IEEE HaLow (802.11ah) Devices: An IOT point-of-view

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Outline

- IEEE 802.11ah – Purpose
- Key Features
- Intersection with IoT world
- What is good and bad
- Take away messages

IEEE 802.11ah: Purpose

- Standard PAR
  - **Frequency**: Operation in license-exempt bands <1 GHz
  - **Range**: A transmission range of up to 1 km
  - **Minimum Data rate**: A minimum data rate of at least 100 kbit/s
  - **Optional**: Support for modes capable of higher speeds (up to several Mbps)
- The need for another IoT device
  - **LoRa & Sigfox**: Extremely low speed (100 bps – 50 Kbps), suitable only for tiny sensor data/packets
  - **Wi-Fi (11abgn):** High speed (up to 600 Mbps) but excessive for most sensors
  - **Intention**: IEEE 802 long-range option device capable of handling substantial and versatile payloads
- Spectrum availability
  - Non-unified WW spectrum
  - Wider selection of operating BWs for country specific regulations
  - Strict spectrum mask adherence as per country specific rules

PHY Features

- Narrow band channels and data rate
  - Standard supports 1 MHz/ 2 MHz/ 4 MHz/ 8 MHz and 16 MHz bandwidths
  - Data rate scales accordingly from 150 Kbps to 347 Mbps
  - Same MCS set as legacy: 0 to 7 and additional 8,9 (256 QAM) and 10 (extended range MCS0 mode)
- 10x downclock version of IEEE 802.11ac
  - 2 MHz channel of 11ah is equivalent to 20 MHz channel of 11ax
- High data rate support
  - Supports upto 4 Spatial streams and data rate doubles or quadruples at short distances from AP
  - Higher QAM MCS support
- Long range support
  - 24.5 dB* pathloss advantage compared to 2.4 GHz devices: >2 Km for MCS10
  - Good wall penetration
  - Channels available WW at various BWs and carriers in 850-950 MHz band

*8.5 dB (FSPL) + 10 dB (10x BW reduction) + 6 dB (1 MHz BW and 2x repetition coding compared to 20 MHz MCS0)

MAC Features

- High MAC efficiency and power save options
  - MAC header compression, TWT and RAW, Extended sleep time counter, U-APSD, WMM-APSD, NDP Paging, etc.
- No need for additional Gateway before data hits the wired infrastructure
- Enhanced security features of Wi-Fi 11ax
- 8191 STA support per AP and seamless handover between bands
- World-wide bands (channels) support

IoT Centric Features

- IEEE framework for infrastructure and security
  - Unlike NB-IoT or LoRA, IEEE 802 network infrastructure does not need expensive infrastructure
  - Standard IEEE Mesh network and WPA3 security supported
  - Amenable to “Clock reduction” implementation on SoC
  - “MLO” support was discussed in the standard-body
  - 8192 STA supported per AP
- Huge advantage on Electromagnetic path-loss and attenuation thru walls
  - Mainly due to lower carrier frequency
  - More channels available due to narrow-band options
  - Wide selection of data-rates depending on the application
- Power save options for enabling long battery life
  - Beacon frequency management
  - WFA certification
  - Media contention and collision management thru paging

IoT Devices: Comparison of features

Criteria	Wi-Fi 11ah	Wi-Fi .11n	LoRa	Sigfox	NB-IOT	BLE / BT5	Z-Wave	ZigBee
Energy Efficiency	High	High	Low	Low	Low	High	Med	Med
Idle Power Consumption	Low	High	Low	Low	Low	Low	Low	Low
Data Rate	150 Kbps - 86.7 Mbps	6.5 Mbps - 600 Mbps	100 bps- 50 Kbps	100 bps - 600 bps	20 Kbps - 25 Kbps	125 kbps - 2 Mbps	100 Kbps	250 Kbps
Range	1 km	100 m	10 km	10 km	10 km	<100 m	30 m	20 m
Material Penetration	Best	Poor	Best	Best	Good	Poor	Good	Poor
Security	Best	Best	Poor	Poor	Good	Good	Good	Good
Network Capacity	Best	Best	Poor	Worst	Poor	Good	Good	Poor
Interoperability	IEEE Std	IEEE Std	Proprietary	Proprietary	3GPP	Bluetooth	Proprietary	IEEE Std
Native IP support	Yes	Yes	None	None	Yes limited	None	None	None

Courtesy: Morse micro

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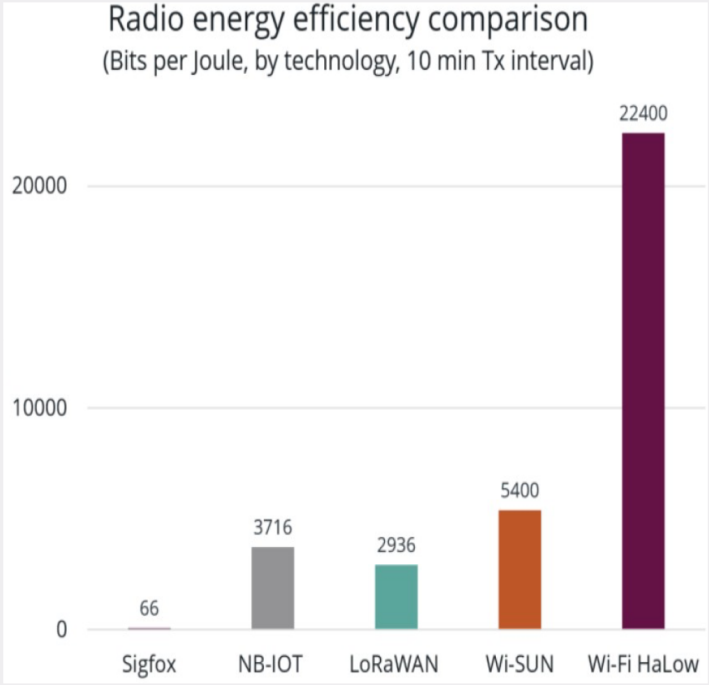
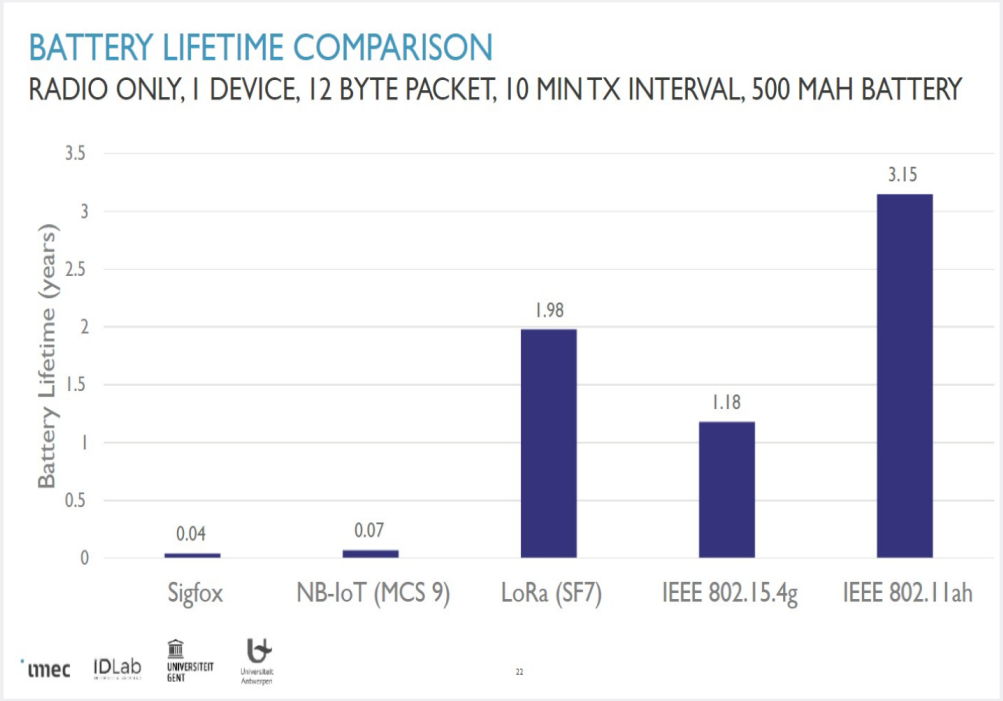
What is good: Comparison of Energy





Wi-Fi HaLow demonstrates at least four times (4x) more energy- efficiency than several other well-known IoT technology options
Source: Wi-Fi Alliance: Wi-Fi HaLow Technology Overview

Wi-Fi HaLow Battery lifetime comparison with several well-known IoT technology options
Source: A study by IMEC Research Group: The Long Life of IoT Devices

Courtesy: Morse micro

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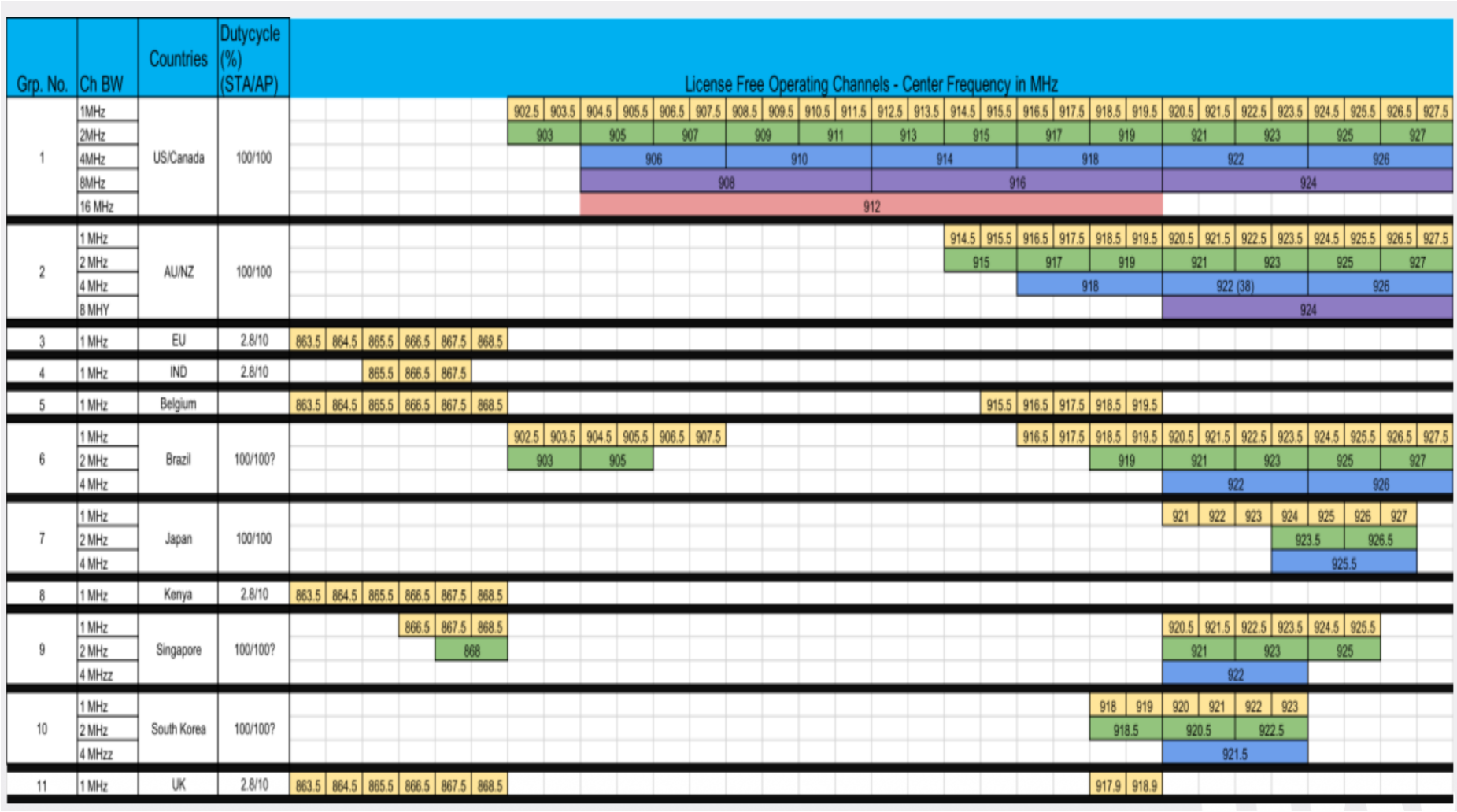
What is good: Power save options

- Short Beacon and Short Frame Header support
  - Some fields are removed in short beacons to improve efficiency. E.g., DA, BSSID, etc.
  - PV1 is short compared to PV0: > 50% reduction in size
- NDP CMAC Frames
  - Reduces the overhead for the control frames (PS-Poll, ACK, etc.)
  - ACK is 0 or 1. Why send it as additional payload?
  - Small Frame Transmission and Expanded NDP Control frame
- Relay Node support - Reduces the interference
  - Relay communicates between AP and STA
- Hierarchical STA organization
  - TIM/AAID is organized as pages, blocks and sub-blocks
- New Power-save Mechanisms
  - Wakeup times are controlled by hierarchical TIM and TWT and RWA
  - TXOP-based and Group-based Sectorization
  - Fast Association and Authentication - CAC and DAC supported

What is good for IoT

- Many field/theoretical measurements show promising results
  - "*WiFi HaLow for Long-Range and Low-Power Internet of Things: System on Chip Development and Performance Evaluation",* IEEE Communications Magazine, July 2021
  - "*Practical evaluation of wi-fi halow performance*" Internet of Things, Vol. 24, 2023
  - "*An Experimental Field Comparison of Wi-Fi HaLow and LoRa for the Smart Grid*", MDPI Sensors, Aug. 2023.
- Good development ecosystems available
  - You can buy modules, AP/STAs in Mouser and reference designs
  - More than one OEM: Quectel, Azurewave, AsiaRF, etc.
  - Two vendors on devices: **Morse Micro** and **Newracom**
  - **Fully integrated SoC with internal PA available with WW Tx mask compliance**
  - Software stack and OS support available from silicon vendors for ease of integration
- WFA certification
- Support for Matter – enables faster application development

What is bad:WW Spectrum Allocations



Grp. No.	Ch BW	Countries	Dutycycle (%) (STA/AP)	License Free Operating Channels - Center Frequency in MHz
1	1MHz	US/Canada	100/100	902.5 903.5 904.5 905.5 906.5 907.5 908.5 909.5 910.5 911.5 912.5 913.5 914.5 915.5 916.5 917.5 918.5 919.5 920.5 921.5 922.5 923.5 924.5 925.5 926.5 927.5
	2MHz			903 905 907 909 911 913 915 917 919 921 923 925 927
	4MHz			906 910 914 918 922 926
	8MHz			908 916 924
	16 MHz			912
2	1 MHz	AU/NZ	100/100	914.5 915.5 916.5 917.5 918.5 919.5 920.5 921.5 922.5 923.5 924.5 925.5 926.5 927.5
	2 MHz			915 917 919 921 923 925 927
	4 MHz			918 922 (38) 926
	8 MHY			924
3	1 MHz	EU	2.8/10	863.5 864.5 865.5 866.5 867.5 868.5
4	1 MHz	IND	2.8/10	865.5 866.5 867.5
5	1 MHz	Belgium		863.5 864.5 865.5 866.5 867.5 868.5 915.5 916.5 917.5 918.5 919.5
6	1 MHz	Brazil	100/100?	902.5 903.5 904.5 905.5 906.5 907.5 916.5 917.5 918.5 919.5 920.5 921.5 922.5 923.5 924.5 925.5 926.5 927.5
	2 MHz			903 905 919 921 923 925 927
	4 MHz			922 926
7	1 MHz	Japan	100/100	921 922 923 924 925 926 927
	2 MHz			923.5 926.5
	4 MHz			925.5
8	1 MHz	Kenya	2.8/10	863.5 864.5 865.5 866.5 867.5 868.5
9	1 MHz	Singapore	100/100?	866.5 867.5 868.5 920.5 921.5 922.5 923.5 924.5 925.5
	2 MHz			868 921 923 925
	4 MHzz			922
10	1 MHz	South Korea	100/100?	918 919 920 921 922 923
	2 MHz			918.5 920.5 922.5
	4 MHzz			921.5
11	1 MHz	UK	2.8/10	863.5 864.5 865.5 866.5 867.5 868.5 917.9 918.9

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What it means for India/EU IoT market

- **11ah [India, EU]:** For digital transmissions with occupied bandwidth (OBW) between 600K and 1 MHz, the maximum allowed Tx Power is limited to 25 mW (+14 dBm) [Ref: EN 304-220]
  - There is a <10% duty cycle limit for an AP device and <2.8% duty cycle limit for a STA device [Ref: India GSR. 853 (E) dated 10-Dec-2021]
- **LoRa [India, EU]** Though being a low bandwidth device with OBW of 125 KHz, upto 25mW Tx power is only permitted
  - <0.1% duty cycle limit applies in EU [EN 300-220]
  - 10% duty cycle limit applies for AP and upto 2.5% limit applies for STA [India GSR. 853 (E) dated 10-Dec-2021]
- Number of bytes that can be transferred in 1 sec for 11ah with 2.8% duty cycle is >100 Kbps (STS=1)
  - Tens of voice channels and several sensor data can be transferred even with this restriction
  - With 25 mW (14 dBm) Tx power restriction, the range can be lower
    - But, for the same Tx power LoRA can send only few tens of bps compared to 100 Kbps for 11ah
- These data rates are good enough for many IoT applications, if not for live camera feed
- Is there a need for (Fragmented) HaLow infrastructure market?
  - Need for company which provides the standard deployment models for sensor market (like TATA comm. experimented on LoRA few years ago)
  - It is lot easier for HaLow mesh network deployment, but field experimentation for india/EU terrain pending
  - Govt. regulatory approvals

Feasible End Applications

- **Home automation**
  - Replacement for ZigBee, BLE, etc.
  - Multi-floor coverage is feasible
- **Utility meter reading**
  - Over the curb mobile-AP or collecting data device is feasible
- **Agri automation**
  - Low cost infra is easy to deploy over hundreds of acres
  - Cattle movement sensing and tracking
- **Disaster recovery network** when cellular infra is down
  - Easy to setup mesh on the fly
- Building basement safety and security and parking automation
  - Integrates well with standard 802 networks
- Industry automation
  - Small scale industry is viable

Thank you

Questions?

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At MMRFIC, we believe communication drives the world forward. Our team leverages hi-tech semiconductor technologies to engineer advanced radio frequency systems for critical mission control, high-performance operations, and beyond. Providing support from conception to prototype, we help clients push communication boundaries.

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IOT Devices: Comparison of Protocol Features

- Desirable IoT device features
  - Range, Long battery life, scalability
  - Latency, paging, data rate
  - Co-existence, Security

Standard	Group-ing	Relay	Long range	Scalabi-lity	Polling	Less con-tention	ISM band	Distributed	Heterog-eneity	Coexist-ence	High through-put	Low latency	NDP frame
802.15.4	✓	✓	✗	✗	✓	✗	✓	✗	✗	✗	✗	✗	✗
802.11ah	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓
NB-IoT	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✗
LoRa	✓	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✓	✗
SigFox	✓	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✓	✗
RFID	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✓	✗

Ref: N. Ahmed, et al, “MAC Protocols for IEEE 802.11ah-based Internet of Things: A Survey ”,IEEE Internet of Things Journal, Aug. 2021

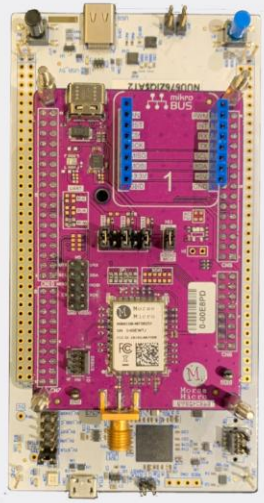
Morse Micro Platforms

WI-FI HALOW HARDWARE PLATFORMS

Platforms at a glance

MM6108-EKH01

Wi-Fi HaLow RPi-Hat + RPi + Enclosure



MM6108-EKH08-01

Wi-Fi HaLow Shield + STMicro STM32WB55RG

MM6108-EKH04

Wi-Fi HaLow Router / USB Adapter / Ethernet Adapter

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Software Stack and OS Support

WI-FI HALOW SOFTWARE PLATFORMS

Software Support

AP Platforms (EKH01 & EKH04):

- OS Support
  - Linux (RPi4B)
  - OpenWRT (Mediatek)
  - Full compliance with WFA-HaLow
- Features
  - Native Linux cfg80211/mac80211
  - Various modes of operation
    - AP & STA modes
    - Extender / Router
    - Bridge (AP/STA)
  - WMM
  - WPA3-SAE (PMF) & OWE
  - DPP - Device Provisioning Protocol
  - TWT - Target Wakeup Time
  - RAW - Restricted Access Window
  - WFA Easy-Mesh and 802.11s Mesh
  - IBSS (Ad-Hoc) with BATMAN
  - CAC (Centralized Auth Control)

STA Platform (EKH08):

- OS Support
  - FreeRTOS (STM32 MCU)
  - Full compliance with WFA-HaLow
- Features
  - LWIP support (IPv6, IPv4, TCP/UDP)
  - WMM
  - WPA3-SAE (PMF) & OWE
  - RAW - Restricted Access Window
  - BSS Colour
  - Proprietary Power Save Extensions
  - TIM Segmentation
  - S1G Rate Control