Transmission of IPv6 Packets over Short-Range Optical Wireless Communications (IPv6 over OWC)

draft-ietf-6lo-owc-03

by

Younghwan Choi (ETRI),

Cheol-min Kim (KETI), Carles Gomez (UPC)

Status of “IPv6 over OWC”

- draft-choi-6lo-owc-00 (IETF 117, San Francisco, July 2023)
  - The Introduction to the new I.D. IPv6 over OWC
- draft-choi-6lo-owc-01 (IETF 118, Prague, November 2023)
  - Revision addressing technical issues related to IPv6 over OWC
- draft-choi-6lo-owc-02 (IETF 119, Brisbane, March 2024)
  - Revision incorporating comments from IETF118
  - Addition of SCHC in IPv6 over OWC
- draft-ietf-6lo-owc-00 & 01 (IETF 120, Vancouver, July 2024)
  - I.D.-00 (an initial draft of draft-choi-6lo-owc-02 with typos fixed)
  - Addition of SCHC in IPv6 over OWC (new texts and figures in § 4.5.2 & § 6.)
- draft-ietf-6lo-owc-02 (IETF 121, Dublin, November 2024)
  - Revision for Fig.5, Fig.7 and Fig.8
  - IANA comment about the I.D.-01 & References
- **draft-ietf-6lo-owc-03 (IETF 122, Bangkok, March 2025)**
  - **Comments and feedback from IEEE802.15 members**
  - **Comments and feedback from the 6lo meeting in IETF 121**
  - **IANA comment about the I.D.-02**

Comments and feedback (in detailed)

- **From IEEE 802.15 members**
  - **(IEEE-#1)** Introduction – Highlight scenarios where OWC outperforms other wireless technologies in IoT
  - **(IEEE-#2)** Terminology – Ensure definitions for acronyms like SCHC and DAD to improve accessibility
  - **(IEEE-#3)** Internet Connectivity – Clarify single-hop vs. multi-hop scenarios and discuss interoperability with Wi-Fi/Bluetooth, or other 6Lo technologies
  - **(IEEE-#4)** Additional Considerations – Address interference from ambient light, energy efficiency, etc.
  - **(IEEE-#5)** OWC-related Developments – introduce IEEE 802.15.13-2023 & 802.11bb-2023

- **From the 6lo meeting in IETF 121**
  - **(IETF-#1)** Discussion on whether signaling should indicate that compression is optional
  - **(IETF-#2)** Suggested possibility of a generic SCHC functionality across different LL technologies

- **From IANA**
  - **(IANA-#1)** change "47" to "47 (suggested)" in the section of IANA Considerations.

Updates of I.D.-03 (from the I.D.-02)

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6lo — Y. Choi, Ed. — ETRI
Internet-Draft — C-M. Kim — KETI
Intended status: Standards Track
Expires: 24 April 2025 — C. Gomez — Universitat Politecnica de Catalunya
21 October 2024

Transmission of IPv6 Packets over Short-Range Optical Wireless Communications
draft-ietf-6lo-owc-02

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6lo — Y. Choi, Ed. — ETRI
Internet-Draft — C-M. Kim — KETI
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Transmission of IPv6 Packets over Short-Range Optical Wireless Communications
draft-ietf-6lo-owc-03

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⇒ : updated

Updates of I.D.-03 (from the I.D.-02)

- IEEE-#4, incorporated into Section (§), Abstract.

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Abstract

IEEE 802.15.7, "Short-Range Optical Wireless Communications" defines wireless communication using visible light. It defines how data is transmitted, modulated, and organized in order to enable reliable and efficient communication in various environments. The standard is designed to work alongside other wireless communication systems and supports both line-of-sight (LOS) and non-line-of-sight (NLOS) communications. This document describes how IPv6 is transmitted over short-range optical wireless communications (OWC) using IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) techniques.

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Abstract

IEEE 802.15.7, "Short-Range Optical Wireless Communications" defines wireless communication using visible light. It defines how data is transmitted, modulated, and organized in order to enable reliable and efficient communication in various environments. The standard is designed to work alongside other wireless communication systems and supports both Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) communications. However, ambient light interference from natural sunlight or artificial lighting sources can impact signal reliability. To mitigate this, advanced modulation techniques, optical filtering, and adaptive power control can be employed. This document describes how IPv6 is transmitted over short-range optical wireless communications (OWC) using IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) techniques.

Address interference from ambient light, energy efficiency, etc.

Updates of I.D.-03 (from the I.D.-02)

- IEEE-#1 & #IEEE-#5, incorporated into § 1 (Introduction).

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operational efficiency and decision-making processes across different industrial sectors.

Optical Wireless Communications (OWC) stands as one of the potential candidates for IoT wireless communication technologies, extensively applied across various industrial domains. The [IEEE802.15.7] standard outlines the procedures for establishing bidirectional communications between two OWC devices. Furthermore, IEEE 802.15.7 delineates a comprehensive OWC standard, encompassing features like Visible Light Communication (VLC), Short-Range Communication, Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) Support, High and Low Data Rates, Energy Efficiency, and Secure Communication.

OWC has potential to support IPv6-based IoT networking as one of the low-power wireless personal network (LoWPAN) technologies. OWC supports various network topologies, including peer-to-peer and star configurations. With IPv6 over OWC, it is possible to extend the network topology to include the mesh topology by using a route-over mechanism. However, IPv6 over OWC needs 6LoWPAN technologies

OWC related-Developments – introduce IEEE 802.15.13-2023 & 802.11bb-2023

Highlight scenarios where OWC outperforms other wireless technologies in IoT

[RFC4944] [RFC6282] [RFC6775] [RFC8505] because of the low bit rates, limited frame size and energy constraints of OWC.

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operational efficiency and decision-making processes across different industrial sectors.

Optical Wireless Communications (OWC) stands as one of the potential candidates for IoT wireless communication technologies, extensively applied across various industrial domains. The [IEEE802.15.7] standard outlines the procedures for establishing bidirectional communications between two OWC devices. Furthermore, IEEE 802.15.7 delineates a comprehensive OWC standard, encompassing features like Visible Light Communication (VLC), Short-Range Communication, Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) Support, High and Low Data Rates, Energy Efficiency, and Secure Communication. In addition, the standard has evolved through subsequent related developments to address emerging application requirements:

* [IEEE802.15.7a] introduces Optical Camera Communications (OCC), utilizing image sensors for data reception, making OWC applicable to smart city applications and enhanced vehicular communication.

* [IEEE802.15.13-2023] was developed for industrial IoT and includes new PHYs with pulse modulation (OOK/FDE) and adaptive OFDM for factory automation and real-time industrial networking.

* [IEEE802.11bb-2023] extends Wi-Fi technology to optical communication, leveraging the existing 802.11 MAC and PHY layers. This enables seamless integration of OWC into mainstream wireless networks, opening new possibilities for high-speed data transmission in indoor environments.

OWC is immune to Radio Frequency (RF) interference, making it highly suitable for environments such as hospitals, airplanes, and industrial facilities, where RF interference is a concern. Additionally, OWC can leverage existing visible light infrastructure, reducing deployment costs for smart lighting and IoT applications. OWC also provides energy-efficient operation. Nevertheless, OWC performance is affected in Non-Line-of-Sight (NLoS) links, and by interference produced by ambient light sources.

OWC supports various network topologies, including peer-to-peer and star configurations. With IPv6 over OWC, it is possible to extend the network topology to include the mesh topology by using a route-over mechanism. However, IPv6 over OWC needs 6LoWPAN technologies [RFC4944] [RFC6282] [RFC6775] [RFC8505] because of the low bit rates, limited frame size and energy constraints of OWC. Implementing header compression (e.g., 6LoWPAN or SCHC) significantly reduces packet size, lowering transmission power requirements and extending battery life for IoT devices. This makes OWC a viable alternative for low-power wireless communication in energy-constrained environments.

Updates of I.D.-03 (from the I.D.-02)

- IEEE-#2, incorporated into § 2 (Conventions and Terminology).

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```
2.  Conventions and 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.

   This specification requires readers to be familiar with all the terms
   and concepts that are discussed in "IPv6 over Low-Power Wireless
   Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem
   Statement, and Goals" [RFC4919], "Transmission of IPv6 Packets over
   IEEE 802.15.4 Networks" [RFC4944], and "Neighbor Discovery
   Optimization for IPv6 over Low-Power Wireless Personal Area Networks
   (6LoWPANs) [RFC6775].
```

```
   6LoWPAN Border Router (6LBR):
      A border router located at the junction of separate 6LoWPAN
      networks or between a 6LoWPAN network and another IP network.
      There may be one or more 6LBRs at the 6LoWPAN network boundary.  A
      6LBR is the responsible authority for IPv6 prefix propagation for
      the 6LoWPAN network it is serving.  An isolated LoWPAN also
      contains a 6LBR in the network that provides the prefix(es) for
      the isolated network.
```

Ensure definitions for acronyms like SCHC and DAD to improve accessibility

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```
2.  Conventions and Terminology

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and
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   BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all
   capitals, as shown here.

   This specification requires readers to be familiar with all the terms
   and concepts that are discussed in "IPv6 Stateless Address
   Autoconfiguration" [RFC2462], "IPv6 over Low-Power Wireless Personal
   Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement,
   and Goals" [RFC4919], "Transmission of IPv6 Packets over IEEE
   802.15.4 Networks" [RFC4944], and "Neighbor Discovery Optimization
   for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)
   [RFC6775], and "SCHC: Generic Framework for Static Context Header
   Compression and Fragmentation" [RFC8724].
```

```
   6LoWPAN Border Router (6LBR):
      A border router located at the junction of separate 6LoWPAN
      networks or between a 6LoWPAN network and another IP network.
      There may be one or more 6LBRs at the 6LoWPAN network boundary.  A
      6LBR is the responsible authority for IPv6 prefix propagation for
      the 6LoWPAN network it is serving.  An isolated LoWPAN also
      contains a 6LBR in the network that provides the prefix(es) for
      the isolated network.

   Duplicate Address Detection (DAD):
      A mechanism used in IPv6 networks to ensure that no two devices
      share the same address, preventing address conflicts.

   Static Context Header Compression and fragmentation (SCHC):
      Static Context Header Compression and fragmentation (SCHC), a
      generic framework.
```

Updates of I.D.-03 (from the I.D.-02)

- IETF-#1 & IETF-#2, incorporated into § 4.5.2 (SCHC header compression)

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```
4.5.2.  SCHC header compression

   In addition, OWC devices MAY utilize the header compression mechanism
   offered by Static Context Header Compression and fragmentation (SCHC)
   [RFC8724].  For instance, SCHC may be used to compress IPv6 headers,
   IPv6/UDP headers, IPv6/UDP/CoAP (if CoAP is used), etc.  [RFC8724].

   In the star topology, in order to signal that a node supports SCHC
   for header compression, the node uses the 6LoWPAN Capability
   Indication Option (6CIO), with a new 6LoWPAN Capability Bit called
   the "S" bit, defined by the present specification.  The "S" bit is
   the last bit (47th bit) of the "6LoWPAN Capability Bits" registry
   (see Figure 5).

    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |   Length = 1  |   Reserved    |X|A|D|L|B|P|E|G|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Reserved                            |S|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

          Figure 5: New 6LoWPAN Capability Bit in the 6CIO
```

Discussion on whether signaling should indicate that compression is optional

Suggested possibility of a generic SCHC functionality across different LL technologies

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```
4.5.2.  SCHC header compression

   In addition, Static Context Header Compression and fragmentation
   (SCHC)[RFC8724] is optionally used in OWC networks to reduce
   overhead.  A signaling mechanism SHOULD be implemented to indicate
   whether a node supports SCHC compression.  For instance, SCHC MAY be
   used to compress IPv6 headers, IPv6/UDP headers, IPv6/UDP/CoAP (if
   CoAP is used), etc.  [RFC8724].

   In the star topology, in order to signal that a node supports SCHC
   for header compression, the node uses the 6LoWPAN Capability
   Indication Option (6CIO), with a new 6LoWPAN Capability Bit called
   the "S" bit.  This 'S' bit is intended to indicate generic SCHC
   functionality, making it applicable beyond OWC networks.  Future
   standardization efforts may define a generic specification for the
   'S' bit that extends to other link-layer technologies.  The "S" bit
   is the last bit (47th bit) of the "6LoWPAN Capability Bits" registry
   (see Figure 5).

    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |   Length = 1  |   Reserved    |X|A|D|L|B|P|E|G|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Reserved                            |S|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

          Figure 5: New 6LoWPAN Capability Bit in the 6CIO
```

Updates of I.D.-03 (from the I.D.-02)

- IEEE-#3, incorporated into § 5 (Internet Connectivity Scenario).

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5. Internet Connectivity Scenarios

RFC IPv6 over OWC October 2024

Clarify single-hop vs. multi-hop scenarios and discuss interoperability with Wi-Fi/Bluetooth, or other 6Lo technologies

5.1. OWC Device Network Connected to the Internet

Figure 7 illustrates an example of an OWC device network connected to the Internet. Another OWC devices may run as 6LNs and 6LRs, and they communicate with the 6LBR, as long as both are within each other's range.

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5. Internet Connectivity Scenarios

The scenarios in this section provide useful context for understanding OWC device network configurations. To further clarify, OWC can operate in two primary configurations.

* Single-hop networks: Suitable for small-scale IoT applications such as small-scale smart home automation, where OWC-enabled devices communicate directly.

* Multi-hop networks: Suitable Where OWC devices relay data across multiple hops to extend the network range (e.g., for industrial IoT deployments). Additionally, interoperability with other 6lo wireless technologies can be considered. In hybrid networks, IPv6 over OWC can coexist with these technologies by utilizing IPv6 routing mechanisms, allowing seamless integration with existing infrastructure.

5.1. OWC Device Network Connected to the Internet

Figure 7 illustrates an example of an OWC device network connected to the Internet. Another OWC devices may run as 6LNs and 6LRs, and they communicate with the 6LBR, as long as both are within each other's range.

Updates of I.D.-03 (from the I.D.-02)

- IANA-#1, incorporated into § 6 (IANA Considerations).

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6. IANA Considerations

IANA is requested to make the following addition to the "6LoWPAN Capability Bits" registry, as follows:

Bit	Description	Reference
47	SCHC Support (S bit)	RFC This

Figure 9: New 6LoWPAN Capability Bit (S bit)

draft-ietf-6lo-owc-03.txt

6. IANA Considerations

IANA is requested to make the following addition to the "6LoWPAN Capability Bits" registry, as follows:

Bit	Description	Reference
47 (suggested)	SCHC Support (S bit)	RFC This

Figure 9: New 6LoWPAN Capability Bit (S bit)

change "47" to "47 (suggested)" in the section of IANA Considerations.

Updates of I.D.-03 (from the I.D.-02)

- IEEE-#2 & IEEE-#5, incorporated into § 8 (References).

8. References

8.1. Normative References

[IEEE802.15.7]
IEEE, "IEEE Standard for Local and metropolitan area networks--Part 15.7: Short-Range Optical Wireless Communications", IEEE Std 8802.15.7-2018, DOI 10.1109/IEEESTD.2019.8697198, April 2019, <https://ieeexplore.ieee.org/document/8697198>.

8.2. Informative References

Reference for "DAD"

References for the OWC-related developments

8. References

8.1. Normative References

[IEEE802.15.7]
IEEE, "IEEE Standard for Local and metropolitan area networks--Part 15.7: Short-Range Optical Wireless Communications", IEEE Std 802.15.7-2018, DOI 10.1109/IEEESTD.2019.8697198, April 2019, <https://ieeexplore.ieee.org/document/8697198>.

[RFC2462] Thomson, S. and T. Narten, "IPv6 Stateless Address Autoconfiguration", RFC 2462, DOI 10.17487/RFC2462, December 1998, <https://www.rfc-editor.org/info/rfc2462>.

8.2. Informative References

[IEEE802.11bb-2023]
IEEE, "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: Light Communications", IEEE Std 802.11bb-2023, June 2023, <https://standards.ieee.org/ieee/802.11bb/10823>.

[IEEE802.15.13-2023]
IEEE, "IEEE Standard for Multi-Gigabit per Second Optical Wireless Communications (OWC), with Ranges up to 200 m, for Both Stationary and Mobile Devices", IEEE Std 802.15.13-2023, February 2023, <https://standards.ieee.org/ieee/802.15.13/10269>.

[IEEE802.15.7a]
IEEE, "IEEE Standard for Local and Metropolitan Area Networks - Part 15.7: Short-Range Optical Wireless Communications Amendment 1: Higher Rate, Longer Range Optical Camera Communication (OCC)", IEEE Std 802.15.7a-2024, December 2024, <https://standards.ieee.org/ieee/802.15.7a/10367>.

Further Updates

```
7.  Security Considerations

   [TBD]
```

- **For § 7 (Security Considerations)**, a new contributor, Munhwan Choi (ETRI) has been invited.
- According to his further contribution, **some of his stable contents will be incorporated** in the next updates.
- After all contributed, his draft will not keep updated any more (will be expired)

draft-choi-6lo-owc-security-00

```
6lo                                                        M. Choi, Ed.
Internet-Draft                                                 Y. Choi
Intended status: Informational                                    ETRI
Expires: 13 April 2025                                 10 October 2024

   Security considerations for IPv6 Packets over Short-Range Optical
                        Wireless Communications
                   draft-choi-6lo-owc-security-00

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```

※ A New I.D., draft-choi-6lo-owc-security : Recently updated into I.D.-01
(https://datatracker.ietf.org/doc/draft-choi-6lo-owc-security/)

Please read the draft
and
welcome any feedback !!

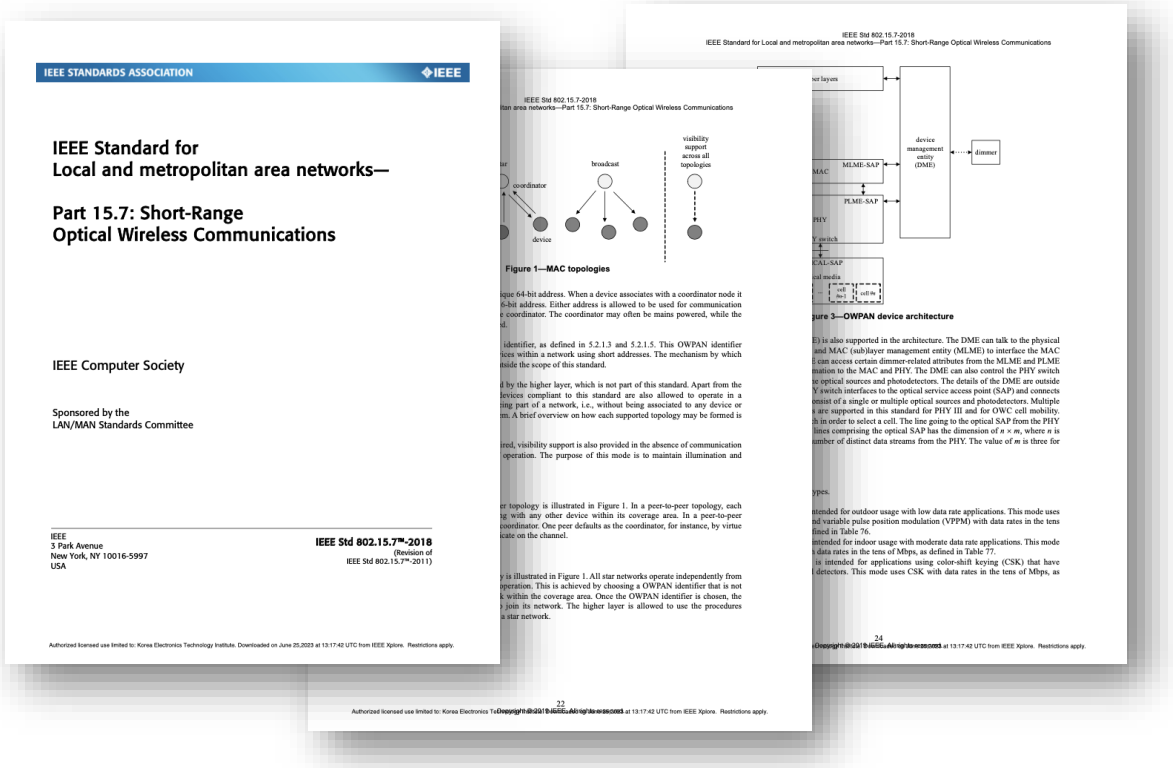
Thank you.

Ref.#1: Short-Range Optical Wireless Communications (OWC) ?

- **OWC** uses **intensity modulation of optical sources**, such as **Light Emitting Diodes (LEDs)**.
- **OWC** combines lighting and **bidirectional data communications**.
- **OWC** can be applied to various domains including area **lighting, signboards, streetlights, vehicles, traffic signals, displays, LED panels, and digital signage, smart phones** ...
- **OWC** devices can be powered by **limited energy sources (e.g., battery or energy harvesting)** for energy-efficient services.

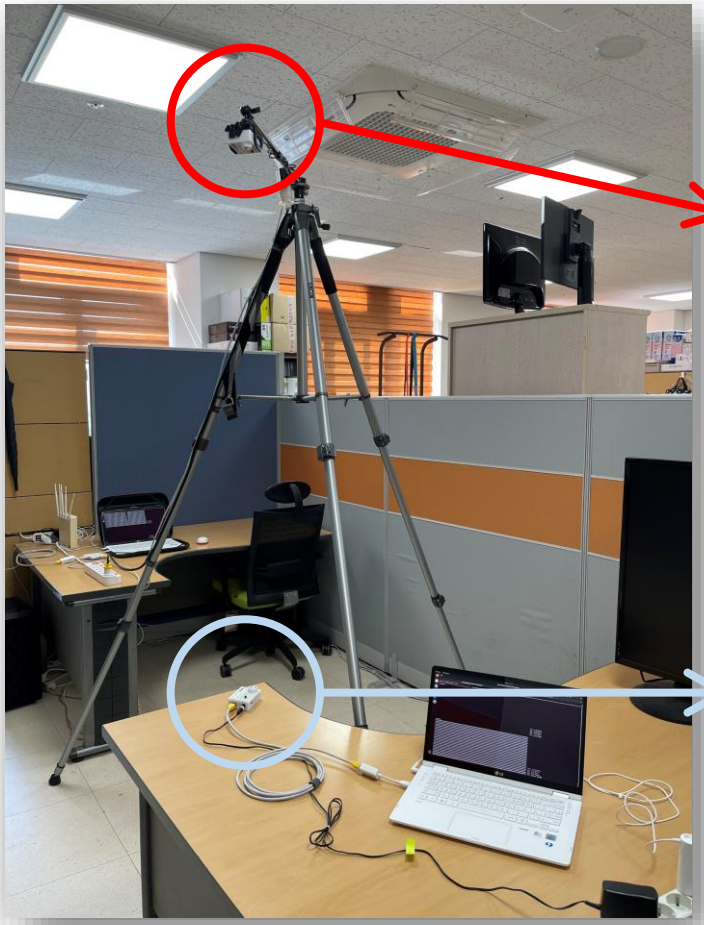
Ref.#2: OWC v.s. IEEE 802.15.7

- OWC is defined by **IEEE 802.15.7 standard**
  providing six key characteristics, including



Visible Light Communication (VLC),
Short-Range Bidirectional Communication,
Line-of-Sight (LOS) &
Non-Line-of-Sight (NLOS) Support,
High and Low Data Rates,
Energy Efficiency,
and Secure Communication.

Ref.#3: Test-bed for “IPv6 over OWC”

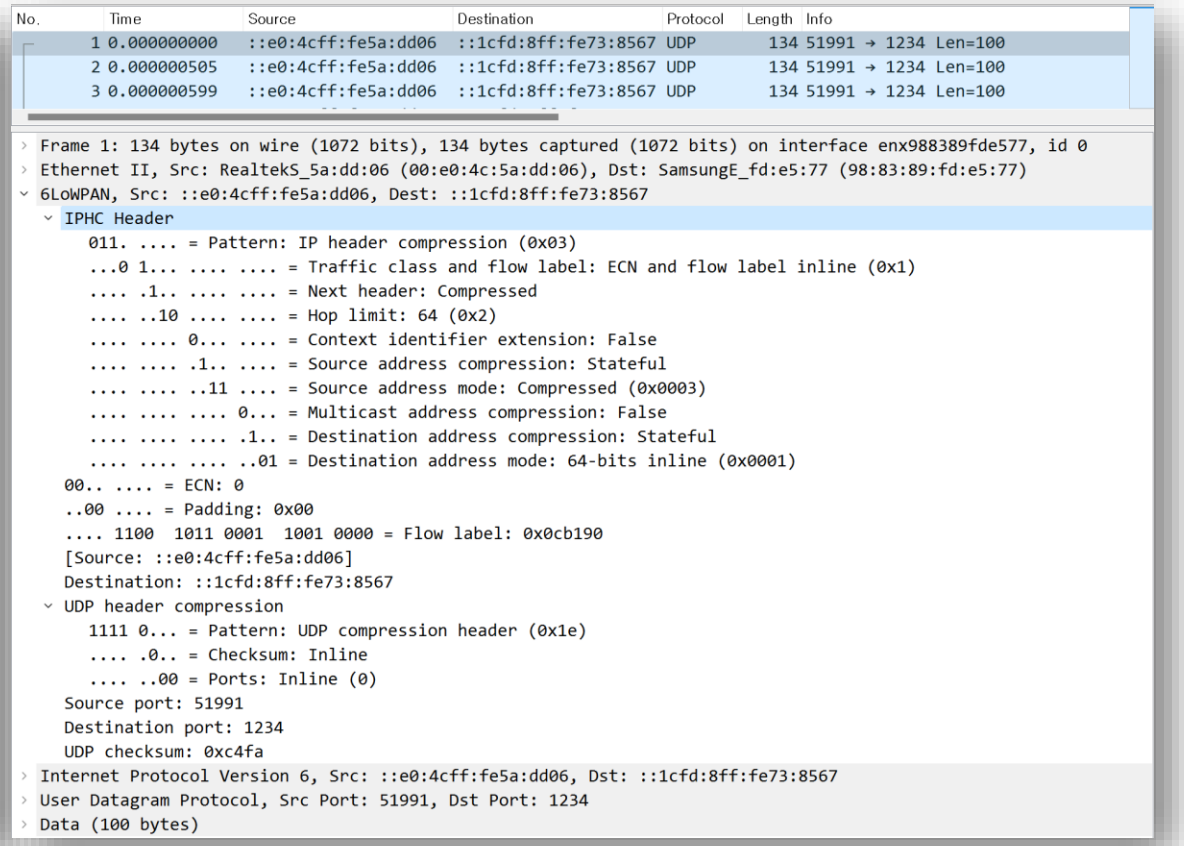


Ref.#4: Test Results of “IPv6 over OWC”

- Ping responses

```
PING 2001:db8:aaaa::1cfd:08ff:fe73:8567(2001:db8:aaaa:0:1cfd:8ff:fe73:8567) 100 data bytes
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=1 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=2 ttl=63 time=1.68 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=3 ttl=63 time=1.68 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=4 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=5 ttl=63 time=1.67 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=6 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=7 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=8 ttl=63 time=1.67 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=9 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=10 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=11 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=12 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=13 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=14 ttl=63 time=1.63 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=15 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=16 ttl=63 time=1.62 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=17 ttl=63 time=1.67 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=18 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=19 ttl=63 time=1.62 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=20 ttl=63 time=1.62 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=21 ttl=63 time=1.68 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=22 ttl=63 time=1.62 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=23 ttl=63 time=1.64 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=24 ttl=63 time=1.65 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=25 ttl=63 time=1.67 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=26 ttl=63 time=1.62 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=27 ttl=63 time=1.66 ms
108 bytes from 2001:db8:aaaa:0:1cfd:8ff:fe73:8567: icmp_seq=28 ttl=63 time=1.64 ms
```

- Wireshark captured



Ref.#5: IEEE WCL about “IPv6 over OWC”

Cheol-min Kim, Sang-Kyu Lim, Jin-Doo Jeong, Younghwan Choi, Seok-Joo Koh, "**6LoWPAN Over Optical Wireless Communications for IPv6 Transport in Internet of Things Networks**” **IEEE Wireless Communications Letters**, Vol. 11, Issue 6, June 2022.