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Abstract

With the dramatic increase in the number of IoT devices, wireless communication technologies in the Sub-1 GHz frequency bands featuring LPWAN are in disarray. These technologies include standardized IEEE 802.15.4g/Wi-SUN, IEEE 802.11ah/Wi-Fi HaLow, and proprietary SigFox, LoRaWAN and others. These communication technologies use lower frequencies than conventional Wi-Fi in the 2.4/5/6 GHz bands and are used in critical infrastructure such as smart meters in addition to applications such as sensor data collection, environmental monitoring and surveillance cameras for security. However, performance degradation has been observed on IEEE 802.15.4g in environments where IEEE 802.15.4g devices are densely deployed with other interfering devices. IEEE 802.19.3 specifies recommended best practices and coexistence mechanisms which enable IEEE 802.15.4g-FSK PHY and IEEE 802.11ah OFDM PHY based systems to effectively coexist in Sub-1 GHz bands. IEEE 802.19.3 was published in April 2021. Subsequently, new functions have been specified in the standards, frequency regulations have been updated and new market requirements have emerged. Accordingly, new coexistence mechanisms are needed. This paper describes the status and future prospects of the IEEE 802.19.3a Task Group started in March 2024 towards spectrum resource efficiency and higher network performance as an amendment of IEEE 802.19.3-2021 standard.

Workshop on Smart Radio for IoT Era (SRIoT 2024)

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***Abstract*—With the dramatic increase in the number of IoT devices, wireless communication technologies in the Sub-1 GHz frequency bands featuring LPWAN are in disarray. These technologies include standardized IEEE 802.15.4g/Wi-SUN, IEEE 802.11ah/Wi-Fi HaLow, and proprietary SigFox, LoRaWAN and others. These communication technologies use lower frequencies than conventional Wi-Fi in the 2.4/5/6 GHz bands and are used in critical infrastructure such as smart meters in addition to applications such as sensor data collection, environmental monitoring and surveillance cameras for security. However, performance degradation has been observed on IEEE 802.15.4g in environments where IEEE 802.15.4g devices are densely deployed with other interfering devices. IEEE 802.19.3 specifies recommended best practices and coexistence mechanisms which enable IEEE 802.15.4g-FSK PHY and IEEE 802.11ah OFDM PHY based systems to effectively coexist in Sub-1 GHz bands. IEEE 802.19.3 was published in April 2021. Subsequently, new functions have been specified in the standards, frequency regulations have been updated and new market requirements have emerged. Accordingly, new coexistence mechanisms are needed. This paper describes the status and future prospects of the IEEE 802.19.3a Task Group started in March 2024 towards spectrum resource efficiency and higher network performance as an amendment of IEEE 802.19.3-2021 standard.**

***Index Terms*—Wireless coexistence, IEEE 802.19.3a, IEEE 802.15.4g, IEEE 802.11ah, CSMA/CA, Spectrum Efficiency, IoT.**

I. Introduction

Sub-1 GHz (S1G) frequency bands are getting attraction against the backdrop of the proliferation of IoT (Internet of Things) devices. Standardized communication technologies such as IEEE 802.15.4g/Wi-SUN and IEEE 802.11ah/Wi-Fi HaLow and proprietary communication technologies such as SigFox, LoRaWAN and ELTRES have been introduced to the LPWAN (Low Power Wide Area Network) market. These technologies have features of low data rate, long communication distance, flexible network topology and low power consumption for sensor networks. These technologies are used for critical infrastructures such as smart metering and industrial IoT applications in addition to IoT applications such as sensor data collection, environmental monitoring and surveillance application for security sensors and security cameras. Traditionally, many IoT applications have been insensitive to missing packets, but QoS-aware applications are increasing. Therefore, the dramatic increase in the number of IoT devices and the coexistence performance of different technologies cause concerns for communication quality. There are also issues arising from limited international harmonization of frequency regulations. S1G bands such as 920 MHz band are unlicensed frequency bands, similar to 2.4 GHz and 5 GHz bands. However, different countries have significantly different frequency regulations in S1G bands, with differences such as channel allocation, channel bandwidth, transmission power, and transmission duty cycle. Therefore, S1G bands present different challenges compared to other frequency bands.

Accordingly, the IEEE 802.19.3a Task Group was formed in February 2024 to update and expand coexistence recommendations to address new standard features, updated frequency regulations, new market requirements, increasing data traffic, greater device density, and increased potential for congestion based on both IEEE 802.11ah and IEEE 802.15.4g-OFDM PHY mode.

The rest of this paper is organized as follows. Section II presents IEEE 802.19.3a standardization status and difference from conventional IEEE 802.19.3 [1]. Study items for the IEEE 802.19.3a Task Group are provided in Section III. Use case and simulation methodology are described in Section IV. Finlay, we conclude our paper with future plans in Section V.

II. IEEE 802.19.3a Amendment

Initial discussion to set up IEEE 802.19.3a to update IEEE 802.19.3-2021 started in the IEEE 802.19 Working Group in July 2023 based on regulation updates, market requirement changes and IEEE 802.15.4 channel access mechanism enhancement [2]. S1G (920 MHz) regulations in Japan have been updated to support a maximum 4 MHz aggregated channels, increased from the prior maximum of 1 MHz [3] [4]. Activity in IEEE 802.15 Working Group has resulted in enhancements to the IEEE 802.15.4 channel access options to address new requirements for metering systems in Japan. A new IEEE 802.15.4 channel access option named Suspendable CSMA/CA, proposed by authors of this paper in [5] [6], has been adopted by the IEEE 802.15 Working Group. Suspendable CSMA/CA allows to IEEE 802.15.4 devices to suspend the backoff timer when channel is detected to be busy. This function can reduce backoff failure incurred by the exceeding the backoff threshold (macMaxCSMABackoffs) improving coexistence in the presence of interfering devices. It will positively impact coexistence behavior of implementations based on the IEEE 802.15.4 standard.

Enhanced S1G band Study Group was formed to create a PAR (Project Authorization Request) and CSD (Criteria for Standards Development) to identify the project scope at IEEE 802.19 Working Group session in November 2023 [7]. The IEEE New Standards Committee (NesCom) and Standards Board approved the PAR a in February 2024. The 802.19 working group formed the IEEE 802.19.3a Task Group to develop an amendment to the standards. Project IEEE 802.19.3a will develop further best practices and strategies to improve coexistence of IEEE 802.11ah and IEEE 802.15.4-OFDM PHY systems in the S1G frequency bands [7].

The IEEE 802.19.3a Task Group officially started in the IEEE 802 Plenary Meeting in March 2024. The authors of this paper have actively led this standard development. Benjamin A. Rolfe is Task Group Chair, Kazuto Yano is Task Group Vice Chair, and Yukimasa Nagai is Task Group Secretary.

III. Wireless coexistence Study in IEEE 802.19.3a

IEEE 802.19.3a will add recommended best practices for better wireless coexistence between IEEE 802.11ah and IEEE 802.15.4g-OFDM PHY systems. Discussion topics have been agreed at IEEE Plenary Meeting in March 2024.

- Analysis such as simulations and/or measurements studies
- Spectrum situation from different locations
- Study and measurement methods
- Regulatory updates for EU/US/JP
- Application and use case information
- Ideas on developing interference models
- Technical requirements and constraints

The use cases and simulation model used in IEEE 802.19.3 can be also used for IEEE 802.19.3a. Details are given in the next section. New conditions to be considered in IEEE 802.19.3a are also described.

IV. Use case and simulation methodology

Figure 1 shows typical coexistence use case of smart utility networks using IEEE 802.15.4g/Wi-SUN and smart home networks using IEEE 802.11ah/Wi-Fi HaLow in the S1G band. In smart utility use case, the HEMS GW (Home Energy Management System Gateway), as an indoor data hub, connects to the appliances using IEEE 802.15.4g. The Smart Meter installed on the wall outside house uses IEEE 802.15.4g to communicate with the DCU (Data Concentrator Unit) to send messages corresponding to electricity usage and demand response. The smart meters which cannot directly communicate with the DCU, communicate with the DCU via neighboring smart meters by the multi-hop (mesh) communication. IEEE 802.15.4g can also be used for other critical infrastructures such as gas, water and storage battery systems. In the smart home use case, IEEE 802.11ah, the basis for Wi-Fi HaLoW, operating in S1G bands, is promising for home automation, smart appliance, healthcare, wearable and content synchronization between home server and vehicles. In addition, the Wi-Fi Router installed in the house can use 2.4/5 GHz bands to connect to smartphones and tablets to communicate with intercoms, surveillance cameras, security sensors and other devices around house. Thus, IEEE 802.15.4g and IEEE 802.11ah are expected to be used in the same area for various IoT applications and devices. These same use case scenarios can be used for IEEE 802.19.3a.

Figure 2 shows our ns-3 based coexistence simulation architecture used by the IEEE 802.19.3 Task Group to evaluate coexistence performance between IEEE 802.15.4g-FSK PHY and IEEE 802.11ah in S1G bands. Both IEEE 802.15.4g and IEEE 802.11ah modules are implemented in one ns-3 simulator. Additional coexistence interfaces and functions in PHY/channel modules are provided to notify "Tx Information (Tx Info)" between the IEEE 802.15.4g module and the IEEE 802.11ah module to calculate mutual interference. Tx info includes transmit timing, device position and Tx power. Each PHY module calculates Frame Error Rate (FER) using Signal to Interference Noise Ratio (SINR) versus Bit Error Rate (BER) in consideration of frame transmissions from the bother system and notifies "Tx Info" to the other channel module. In the channel module of both IEEE 802.15.4g and IEEE 802.11ah, receive power can be calculated with the propagation model considering the channel bandwidth difference, 400 kHz for IEEE 802.15.4g and 1 MHz for IEEE 802.11ah. In our simulations, we use the same center frequency for IEEE 802.15.4g and IEEE 802.11ah channels. For IEEE 802.19.3a standard development, in addition to IEEE 802.15.4g-FSK PHY for IEEE 802.19.3, IEEE 802.15.4g-OFDM PHY will be implemented in IEEE 802.15.4g PHY module.

IEEE 802.19.3 Task Group has defined simulation use cases and scenarios for coexistence evaluation between IEEE 802.11ah and IEEE 802.15.4g [9]. All IEEE 802.11ah STAs and IEEE 802.15.4g nodes are deployed in a 200 m diameter area with density of 500 / km^2. 15 STAs / nodes for each of IEEE 802.11ah network and IEEE 802.15.4g network are accommodated in the area. Figure 3 shows the example of deployment of IEEE 802.11ah and IEEE 802.15.4g for simulation as agreed by the IEEE 802.19.3 Task Group. This same configuration and scenario can be used for IEEE 802.19.3a analysis, with the enhanced PHY modeles.

Table I shows the candidate simulation parameters for use by the IEEE 802.19.3a Task Group. In addition to conventional parameters discussed in IEEE 802.19.3, new features for IEEE 802.15.4g-OFDM PHY and 4 MHz channel bandwidth for IEEE 802.11ah will be evaluated to compare performance with the combination of IEEE 802.11ah (1 MHz PHY) and IEEE 802.15.4g-FSK. OFDM Option 3 MCS4 (300 kbps) and MCS5 (400 kbps) are added for IEEE 802.15.4g-OFDM PHY in consideration of node deployment and transmission range as shown in Figure 3.

V. Conclusion

This paper describes the status and future prospects of the IEEE 802.19.3a Task Group started in March 2024 toward

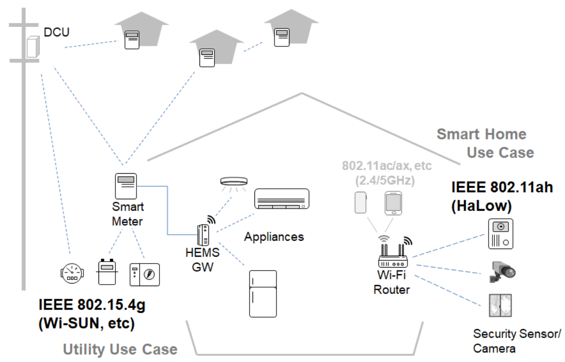

Fig. 1. IoT application coexistence use case of smart utility using IEEE 802.15.4g and smart home using IEEE802.11ah in S1G band [8].

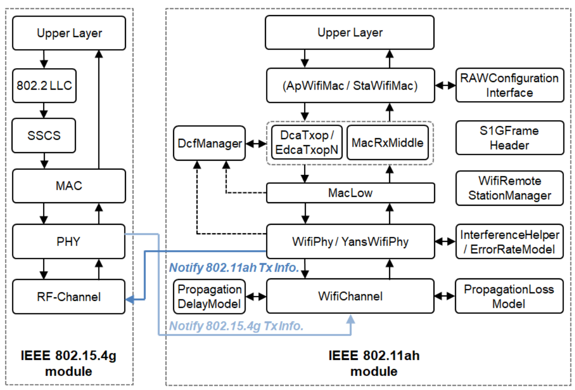

Fig. 2. IEEE 802.11ah and IEEE 802.15.4g coexistence simulation architecture using ns-3 based simulator [8].

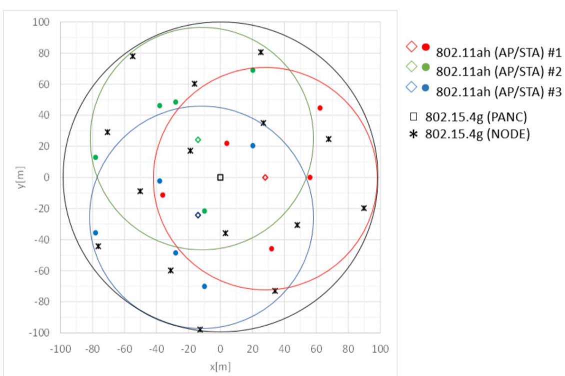

Fig. 3. IEEE 802.11ah and IEEE 802.15.4 node deployment for simulation which discussed in IEEE 802.19.3. [9].

spectrum resource efficiency and higher network performance as an amendment of IEEE 802.19.3-2021 standard. Discussion topics at IEEE 802.19.3a are presented. New features for IEEE 802.15.4g-OFDM PHY and 4 MHz channel bandwidth for IEEE 802.11ah should be evaluated to compare to performance with the combination of IEEE 802.11ah (1 MHz PHY) and IEEE 802.15.4g-FSK PHY. These features are being implemented on our simulator developed for IEEE 802.19.3 standard development. As future works, our group will provide simulation results and measurement results based on use case and simulation parameters that will be agreed in IEEE 802.19.3a Task Group after IEEE 802.19 Plenary Meeting in July 2024.

TABLE I
CANDIDATE SIMULATION PARAMETERS FOR IEEE 802.19.3A

Parameter	Value	Note
Network parameters		
Network offered load	20 - 120 [kbps] @ 1 [MHz] CS 80 - 480 [kbps] @ 4 [MHz] CS	11ah
	20 - 100 [kbps]	15.4
Data packet payload Size	100 [byte]	Both
PHY parameters		
Frequency	920 [MHz]	Both
Tx Power	20 [mW]	Both
Modulation, Data Rate	BPSK 1/2, N_{ss} = 1, 300 kbps @ 1 [MHz] CS 1350 kbps @ 4 [MHz] CS	11ah
	2-FSK, 100 kbps OFDM Option 3 MCS4, 300 kbps OFDM Option 3 MCS5, 400 kbps	15.4
Channel spacing (CS)	1 and 4 [MHz]	11ah
	400 [KHz]	15.4
MAC parameters (IEEE 802.11ah)		
aSlotTime	52 [us]	11ah
aSIFSTime	160 [us]	11ah
aCCATime	$<$ 40 [us]	11ah
aRxTxTurnaroundTime	Less than 5 [us]	11ah
CW (min, max)	15, 1023	11ah
MAC parameters (JJ-300. 10 v2.2, Table 5-28, 5-29) [10]		
LIFS	1000 (for JJ-300.10) [us]	15.4
phyCCADuration	130 [us]	15.4
aTurnaroundTime	1000 [us]	15.4
aUnitBackoffPeriod	300 [us]	15.4
Rx-to-Tx Turnaround time	300 (300 us or more, 1000 us or less) [us]	15.4
Tx-to-Rx Turnaround time	300 (Less than 300 us) [us]	15.4
macMaxBE	5	15.4
macMinBE	3	15.4
macMaxCsmaBackoffs	4	15.4
macMaxFrameRetries	3	15.4

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