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Re: Questionnaire on the Role of Radio Spectrum Policy to help combat Climate Change

Dear Radio Spectrum Policy Group,

IEEE 802 LAN/MAN Standards Committee (LMSC) thanks the Radio Spectrum Policy Group (RSPG) for issuing the questionnaire on the role of radio spectrum policy to help combat climate change and for the opportunity to provide feedback on this topic.

IEEE 802 LMSC is a leading consensus-based industry standards body, producing standards for wireless networking devices, including wireless local area networks ("WLANs"), wireless specialty networks ("WSNs"), wireless metropolitan area networks ("Wireless MANs"), and wireless regional area networks ("WRANs"). We also produce standards for wired Ethernet networks, and technologies produced by implementers of our standards are critical for all networked applications today.

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IEEE 802 LMSC supports the RSPG's ongoing activities on sustainability and climate change and encourages the RSPG to consider IEEE 802 technologies as playing an important role in providing energy efficient wireless broadband connectivity to EU citizens. Please find below the responses of IEEE 802 LMSC to selected questions of this questionnaire.

Introduction

IEEE 802 wireless technologies use, for most part, license-exempt spectrum to operate. The technologies specified by the IEEE 802 LMSC are used in a range of scenarios where energy efficiency is of utmost importance. For instance, the IEEE 802.15 family of standards provide specifications for technologies, such as sensor or IoT networks, that are often energy constrained or have bursty transmission patterns (e.g., a need to transmit or receive data only rarely, but over a long total product lifespan). The IEEE 802.11 standard [1] is incorporated in a large set of battery-driven devices (e.g., laptops, tablets, and smartphones) used by individuals on a daily basis in professional and private settings that require a high level of energy efficiency to maximize utility of the devices for users. The IEEE 802.11 standard contains features to minimize power consumption and to support bursty transmissions. In particular, the IEEE Std 802.11ah-2016 [2] optimizes for energy efficiency over data rate for devices needing longer range or lower power consumption with extended battery life. Examples of these devices include video cameras and sensors.

[1] This document solely represents the views of IEEE 802 LMSC and does not necessarily represent a position of either the IEEE or the IEEE Standards Association.

This response focuses on mechanisms for energy efficiency that have been guiding the development of IEEE 802 wireless technologies in the last 15 years. First, we introduce an early contribution of the IEEE 802.3 Ethernet Working Group to energy efficiency in networking, and then we exemplify how learnings from that contribution progressed into wireless technologies, producing the highly efficient IEEE 802 technologies of today.

The IEEE Std 802.3az-2010 [3] was an early network standard that considered energy efficiency parameters suitable for standardization. The Low Power Idle feature was defined, comprising two components. The first is disabling the transmitter except for necessary intermittent refresh signaling during the Low Power Idle state. This provides energy savings compared to a continuous idle signal that was used on most links until then. The second is a 'sleep' and 'wake' signal that is sent before the link enters and before the link exits the Low Power Idle state, respectively.

The longer the sleep time, the greater the potential energy saving in the receive device. This however comes at the cost of more buffering in the transmitting device; the transmitter must wait longer for the receiver to accept packets, and therefore latency increases. Since the latency a system can tolerate may vary over time, the IEEE Std 802.3az-2010 defines Link Layer Discovery Protocol (LLDP) messages that allow the default latency to be changed through negotiation between the two ends of the link, enabling the wake time to be changed dynamically. As an example, while a personal computer (PC) is running a voice application, the latency can be set low at the cost of potentially lower energy saving. When use of the voice application is complete, and the PC is just web browsing, the latency and therefore the energy saving can potentially be increased.

Since there is both a latency and an energy overhead in bringing a link out of the Low Power Idle state, at low utilization it may be more energy efficient to bring a link out of the state once, rather than multiple times, to send multiple packets. It might even be possible that a constant low rate of packets will prevent a link from entering the Low Power Idle state. This is where the approach of buffering then bursting packets comes from, assuming that the resultant increase in latency can be tolerated.

The lessons from the standard development activities that led to the IEEE Std 802.3az-2010 and that followed in real-world deployments of this standard in networks in different environments are that there are energy gains to be made from being able to schedule traffic and from being able to transmit large amount of data in bursts rather than smaller amount of data continuously over a long period of time and from being able to idle receivers. These lessons can also be applied to wireless technologies.

For specific IEEE 802 wireless technology features that enable such energy conservation, please refer to our response to Question 11.

Question 4. In your analyses related to energy consumption and/or energy efficiency, what are your reflections on the influence of parameters such as frequency band, type of radio access technology, coverage addressing different areas (urban, suburban, rural)?

Ubiquitous deployments of wireless communications based on IEEE 802 wireless technologies are essential to enable the EU's sustainable development goals and achieve its Digital Decade vision. It has been remarked in several studies produced by or for European institutions that networks using IEEE 802 wireless technologies, in combination with wired backhaul over long distances, are the current leaders in terms of energy efficient networks [4][5].

As has been remarked by the RSPG's opinion on Spectrum Policy in Climate Change published in November 2021 [6], access to large, contiguous frequency blocks reduces the consumption associated with the support of multiple carriers and carrier aggregation. The IEEE Std 802.11ax-2021 [7], the ongoing IEEE P802.11be project [8], IEEE Std 802.15.4z-2020 [11], and the ongoing P802.15.4ab project [14] for instance, introduce capability to operate in the entire 6 GHz band (i.e., 5925 MHz to 7250 MHz). Extending license-exempt operation to the upper 6 GHz band (specifically, 6425 MHz to 7125 MHz) in Europe is aligned with the RSPG's opinion [10].

In addition, as the RSPG recognizes in its opinion that the current EU framework facilitates the roll-out of indoor networks, which in turn contributes to addressing climate change, it is important for the RSPG to consider the future of sub 1 GHz bands to enable wider deployment, especially for indoor settings, of IEEE 802 wireless technologies including IEEE 802.15 family of standards and IEEE Std 802.11ah-2016.

The IEEE 802.15.4 standard has excellent support for IoT devices with low to extremely low energy consumption. IEEE Std 802.15.4-2020 and IEEE Std 802.15.4z-2020 [12] use the 6 GHz to 8 GHz bands for precision ranging applications, with Ultra-Wideband (UWB) technology operation finding adoption for numerous short-range sensing and ranging applications. These technologies are widely deployed in mobile phones and accessories for high integrity distance and direction measurement purposes and will be used in car keys and other very low power consumption device to device use cases. With the constraint of -41.3 dBm/1 MHz power spectral density, or in other terms, 37 nJ/ms, such solutions provide significant energy saving compared to approaches that rely on larger infrastructure. In addition, hundreds of millions of IoT devices using the narrowband (NB) options of IEEE Std 802.15.4-2020 have been deployed in license-exempt spectrum in the sub 1 GHz and 2.4 GHz bands for a broad range of residential, commercial, utility/energy, and industrial applications requiring very low or even ultra-low power consumption. This include devices using highly successful technologies such as Zigbee, Green Power, Smart Energy, and Thread, which are developed based on IEEE 802.15.4 NB technologies.

The IEEE 802.11ah technologies are deployed in scenarios where a sensor device, usually battery-powered, might sporadically need to transmit or receive data of low volume. For these technologies, transmission can be scheduled, and devices remain dormant between transmissions. A design goal of these devices is long lifespan that often lasts tens of years. The IEEE 802.11ah technologies can also be deployed in scenarios where video is transmitted at a range farther than an IEEE 802.11 device operating in other frequency bands. For these

technologies, the devices, such as video-enabled doorbells, have higher transmission rates but may also sleep or doze for long periods of time.

Question 6. Taking into account the scope of the work of the RSPG above, do you wish to share other thoughts or ideas which could be helpful to the RSPG to identify the role radio spectrum policy can play to help combat climate change and mitigate other adverse environmental impacts?

IEEE 802 wireless technologies are typically designed such that they can be either primary or secondary users of a frequency band. The majority of existing deployments of IEEE 802 wireless technologies operate in license-exempt bands or bands where an incumbent user has priority access to the band. This has the advantage of allowing IEEE 802 wireless technologies to be flexible and to co-exist with pre-existing priority services in different bands. We would like to highlight the observation by the RSPG in its 2021 Opinion on Spectrum Policy in Climate Change [6] that spectrum needs and demands to help combat against climate change can change over time. License-exempt designations provide flexibility to the regulator and to technology developers in terms of changing and adapting features to the current needs of society and the economy.

As the number and variety of applications of IEEE 802.15.4 NB and UWB devices continues to grow, radio spectrum policy and spectrum regulations can help combat climate change by creating conditions conducive to lowering power usage. For example, while the IEEE 802.15.4 NB and UWB radios [11] cause very little or no interference to other users of the same spectrum (e.g. there are defined restrictions for UWB radios to operate from 3.1 GHz to 10.6 GHz bands), the IEEE 802.15.4 radios themselves may become blocked by strong nearby signals. While regulations do not protect IEEE 802.15 radios from interference, spectrum policy can keep parts of the spectrum suitable for energy efficient low power device use.

Question 7. What information on energy consumption of the wireless ECNs does your company / the Members of your stakeholders' association collect? Which methodology/ methodologies are being used? Please name any standards that are being used.

IEEE 802 wireless standards specify mechanisms that can be incorporated by implementers in products in the way that the implementers prefer and choose. The specific set of mechanisms chosen by implementers for a product and the use of those implemented mechanisms has a large impact on the energy use of the product.

For this reason, IEEE 802 LMSC does not consider any energy consumption benchmarking. Industry consortia that oversee specific uses of IEEE 802 wireless standards may, however, gather metrics on the energy consumption of implementations destined for those particular use cases.

Question 11. Which actions is your company / the Members of your association taking to improve the energy efficient use of radio spectrum (e.g., switching to new technologies, advertisements to make energy efficient technologies more attractive, sleep mode for base stations, or other actions)?

IEEE 802 wireless standards already and continue to provide a rich toolbox of energy efficient features.

The IEEE 802.11ah-2016 standard [2] is an amendment to the IEEE 802.11 standard [1] that specifies mechanisms for operation of wireless access system/radio LAN (WAS/RLAN) in sub 1 GHz bands. It was developed with sensor and IoT networks in mind and contains an access point (AP) Power Save Mode. In this mode, the AP can signal to non-AP devices in the network that it is going to be in a "doze mode" for a period of time. By negotiating the length of the doze mode in advance, the AP and the non-AP devices can both conserve energy. This amendment introduced many features to increase energy efficiency. These include reducing overhead and relaxing timing for energy limited clients that typically operate from a coin cell. It also introduced Target Wake Time (TWT), which allows long sleeping devices to negotiate a time for the device to be active. This enables optimizing power consumption per device.

The IEEE Std 802.11ax-2021 standard [7], which is an amendment to the IEEE 802.11 standard, includes a new energy efficient feature, namely broadcast TWT, which is a scheduling mechanism for transmissions between an AP and a non-AP. It has the advantage of allowing larger throughput while lowering latency since both devices are not only be aware of when transmissions will be made, but also enable energy efficiency since the devices can be idle or quiet when transmissions do not need to be made.

The IEEE P802.11be project [8] specifies multi-link operation, which defines a way for multiple APs in a single device to coordinate traffic management over several bands. One mechanism provided for in multi-link operation is for the logical controlling entity of the multi-link device to quiet channels which are not necessary given the total data traffic load. In practice, if a multi-link device is capable of simultaneously sending traffic on links operating at 2.4 GHz, 5 GHz and 6 GHz bands, but the current load on the network is such that only one or two of these links are necessary to provide a robust service level, the other one or two links can be quieted dynamically. The links can be un-quieted once the load on the network increases, with the result that the radios consume only the amount of energy they need for a given traffic load.

Starting in September 2022, the IEEE 802.11 Working Group established a project authorization request study group, namely Ultra High Reliability Study Group [15], that investigate physical layer and medium access control layer technologies to improve reliability of WLAN connectivity, reduce latencies, increase manageability, increase throughput including at different signal-to-noise levels and reduce device level power consumption. AP power save mechanisms are one of the topics that are under consideration.

Question 12. What were the triggers for these actions (e.g. legal requirement, economic interests, consumer expectations, competitiveness, etc.)?

IEEE 802 wireless technologies are developed to satisfy market and society needs. Energy-efficient features are expected by consumers, enterprise, and industrial users of IEEE 802 wireless technologies.

Question 13. Were there any difficulties when you attempted to introduce or perform these actions? Please specify.

No.

Question 14. What further actions would enable you to foster (a more) energy efficient spectrum use, if any? Should such an activity be done by national spectrum regulators / ministries / European entities? Please specify and explain.

Spectrum policy and regulations can update and build on methods discussed in the ECC Report 181 [13] to improve efficiency and coexistence in license-exempt spectrum, for example, by discouraging un-needed high-power transmissions, requiring adaptive power control, and optimizing different bands for different communication needs. As an example of optimizing different bands for different communication needs, avoiding allocation of spectrum for technologies that rely on high transmission power especially in the range from 7.125 GHz to 9.5 GHz would enabled increased use of low power technologies such as UWB.

Lower frequencies provide for better free space propagation loss and better clutter propagation loss. This enables energy efficiency for longer distances. Hence, wider adoption of wide band data transmissions in the 915.8 MHz to 919.4 MHz band should be encouraged since this enables energy efficiency. Likewise, relaxation of occupied bandwidth to 2 MHz and removal of duty cycle restrictions will enable greater use of this band for video use cases. Allowing the transmission power of 1 Watt for IEEE 802.11ah technologies enables the video use case to reach a greater distance.

Lastly, as pointed out under Question 4, enabling use of the entire 6 GHz (5925 MHz to 7250 MHz) by license-exempt technologies would facilitate further energy efficiency improvements in networks relying on implementations of IEEE 802 wireless specifications as they would be able to leverage more of the mechanisms (see Question 11) already incorporated in the specifications. As more license-exempt spectrum (e.g. 6 GHz) becomes available, data-intensive applications could be further incentivized to move out of the sub 1 GHz and 2.4 GHz bands and these bands could be focused more on IoT applications. This would tend to reduce interference, reducing the pressure on IoT applications in the sub 1 GHz and 2.4 GHz bands to increase transmit power to overcome interference.

Question 15. Would some kind of spectrum regulation facilitate your motivation to use radio spectrum in a (more) energy efficient way?

See response to Question 14.

Question 16. Taking into account the scope of the work of the RSPG above, do you wish to share other thoughts or ideas which could be helpful to the RSPG to identify the role radio spectrum policy can play to help combat climate change and mitigate other adverse environmental impacts?

License-exempt designations, whether accommodating license-exempt technologies as primary or secondary users of a frequency band, provide flexibility to the regulator and to technology developers in terms of changing and adapting features to the current needs of society and the economy. In addition, license-exempt technologies already have a proven track record of combining energy efficient spectrum use with higher capacity. We encourage global regulators and administrations to adopt policies that encourage technology neutrality and flexible shared spectrum usage to create social and economic benefit advantages for all.

The Wi-Fi Alliance, an industry consortium developing interoperability specifications and certifications for Wi-Fi technologies, has published a set of sustainability information materials that further explain how implementations of IEEE 802.11 wireless technologies contribute to a more sustainable, green networking infrastructure [9][10].

The IEEE 802 LMSC provides wireless standards primarily designed for use of shared and license-exempt operation and enable an ecosystem in which many independent entities can contribute and enable an ever-expanding communications infrastructure, and we believe implementations of our technical standards already contribute to the RSPG's goals.

Conclusion

IEEE 802 LMSC thanks the RSPG for the opportunity to provide this submission and kindly requests the RSPG to take into account our responses in its decision towards the role of radio spectrum policy to combat climate change.

Respectfully submitted

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