

6Lo Working Group
Vega
Internet-Draft
Robles
Intended status: Standards Track
Morabito
Expires: December 19, 2015
Ericsson

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June 17,

2015

**IPv6 over 802.11ah
draft-delcarpio-6lo-wlanah-00**

Abstract

IEEE 802.11 is an established Wireless LAN (WLAN) technology which provides radio connectivity to a wide range of devices. The IEEE 802.11ah amendment defines a WLAN system operating at sub 1 GHz license-exempt bands designed to operate with low-rate/low-power consumption. This amendment supports large number of stations and extends the radio coverage to several hundreds of meters. This document describes how IPv6 is transported over 802.11ah using 6LoWPAN techniques.

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1. Introduction

IEEE 802.11 [[IEEE802.11](#)], also known as Wi-Fi, is an established Wireless LAN (WLAN) technology operating in unlicensed Industrial, Scientific and Medical (ISM) bands. Its IEEE 802.11ah

[[IEEE802.11ah](#)]

amendment is tailored for Internet of Things (IoT) use-cases and at the moment of writing this draft it is in the final stages of IEEE standardization.

IEEE 802.11ah operates in the Sub-1 GHz spectrum which helps reducing the power consumption. It also supports a larger number of stations on a single Basic Service Set (BSS) and it provides power-saving mechanisms that allow radio stations to sleep in order to save power.

However, the system achieves lower throughput compared to 802.11n/ac amendments.

IEEE 802.11 specifies only the MAC and PHY layers of the radio technology. In other words, 802.11 does not specify a networking layer but it is compatible with commonly used internet protocol such as IPv4 and IPv6. As 802.11ah is a low-rate/low-power technology, the communication protocols used above MAC should also take power-efficiency into consideration. This motivates the introduction of 6LoWPAN techniques [[RFC4944](#)] [[RFC6282](#)] for efficient transport of IPv6 packets over IEEE 802.11ah radio networks.

This document specifies how to use 6LoWPAN techniques for 802.11ah. Similar work has been carried out for Bluetooth Low Energy in [[I-D.ietf-6lo-btle](#)].

2. Terminology and Language Requirements

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

Terminology from 802.11ah:

Station (STA): defined in 802.11-2012 [[IEEE802.11-2012](#)] as a wireless station which is an addressable unit.

Sensor-STA: defined in 802.11ah as a device having low-power consumption requirements. This device might be a battery operated device.

Non-sensor STA: defined in 802.11ah as device which usually does not have low-power consumption requirements.

In this document, any type STA (sensor STA/non-sensor STA) is associated with a 6LoWPAN Nodes(6LN).

Access Point (AP): entity maintaining the WLAN Basic Service Set (BSS) and is associated with the 6LoWPAN Border Router (6LBR). It is assumed that APs are connected to the power-line.

The terms 6LoWPAN Router (6LR) and 6LoWPAN Border Router (6LBR) are defined as in [[RFC6775](#)] and in this context 6LoWPAN Nodes (6LN) do not refer to a router (Access Point), just to a host (STA).

3. Overview of 802.11ah

The IEEE 802.11 technology uses the unlicensed spectrum in different ISM bands, using CSMA/CA techniques. Specifically 802.11ah is designed to operate in ISM band below Sub-1 Ghz with a bandwidth of 1Mhz/2Mhz (depending of configuration). The system is formed by an

Access Point (AP) which maintains a Basic Service Set (BSS) and stations (STAs). STAs are connected to the AP in a star topology.

The 802.11ah is more energy efficient compared to other conventional 802.11 technologies because of the lower operating frequency and the use of mechanisms which allow STAs to doze periodically and request downlink data when switching to active mode i.e. Traffic Indication Map (TIM) operation, non-TIM operation, Target Wakeup Time (TWT)

An exemplary deployment of a 802.11ah BSS may include a large number of STAs associated to a BSS where STAs are sleeping (dozing) most of the time and they may monitor periodic beacon-frame transmissions containing Traffic Indication Maps (TIM). Data packets intended to STAs cannot be delivered when STAs sleep, thus the TIM indicates which STAs have downlink data buffered at the AP. After reading the TIM, STAs request their buffered data by transmitting a Power-Saving Poll (PS-Poll) frame to the AP. After the downlink data is delivered, STAs enter into sleep mode again. For uplink data delivery, STAs might transmit as soon as it has data available.

There might be STAs that do not monitor constantly the TIM and request downlink data sporadically after waking up.

3.1. Link layer topology of 802.11ah

The 802.11ah defines a star topology at L2 link connectivity, where the STAs are connected to the AP and any communication between STAs passes through the AP. The mesh topology at L2 level is not defined in 802.11ah. In addition, the wireless communication between Access Points is not supported directly in 802.11ah. However, it is possible to set-up a mesh of APs with the IEEE 802.11s amendment which is out of scope of this document. Finally, the 802.11 standard does not define its own networking layer but is compatible with commonly used protocols e.g. IPv4, IPv6.

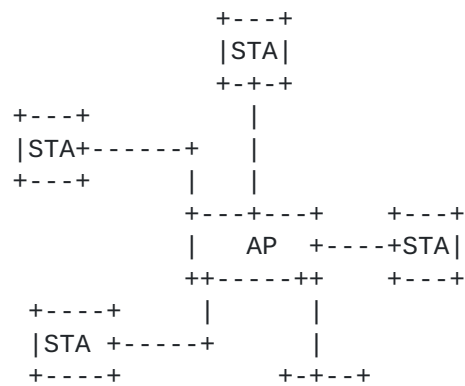




Figure 1: Link Layer Topology

It is important to note that the communication link is unidirectional at any given point in time and that the medium is shared by CSMA/CA techniques which avoid that two or more STAs utilize the medium simultaneously.

3.2. Device Addressing and Frame Structure

The 802.11 physical transmission is composed by a preamble which is used to prepare a receiver for frame decoding, basic physical layer information, and the physical layer payload which encapsulates the MAC Protocol Data Unit (MPDU).

There can be different classes of MAC frames in 802.11, the MAC data frame is the only one carrying higher layer data. Other frames are control and management frames which are used to maintain MAC layer functions. The 802.11/802.11ah MAC addresses use the EUI-48 bit address space.

A MAC Data frame in 802.11 is composed by a MAC header, a MAC payload and a Frame Check Sequence (FCS) which are encoded in an MPDU. The MAC payload carries Link Layer Control PDUs which encapsulates for example IP packets. There are two protocol versions for MAC frame formats, the Protocol Version 0 (PV0) is used in systems existing before 802.11ah such as 802.11n/ac and the Protocol Version 1 (PV1) has less overhead than PV0 specified in 802.11ah.

Segmentation at MAC layer is possible if required.

3.3. Protocol Version 0

The elements of the MAC data frame with PV0 is depicted in the picture below.

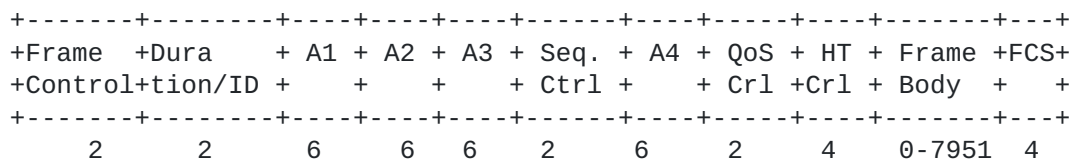


Figure 2: MAC frame PV0

Frame Control: contains information relevant in link layer such as the Protocol Version, frame type and subtype, Power Management, Fragmentation Information, among others.

A1: indicates the recipient of the frame and it contains the 6-bytes MAC address or the Short ID (2-bytes) provided by the AP after association in a given BSS. TBD: further definition of Short ID.

A2: indicates the transmitter of the frame and it contains the 6-bytes MAC address or the Short ID (2-bytes) provided by the AP after association in a given BSS.

Frame Body: is of variable-length field and contains the MAC payload for example L3 packets.

FCS: The Frame Check Sequence field is a 32-bit field containing a 32-bit CRC which is calculated over all the fields of the MAC header and the Frame Body field

Missing descriptions to be completed later.

3.4. Protocol Version 1

With a 802.11ah basic feature set and following the PV1, the maximum MPDU size is 511 bytes. The MAC header for the PV1 format is at least formed by a Frame Control field and the address fields. Other fields are optional.

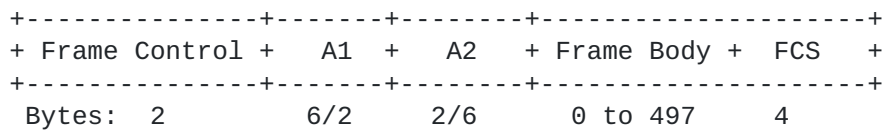


Figure 3: MAC frame PV1 of 802.11ah

Frame control: see above.

A1: indicates the recipient of the frame and it contains the 6-bytes MAC address or the Short ID (2-bytes) provided by the AP after association in a given BSS.

A2: indicates the transmitter of the frame and it contains the 6-bytes MAC address or the Short ID (2-bytes) provided by the AP after association in a given BSS.

Frame Body: The minimum length for non-data frames is 0 bytes. The maximum length depends for example of the MAC header overhead and among other things. For the a basic PV1 data frame with A1/A2 fields carrying MAC addresses and no other optional MAC header fields, the maximum frame body length is 497-bytes.

3.5. Link Layer Control

The Logical Link Control (LLC) layers works as the interface between higher layers, for example IP, and the 802.11 MAC. It supports higher layer protocol discrimination via the EtherType value utilizing the EtherType protocol discrimination method (EPD) defined in IEEE 802-2014 [[IEEE802-2014](#)]. Examples of EtherTypes are 0x0800 and 0x8DD, which are used to identify IPv4 and IPv6, respectively.

LLC Header Format: TBD.

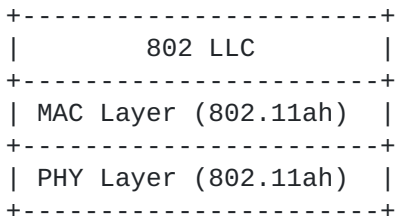


Figure 4: WLAN Protocol Stack

4. Uses Cases

[RFC7548] define use cases for the management of constrained networks, these uses cases are apply as well to 802.11ah

As a starting point in 802.11ah specification work, the Task Group AH

proposed the following use-case categories [[ReferenceUseCase802.11ah](#)]:

- Sensor and Meters, where large number of sensor deliver data through 802.11ah connectivity
- Backhaul Sensor and meter data, where 802.11ah STA can be either directly integrated with a sensor or it will aggregate data from other tree of wireless sensors and then deliver 802.11ah connectivity
- Extended Range Wi-Fi, where the typical range of the Wi-Fi connection will extended due to the use of lower frequencies and other techniques.

5. 6LoWPAN over 802.11ah

IPv4 and IPv6 are compatible with 802.11ah via the LLC. However, this technology presents a trade-off between energy savings and bit rate of the link. Consequently, 6LoWPAN techniques are beneficial to

reduce the overhead of transmissions, save energy and get a better throughput. With 6LoWPAN, the nodes, i.e. 6LN, 6LBR, are co-located

located on the same devices with 802.11 features. The typical 802.11ah network uses a star topology where the 6LBR functionally is co-located with the AP. 6LNs are co-located with STAs and are connected

to the 6LBR through a 802.11ah link. The mesh topology at MAC level is not defined by the 802.11ah standard implying that the 6LBR is the

only router present in the network. Thus, there is no presence of 6LoWPAN Routers (6LR).

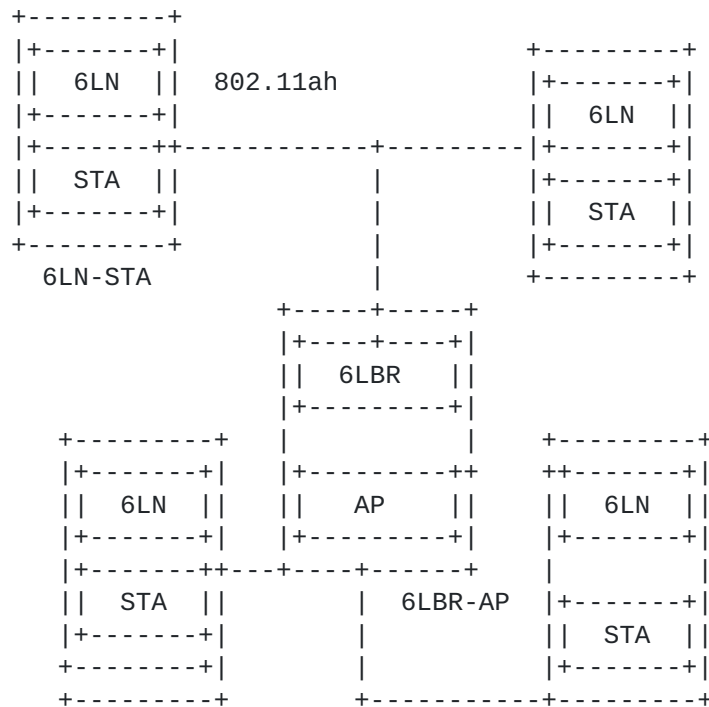


Figure 5: Network Topology

There exists the possibility to have a 802.11ah relay node at L2 to extend the range of an AP. This however is experienced as a single hop by the 6LoWPAN network. In case there is need to connect wirelessly several APs in a mesh topology, the 802.11s might be considered as a possibility. However, the 802.11s is not directly

compatible with 802.11ah and should be considered as a different radio technology based on 802.11 integrated to the system.

The devices in this kind of networks, not necessarily have constrained resources (memory, CPU, etc), but the radio link capacity is limited. It might be that APs are connected to mains power and STAs might be for example battery operated sensors. Therefore 6LoWPAN techniques might be good to support transmission of IPv6 packets over 802.11ah battery operated devices. Related to performance gain, a reduction in air-time is achieved if the stack is compressed. The communication 6LN-6LN is not supported directly using link-local addresses, it is done through the 6LBR using the shared prefix used on the subnet. This specification requires IPv6 header compression format specified in [RFC6282].

In Figure below is showed the stack for PHY and IPv6 including 6LoWPAN

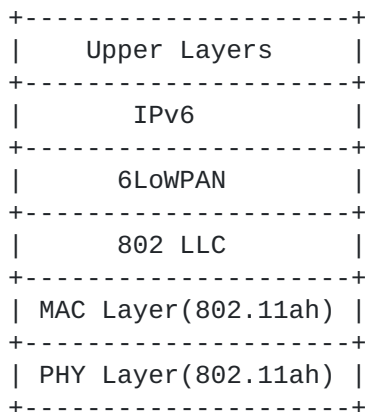


Figure 6: Protocol Stack with 6LoWPAN

6. Stateless address autoconfiguration

The IPv6 link local address follows [Section 5.3 of \[RFC4862\]](#) based on the 48-bit MAC device address.

To get the 64-bit Interface Identifier (IID) [RFC 7136](#) [RFC7136] MUST be followed. [Section 5](#) of this RFC states:

"For all unicast addresses, except those that start with the binary value 000, Interface IDs are required to be 64 bits long. If derived from an IEEE MAC-layer address, they must be constructed in Modified EUI-64 format."

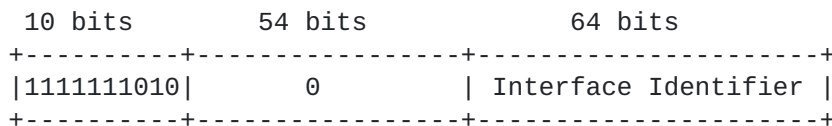


Figure 7: IPv6 link local address

Following Appendix-A of [RFC 4291 \[RFC4291\]](#) the IID is formed inserting two octets, with hexadecimal values of 0xFF and 0xFE in the middle of the 48-bit MAC. The IID would be as follow where "a" is a bit of the 48 MAC address.

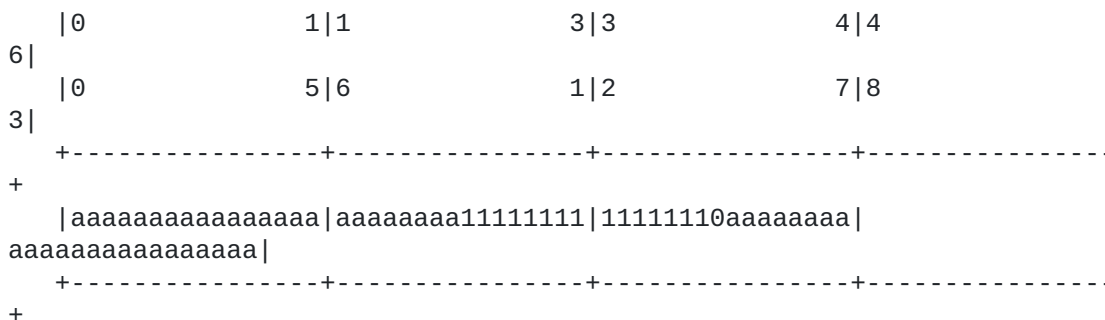


Figure 8: Modified EUI-64 format

For non-link-local addresses a 64-bit IID MAY be formed by utilizing the 48-bit MAC device address. Random IID can be generated for 6LN using alternative methods such as [[I-D.ietf-6man-default-iids](#)].

7. Neighbour Discovery in 802.11ah

Neighbour Discovery approach for 6LoWPAN [[RFC6775](#)] is applicable to 802.11ah topologies. Related to Host-initiated process, use of Address Registration Option (ARO), through the Neighbour Solicitation (NS) and Neighbour Advertisement (NA). Router Solicitation and Router Advertisement are applicable as well following [[RFC6775](#)].

As the topology is star, Multihop Distribution of prefix and 6LoWPAN header compression; and Multihop Duplicated Address Detection (DAD) mechanism are not applicable, since this technology does not cover multihop topology.

8. Header compression

For header compression are applicable the rules proposed in [[RFC6282](#)]. [Section 3.1.1](#) mentions the base Encoding in principle apply to 802.11ah.



```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| 0 | 1 | 1 | TF  |NH | HLIM |CID|SAC| SAM | M |DAC| DAM |
+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Figure 9: LOWPAN_IPHC base Encoding

As specified in [RFC6282]. TF: Traffic Class; Flow Label; NH: Next Header; HLIM: Hop Limit; CID: Context Identifier Extension (TBD: How it would work in 802.11ah); SAC: Source Address Compression. (TBD whether the source address would be eliminated in link-local address); SAM: Source Address Mode; M: Multicast Compression (TBD: How it would work with 802.11ah); DAC: Destination Address Compression;

DAM:

Destination Address Mode.

9. Fragmentation

802.11ah perform fragmentation at L2, thus the fragmentation at L3 would be not necessary.

10. Multicast at IP level

802.11ah supports broadcast and multicast at link layer level, both can be used to carry multicast IP transmission depending on the system's configuration. TBD: add an example.

11. Internet Connection

For Internet connection, the 6LBR acts as router and forwarding packets between 6LNs to and from Internet.

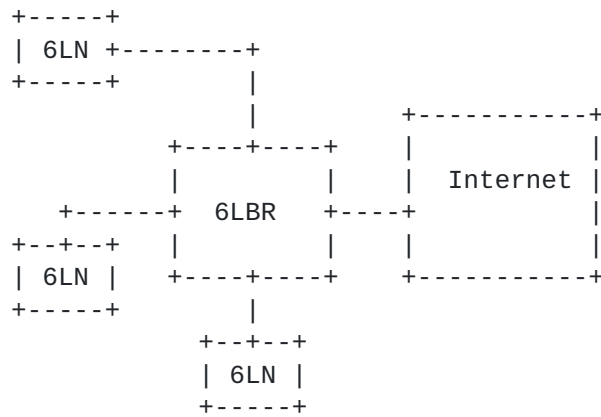


Figure 10: Internet connection of 6Lo network

12. Management of the Network

TBD: how LightWeight Machine to Machine (LWM2M) or CoAP Management Interface (COMI) [[I-D.vanderstok-core-comi](#)] aspects can be applied to this technology, considering [[RFC7547](#)]

13. IANA Considerations

There are no IANA considerations related to this document.

14. Security Considerations

The security considerations defined in [[RFC4944](#)] and its update [[RFC6282](#)] can be assumed valid for the 802.11ah case as well. Indeed, the transmission of IPv6 over 802.11ah links meets all the requirements for security as for IEEE 802.15.4. The standard IEEE 802.11ah defines all those aspects related with Link Layer security. As well as for other existing WiFi solutions, 802.11ah Link Layer supports security mechanism such as WPA, WPS, 802.1X. To have a deeper understanding on how the Key Management processes are handled in 802.11ah, please refer to [TBD]

Implementations defined in [[I-D.ietf-6man-default-iids](#)], [[RFC3972](#)], [[RFC4941](#)], or [[RFC5535](#)], can be considered, for example, as methods to support non-link local addresses.

Privacy - TBD.

15. Acknowledgements

This work is partially funded by the FP7 Marie Curie Initial Training Network (ITN) METRICS project (grant agreement No. 607728)

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