IEEE P802.11  
Wireless LANs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| A CSD Proposal for Light Communications (LC) | | | | |
| Date: 2017-11-05 | | | | |
| Author(s): | | | | |
| Name | Affiliation | Address | Phone | email |
| Nikola Serafimovski | pureLiFi Ltd. | 2nd Floor, Rosebery House  9 Haymarket Terrace Edinburgh EH12 5EZ United Kingdom | +44 131 516 1816 | nikola.serafimovski@purelifi.com |
| John Li | Huawei |  |  | john.liqiang@huawei.com |
| Jiamin Chen | Huawei |  |  | jiamin.chen@mail01.huawei.com |
| Christophe Jurczak | Lucibel |  |  | Christophe.jurczak@lucibel.com |
| Volker Jungnickel | Fraunhofer HHI | Einsteinufer 37, 10587 Berlin, Germany |  | volker.jungnickel@hhi.fraunhofer.de |
| Gaurav Patwardhan | HPE |  |  | gaurav.patwardhan@hpe.com |
| Mark Rison | Samsung |  |  | [m.rison@samsung.com](mailto:m.rison@samsung.com) |

Abstract

This submission is the CSD proposal from the IEEE 802.11 Light Communications (LC) Study Group.

# 1. IEEE 802 criteria for standards development (CSD)

The CSD documents an agreement between the WG and the Sponsor that provides a description of the project and the Sponsor's requirements more detailed than required in the PAR. The CSD consists of the project process requirements, 1.1, and the 5C requirements, 1.2.

## 1.1 Project process requirements

### 1.1.1 Managed objects

Describe the plan for developing a definition of managed objects. The plan shall specify one of the following:

1. The definitions will be part of this project. **YES**
2. The definitions will be part of a different project and provide the plan for that project or anticipated future project.
3. The definitions will not be developed and explain why such definitions are not needed.

### 1.1.2 Coexistence

A WG proposing a wireless project shall demonstrate coexistence through the preparation of a Coexistence Assurance (CA) document unless it is not applicable.

1. Will the WG create a CA document as part of the WG balloting process as described in Clause 13? **YES**
2. If not, explain why the CA document is not applicable.

## 

## 1.2 5C requirements

## 1.2.1 Broad Market Potential

Each proposed IEEE 802 LMSC standard shall have broad market potential. At a minimum, address the following areas:

a) Broad sets of applicability.

We live in an increasingly connected world. The demand for wireless communications is increasing at nearly 50% per year according to the Cisco Visual Networking Index [1]. Three numbers capture the global ever-accelerating need for wireless bandwidth: by 2021 over 11 billion connected devices will be mobile, 70% of the IP traffic will be from mobile devices, 78% of the internet traffic will be video requiring high speed wireless. This enormous utilization results in a need for a continued increase of the connection speed and the capacity of wireless networks. This capacity could be satisfied by introducing additional unlicensed spectrum.

There are multiple solutions that can provide an increase in the available spectrum and increase the spectrum reuse efficiency in a given area, as well as increased speed. 60 GHz radio solutions, originally defined in IEEE Std 802.11ad (now part of IEEE Std 802.11-2016) and being extended in IEEE P802.11aj and P802.11ay are such examples. However, the continuous deployment and growth of 802.11 technology relies on exploiting further unlicensed spectrum based on the expected growth in the future. Additionally, non-RF based wireless solutions may be preferred for multiple complementary use-cases, like environments where traditional RF solutions are not allowed due to safety and/or security considerations, underwater communications..

The light spectrum, for the most part, has been underutilised for free space communication. Both the visible light spectrum and the IR spectrum are unlicensed and could be used primarily in short-range wireless scenarios. In addition, the use of light for communications also supports the increasingly dense deployment of smaller and smaller cells.

The deployment of high-power solid state light sources together with large-area photodiodes and advanced electronics are key for the success of light communications (LC). In addition, physical (PHY) layer and medium access control (MAC) technologies have evolved significantly and are able to address existing use-cases for LC with enhanced performance as well as additional use-cases. Among those use-case is the complimentary deployment in traditional markets for 802.11, such as industrial wireless, home and enterprise networks, backhauling scenarios, underwater communication and wireless access in medical environments. [[1]](#footnote-1)

LC is a powerful complement to RF in environments where communications should be more secure (banks, R&D centers, defense, etc.) and where radio waves may be restricted (hospitals, electro magnetic interference (EMI) sensitive industrial facilities such as natural gas compression stations, nuclear power plants, etc.). The selection of use cases is driven by the facts that communications using the light spectrum do not interfere with any radio communications, the light spectrum is unlincensed for communications and the communications occur primarily inside the cone of the light.

With people in industrialized nations spending more than 85% of their time indoors (<https://www.nature.com/articles/7500165.pdf>), lighting has the opportunity to become an important communications infrastructure in the future.

b) Multiple vendors and numerous users.

A significant variety of LC vendors currently build various, non-standardized, products for many use-cases that could have significant market growth.

The wider context for the economic considerations for LC is presented in doc. 11-17/0803r1 [2].

The availability of chipsets in the relevant semiconductor technologies (process size and light efficacy for LEDs) is seen as key to reduce power consumption, form factor and costs for LC devices. Standardization is seen by many in the industry as a key facilitator of the mass market for LC. This is apparent given the participation of various entities in the LC Study Group (SG), which typically has 40 individuals presentent representing over 25 different stakeholders.

Stakeholders include chip makers to deliver PHY & MAC sub-systems, system integrators and lighting companies, telecom operators, Internet Service Providers (ISPs), emerging IoT companies, large industrial manufacturers, aviation and transportation industries.

## 1.2.2 Compatibility

Each proposed IEEE 802 LMSC standard should be in conformance with IEEE Std 802, IEEE 802.1AC, and IEEE 802.1Q. If any variances in conformance emerge, they shall be thoroughly disclosed and reviewed with IEEE 802.1 WG prior to submitting a PAR to the Sponsor.

1. Will the proposed standard comply with IEEE Std 802, IEEE Std 802.1AC and IEEE Std 802.1Q? **YES**
2. If the answer to a) is no, supply the response from the IEEE 802.1 WG.

The review and response is not required if the proposed standard is an amendment or revision to an existing standard for which it has been previously determined that compliance with the above IEEE 802 standards is not possible. In this case, the CSD statement shall state that this is the case.

## 1.2.3 Distinct Identity

Each proposed IEEE 802 LMSC standard shall provide evidence of a distinct identity. Identify standards and standards projects with similar scopes and for each one describe why the proposed project is substantially different.

------

The project will have a narrow focus on the definition of the PHY and minimal changes to the MAC layers necessary to enable the use of the light spectrum for wireless communication primarily by transmitting using intensity modulation of the light source and receiving using direct detection.

The difference between LC and the existing 802 light communications standards is the use of the 802.11 MAC as well as the reuse of associated services. This new approach will allow LC to address a wider range of use-cases that are served by local wireless area networks relative to the existing (802.15.7m and 802.15.13) efforts that are focusing on deploying the technology for optical camera communications, low data rate photo-diode communications, and industrial applications.

The key difference between the ITU-T G.vlc effort compared to the proposed 802.11 LC amendment is the use of the 802.11 MAC as well as the targeted deployment of the technology in enterprise and home environments, EMI sensitive environments and more, relative to the focused home networking use-case for the G.vlc technology. Critically, being part of the 802.11 (Wi-Fi) ecosystem enables LC to leverage the existing brand awareness and processes for product development, testing and introduction including eventual certification by the Wi-Fi Alliance.

Tight integration with IEEE 802.11, the coexistence and hand-over with other 802.11 PHY types (through the use of Fast-Session Transfer) will help to increase the LC market by addressing large-volume applications, *e.g.*, together with lighting.

## 1.2.4 Technical Feasibility

Each proposed IEEE 802 LMSC standard shall provide evidence that the project is technically feasible within the time frame of the project. At a minimum, address the following items to demonstrate technical feasibility:

a) Demonstrated system feasibility.

There are many publications demonstrating the hardware feasibility of LC. Greater detail on the technical feasibility of LC, including references for the demonstrated systems can be found here:

<https://mentor.ieee.org/802.11/dcn/17/11-17-0023-09-00lc-lc-tig-draft-report-outline.docx>

b) Proven similar technology via testing, modeling, simulation, etc.

IEEE 802.11 is a mature technology which has a variety of legacy devices and a proven track record, with several billions of devices shipping each year. The increased capabilities envisioned with LC in IEEE 802.11 are in line with the current progress in technology and not expected to impact product development or testing. A significant variety of LC vendors currently build various, non-standardized, products. An example list of these products can be found here:

<https://mentor.ieee.org/802.11/dcn/17/11-17-0023-09-00lc-lc-tig-draft-report-outline.docx>

The amendment will use modeling and simulation as tools for evaluating performance metrics.

**1.2.5 Economic Feasibility**

Each proposed IEEE 802 LMSC standard shall provide evidence of economic feasibility. Demonstrate, as far as can reasonably be estimated, the economic feasibility of the proposed project for its intended applications. Among the areas that may be addressed in the cost for performance analysis are the following:

a) Balanced costs (infrastructure versus attached stations).

The infrastructure costs are expected to be similar to the installation of traditional lighting or Ethernet based networks, as discussed in Slide 3 in doc. 11-17/0803r1 [2].

The cost of stations emboding this technology is not expected to be dramatically different from existing devices incorporating the latest IEEE 802.11 technology.

1. b) Known cost factors.

LC technology is well characterized in terms of cost and is intended for devices, such as fixed assets and mobile devices, which are also well known and characterized in terms of cost. The addition of an LC chipset that is based substantially on existing 802.11 technology in solid state lights creates a realistic estimate for the infrastructure costs.

Similarly, the presence of optical modules and communications modules in mobile devices allows for a realistic estimate of the expected/potential impact on device costs.

c) Consideration of installation costs.

These are substantially similar to current installations for lighting and the market forces are driving demand independent of LC, in particular for Power over Ethernet (PoE) installations suitable for smart buildings, as discussed in Slide 3 in doc. 11-17/0803r1 [2].

d) Consideration of operational costs (e.g., energy consumption).

The added energy cost to support LC is minimal since the energy that is used for illumination may also be used to provide wireless communications. Solid state lights are being used for illumination and communications, reducing constraints on the transmit power for the downlink.

Using LC for uplink can be more power consuming. However, as discussed in [3] (“how does uplink of LC-systems work”), when power consumption is an issue, the uplink could use infrared radiation for uplink with similar level of power consumption as current 802.11 devices, operating in a shorter range.

1. Other areas, as appropriate.

Since seminal work in 1979 [6], LC has been a subject of intense research & development with steady improvements in performance, cost, reliability and compactness [6-13]. While many applications have been imagined, it is intuitive that the exponential growth of LED lighting is shaping a huge market for LC in the next decade. LED lighting in 2016 accounted for <10% of the over 45 billion lighting sockets available. Yet, LED lighting accounted for more than 50% of the revenue for the lighting industry in 2016 and is fast replacing traditional light sources. It is anticipated that LEDs will replace over 70% of the current incandescent and fluorescent lighting by 2020. Nonetheless, the cadence cycle for enterprise lighting and other areas is between 5 to 10 years, which is substantially similar to the cadence cycle for IEEE 802.11 technologies. LC adds communications as a new feature to LED lighting and thus offers significant market growth potential with over 550 million LED lights sold annually for a $100bn lighting market [2].

The light spectrum considered for communications in this project (380 nm – 5000 nm) is already considered license-exempt by some government regulators and falls outside of the remit of most other government regulators including those in Australia, Canada, China, India, Japan, Europe, South Korea and the USA.

**References:**

1. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper, available <https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html>
2. Nikola Serafimovski, Christophe Jurczak, “IEEE 802.11-17/0803r1 Economic Considerations for Light Communications” (<https://mentor.ieee.org/802.11/dcn/17/11-17-0803-01-00lc-economic-considerations-for-lc.ppt>)
3. Global Market Insights, “Li-Fi Market size forecast worth $75.5 billion by 2023”, available at <https://www.gminsights.com/pressrelease/LiFi-market>
4. Nikola Serafimovski et al. “IEEE 802.11-17/1048r0 Light Communications for 802.11”
5. Christophe Jurczak, “IEEE 802.11-17/1500r1 Light Communications Experience of a Lighting Systems Manufacturer”
6. F. Gfeller, U. Babst, “Wireless In-House Data Communication via Diffuse Infrared Radiation,” Proc. Of the IEEE, Vol. 67, No. 11, Nov. 1979.
7. J. M. Kahn, J. R. Barry, “[Wireless infrared communications](http://ieeexplore.ieee.org/abstract/document/554222/), “, Proc. of the IEEE, Vol. 85, No. 2, pp. 265-298
8. [T. Komine](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.T.%20Komine.QT.&newsearch=true); [M. Nakagawa](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.M.%20Nakagawa.QT.&newsearch=true), “Fundamental analysis for visible-light communication system using LED lights,” [IEEE Trans. Consumer Electronics](http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=30), Vol. 50, [No. 1](http://ieeexplore.ieee.org/xpl/tocresult.jsp?isnumber=28566), Feb. 2004, pp. 100 – 107
9. [M.Z. Afgani](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.M.Z.%20Afgani.QT.&newsearch=true) ; [H. Haas](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.H.%20Haas.QT.&newsearch=true) ; [H. Elgala](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.H.%20Elgala.QT.&newsearch=true) ; [D. Knipp](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=%22Authors%22:.QT.D.%20Knipp.QT.&newsearch=true), “ Visible light communication using OFDM,“ 2nd TRIDENTCOM 2006, March 1-3, 2006, Barcelona, Spain.
10. C. Kottke, J. Hilt, K. Habel, J. Vučić, and K. Langer, "1.25 Gbit/s Visible Light WDM Link based on DMT Modulation of a Single RGB LED Luminary," in Proc. ECOC 2012, paper We.3.B.4.
11. L. Grobe et al., "High-speed visible light communication systems," in IEEE Communications Magazine, vol. 51, no. 12, pp. 60-66, December 2013.
12. M. Ayyash et al., "Coexistence of WiFi and LiFi toward 5G: concepts, opportunities, and challenges," in IEEE Communications Magazine, vol. 54, no. 2, pp. 64-71, February 2016.
13. H. Chun et al., "LED Based Wavelength Division Multiplexed 10 Gb/s Visible Light Communications," in Journ. Lightwave Technology, vol. 34, no. 13, pp. 3047-3052, July1, 2016.

1. Please see the Consolidated KPI for PAR CSD for LC (doc. 11-17/1778r1) for links/reference to multiple use-case presentations. [↑](#footnote-ref-1)