IEEE P802.11  
Wireless LANs

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| A CSD Proposal for Light Communications (LC) | | | | |
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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.

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## 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 bandwidth and wireless: by 2021 more than half of 17 billion connected devices will be mobile, 65% of the IP traffic will be from mobile devices, 80% of the internet traffic will be video requiring high speed wireless. This enormous utilization results in a need for a continued increase in the capacity of wireless networks. This capacity can be satisfied by the availability of additional unlicensed spectrum.

There are multiple solutions that can provide an increase in the available spectrum and increase the spectrum reuse in a given area, as well as increased speed. WiGig® solutions, defined in IEEE 802.11ad, .11mc, .11aj and 802.11ay are such examples. However, the continued deployment and growth of 802.11 technology relies on accessing further unlicensed spectrum based on the expected growth in the future. Additionally, non-RF based solutions may be preferred for multiple complementary use-cases, like environments where traditional RF solutions are not allowed due to safety and/or security, underwater communications, M2M or when confidentiality considerations prevents their use for example in the banking and defense industries.

The light spectrum, for the most part, has been underutilised for free space communication. The visible light and near infrared (IR) spectrum alone stretches from approximately 250 THz to 800 THz, which means that there is potentially more than 1000 times more bandwidth than the entire RF spectrum of approx. 300 GHz. 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 enables the increasingly dense deployment of smaller and smaller cells.

The key progress increasing the potential of the LC standard is that it would leverage the introduction and large scale deployment of high-power solid state light sources together with large-area photodiodes and advanced electronics. In addition, PHY and MAC technologies have evolved significantly and are able to address existing use-cases for LC with enhanced performances as well as additional use-cases. Among those are complimentary use in traditional markets for 802.11, such as industrial wireless, home and enterprise networks, backhauling scenarios, underwater communication and wireless access in medical environments.

LC is a powerful complement or alternative to RF, in environments where communications should be more secure (banks, R&D centers, defense, …) and where radio waves may not be permitted or restricted (hospitals, pre-K schools, 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, on the one hand, the light frequency range is interference free and not regulated and, on the other hand, light communications happen inside the cone of the light.

Increasing performance in terms of bandwidth, distance and more can open new use cases and improve others such as AR/VR, M2M communications, robotic telepresence, real time gaming, etc. The pervasiveness of LEDs, technological maturity and the increasing demand for wireless capacity, low latency and high speed all play a significant role in the motivation for creating an LC standard within 802.11.

With people in industrialized nations spending more than 90% of their time indoors, lighting is poised to be a communications infrastructure of the future.

b) Multiple vendors and numerous users.

A wide variety of Light Communications (LC) vendors currently build various, non-standardized, products for many use-cases [4] spanning from kb/s IoT devices which work even with diffused light, up to systems delivering few Gbit/s.

After demonstrating the benefit of LC in various use cases through pilots, it is clear that the demand for LC is growing. The LC market size is forecast to be worth $75 billion by 2022 [2].

Standardization is seen by the industry as a key requirement to address the mass market for LC. Vendors include chip makers to deliver PHY & MAC sub-systems, system integrators and lighting companies, telecom operators, emerging IoT companies, large industrial manufacturers, aviation and transportation industries, etc. It is anticipated that the majority of those vendors, and others, will participate in the standards development process and drive the subsequent commercialization activities.

## 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 part of the MAC layers 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 that are focused on wireless local area networks. This new approach will allow LC that are focused on local wireless area networks relative to the existing (802.15.7m and 802.15.13) efforts that are focusing on deploying the technology for wireless specialty networks which have less challenging requirements on energy efficiency, form factor and cost.

Tight integration with 802.11, the coexistence and hand-over with other 802.11 PHY types will reduce time-to-market for LC in its potential large-volume applications, e.g. together with lighting. Similar to the differences between the work on 60 GHz done within 802.15 and within 802.11, the use of the light spectrum with 802.11 technologies will address new use cases having much larger volumes, in addition to the existing use-cases currently targeted by 802.15. The decision on the technical specifications of LC in 802.11 is the primary objective of the proposed task group on LC in 802.11.

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 environments, EMI sensitive environments and more relative to the focused home networking use-case for the G.vlc standardization work.

## 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 deices shipping eachyear. The increased capabilities envisioned with LC for IEEE 802.11 are in line with the current progress in technology and not expected to impinge testability.

The amendment will use modeling and simulation as a tool 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. In other words, very reasonable in terms of the delivered functionality.

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 a LC chipset that is based substantially on existing 802.11 technology in LED lights creates a very good estimate for the infrastructure costs. Similarly, the presence of optical modules and communications modules in mobile devices allows for a very good 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 solutions suitable for smart buildings.

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. LEDs are being used for illumination and communications, removing 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 or RF for uplink with similar level of power consumption as current 802.11 devices.

1. Other areas, as appropriate.

Since seminal work in 1979 [5], LC has been a subject of intense research & development with steady improvements in performance, cost, reliability and compactness [6-12]. 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. 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 [1].

LC systems should respect regulation and standards established in the lighting industry to avoid becoming health hazards (related to light intensity, color, or flicker) and should not create any electromagnetic interference.

The light spectrum (100 nm – 10000 nm) is already considred license-exempt by some government regulators and falls outside of the remit of most other government regulators including outside of the regulatory authorities 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”
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.