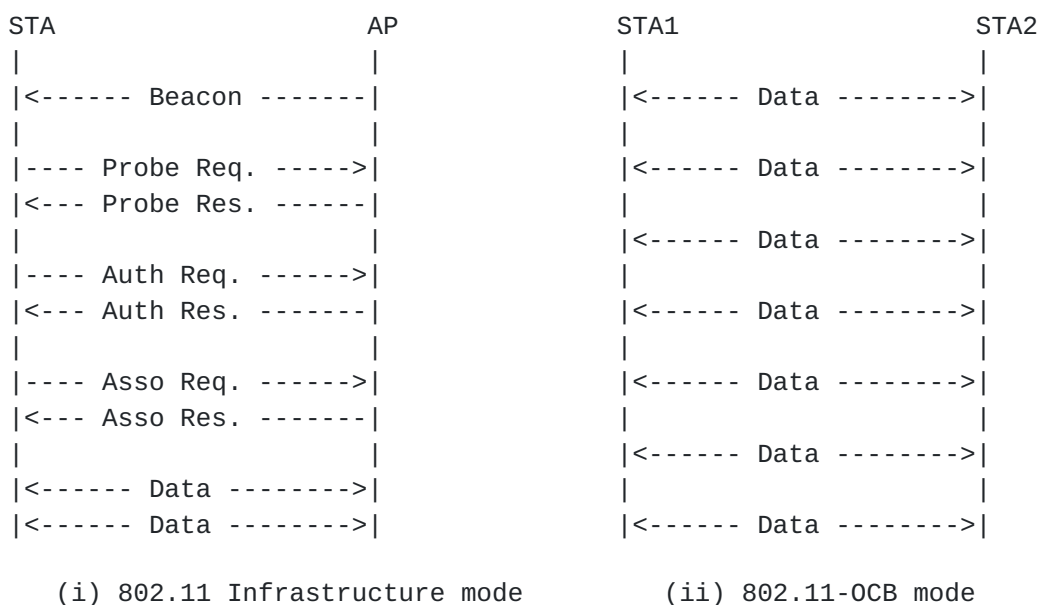


Figure 3: Difference between messages exchanged on 802.11 (left) and 802.11-OCB (right)

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 Amendment, 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-OBUS 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.

- o 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.

- o 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.
- o 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).
- o '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.
- o 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 D](#). 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:

- o 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.
- o The OFDM system must provide a "half-clocked" operation using 10 MHz channel spacings.
- o The chip transmit spectrum mask must be compliant to the "Transmit spectrum mask" from the IEEE 802.11p amendment (but experimental environments tolerate otherwise).
- o 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:

- o 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 E](#). 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 4. 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).

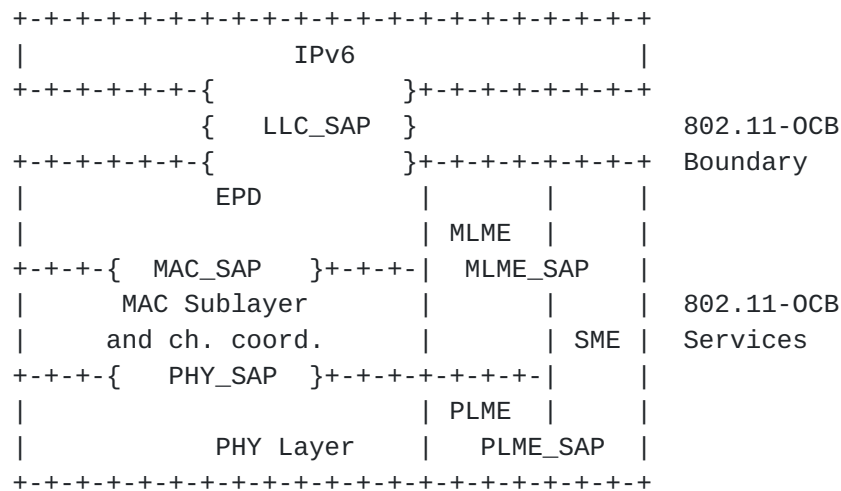


Figure 4: EtherType Protocol Discrimination

Appendix F. 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 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 G. 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:

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

[Appendix H](#). 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 5, 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).

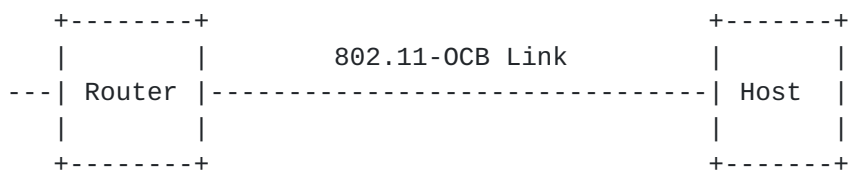


Figure 5: Topology for capturing IP packets on 802.11-OCB

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.

[H.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.

Radiotap Header v0

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Header Revision|  Header Pad   |   Header length   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|
|                               Present flags
|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Data Rate      |              Pad
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

IEEE 802.11 Data Header

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  Type/Subtype and Frame Ctrl  |      Duration      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|
|                               Receiver Address...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
... Receiver Address           |      Transmitter Address...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
... Transmitter Address
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|
|                               BSS Id...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
... BSS Id                     |  Frag Number and Seq Number  |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Logical-Link Control Header

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      DSAP   |I|      SSAP   |C| Control field | Org. code...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
... Organizational Code        |              Type              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```


IPv6 Base Header

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Version| Traffic Class |           Flow Label           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Payload Length           | Next Header | Hop Limit |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |               |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Router Advertisement

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Type   |   Code   |           Checksum           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Cur Hop Limit | M|O| Reserved | Router Lifetime |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Options ... |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

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.

[H.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

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Destination...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
...Destination                       |           Source...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
...Source                             |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Type                       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

IPv6 Base Header

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Version| Traffic Class |           Flow Label           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Payload Length           | Next Header | Hop Limit |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+                                     +
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Router Advertisement

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Type   |   Code   |           Checksum           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Cur Hop Limit | M|O| Reserved | Router Lifetime |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   Options ...
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```


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.

An Adaptation layer 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 I. 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 DSRC 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 respective 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 J. 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 global 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 specified by [RFC 4861](#) cannot be guaranteed. Moreover, 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. However, this does not apply if TBD TBD TBD. 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](#) is may be implemented on OCB. OCB nodes that support [RFC 8505](#) would 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.

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