
IEEE 802.11 standard and ongoing standards development

Thank you for the opportunity to present

IEEE 802/802.11 overview

IEEE 802.11 Current and new work areas

Use cases, WFA acknowledgement



2024 April

Presenter: Dorothy Stanley, Immediate past IEEE 802.11 Working Group Chair

Affiliation: HPE Aruba Networks

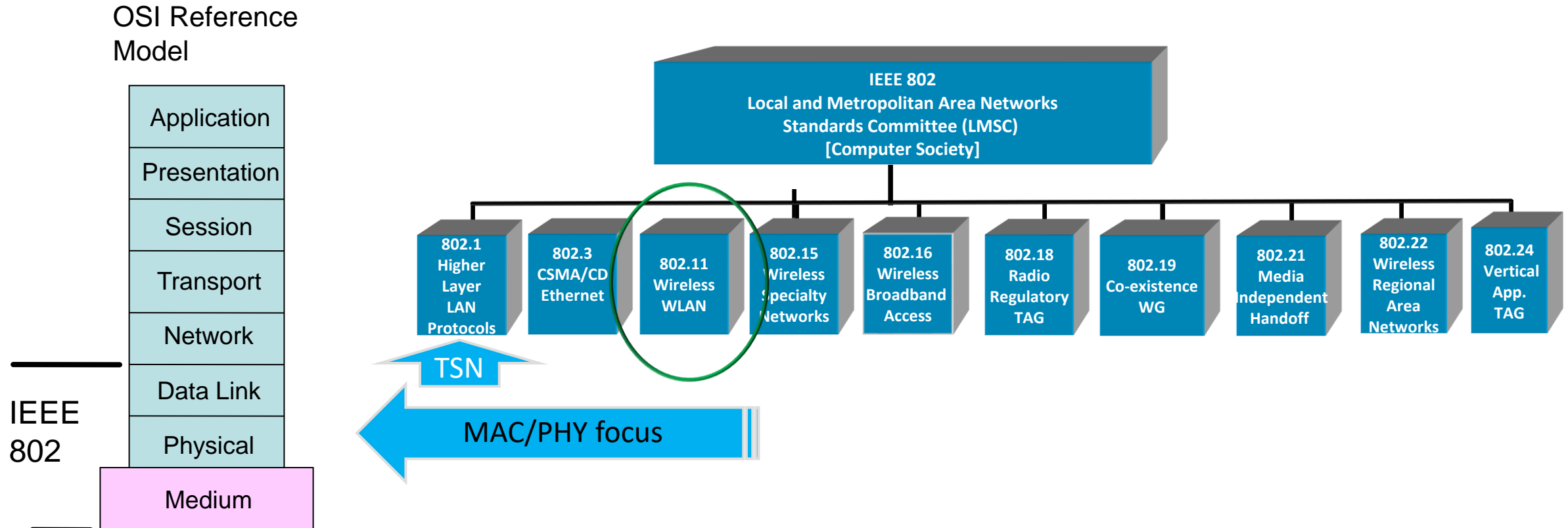
“At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.” IEEE-SA Standards Board Operation Manual (subclause 5.9.3)

2024 April Wi-Fi Now Conference

April 2024

IEEE 802 LAN/MAN Standards Committee standard development covers both Wireless & Wired Media

- Focus on **link and physical layers** of the network stack
- Leverage IETF protocols for upper layers



200+ IEEE Working Groups Developing NEW Standards

Very Broad technical coverage



IEEE Computer Society

- Artificial Intelligence Standards
- Blockchain and Distributed Ledger Standards
- Cloud Computing Standards
- Cybersecurity & Privacy Standards
- Data Compression Standards
- Design Automation Standards
- Functional Safety Standards
- Knowledge Engineering Standards
- **LAN/MAN (IEEE 802™) Standards**
- Learning Technology Standards
- Microprocessor Standards
- Online Gaming Standards
- Simulation Interoperability Standards Organization SAC
- Smart Manufacturing Standards
- Standards Activities Board
- Software & Systems Engineering Standards
- Test Technology Standards

In progress: New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies

P802.11be – Extremely High Throughput in 2.4, 5 and 6 GHz bands, aka Wi-Fi 7

P802.11bf – WLAN Sensing

P802.11bh – Randomized MAC Addresses

P802.11bi – Enhanced Data Privacy

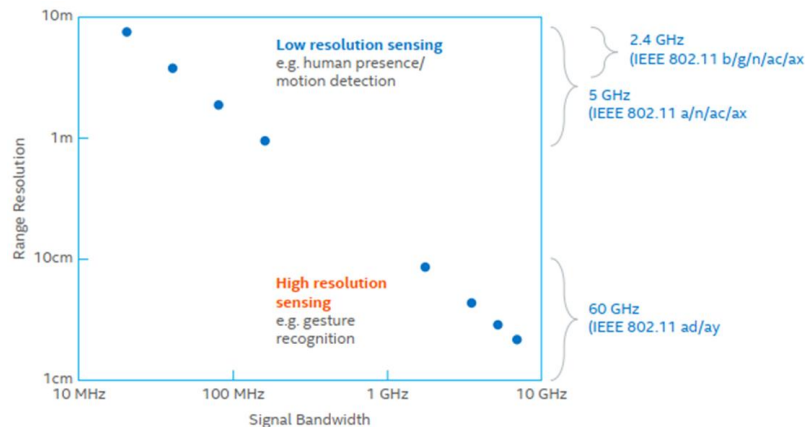
P802.11bk – 320 MHz Ranging

P802.11bn – Ultra High Reliability

NEW → P802.11bp – Ambient Power Communication

802.11be (est 2024)
Wi-Fi 7

- **2.4GHz, 5GHz and 6GHz supported**
- Wider channels (40, 80, 160, 240, **320MHz**)
- Better modulation (**4096-QAM**)
- Backward compatibility with 11a/b/g/n/ac/ax
- Standard targets throughput minimum of 30Gbps, expect 40Gbps+



P802.11be features support increased throughput and performance

Throughput and spectral efficiency

- 320 MHz bandwidth operation
- 16 Spatial Streams and 4096-QAM (Quadrature Amplitude Modulation)
- Multi-band/multi-channel aggregation and operation (MLO)
- Multiple Resource Unit Operation (MRU)
- MIMO protocol enhancements, Enhanced Sounding protocol

Low latency

- Multi-band/multi-channel aggregation and operation (MLO)
- Target Wait Time (TWT) enhancements and Restricted-TWT
- TXOP Sharing
- Stream Classification Service Enhancements
- National Security and Emergency Preparedness (NSEP) priority access operation

Enhancements re: 6 GHz support

- Static Puncturing to avoid pre-defined 20 MHz subchannels, supports efficient, higher bandwidth 6GHz operation
- GCMP-256 support (High performance cipher)

In IEEE 802.11: P802.11be D5.0 completed SA Ballot, expect final 2024 Dec

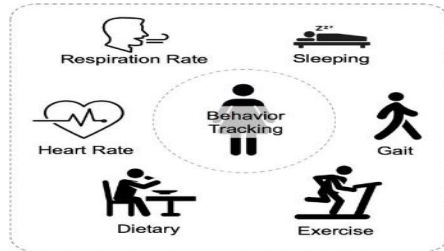
WFA Wi-Fi 7 Certification available
Numerous products in the market

Use Cases:

- Home, enterprise, industrial, IoT
- Outdoor
- AR/VR
- 4K and 8K video streaming
- Remote office
- Cloud computing
- Video calling and conferencing

802.11bf WLAN sensing

- **WLAN sensing is the use of received WLAN signals to detect features of an intended target in a given environment.**
 - Measure range, velocity, angular, motion, presence or proximity
 - Detect objects, people, animals: Enables touchless applications
 - Use in room, house, car, enterprise environments
- **Target frequency bands are between 1 GHz and 7.125 GHz (MAC Service interface) and above 45 GHz (MAC/PHY)**
- **Some use cases**



<https://www.cse.ust.hk/~qianzh/research/sensing-2.jpg>

Smart home



<https://www.pressebox.com/pressrelease/gb-pronova-gmbh/HoloPro-and-the-magic-of-interactive-control/boxid/129647#>

Gesture recognition



http://4.bp.blogspot.com/-_krIHPdn-8/T02hSBvOnI/AAAAAAAAA1A/jAufr2N8k4c/s1600/Kinect%2BGames.jpg

Gaming control



<https://www.lastampa.it/tecnologia/news/2018/06/27/news/router-google-wifi-internet-senza-fili-in-ogni-angolo-della-casa-1.34027426>

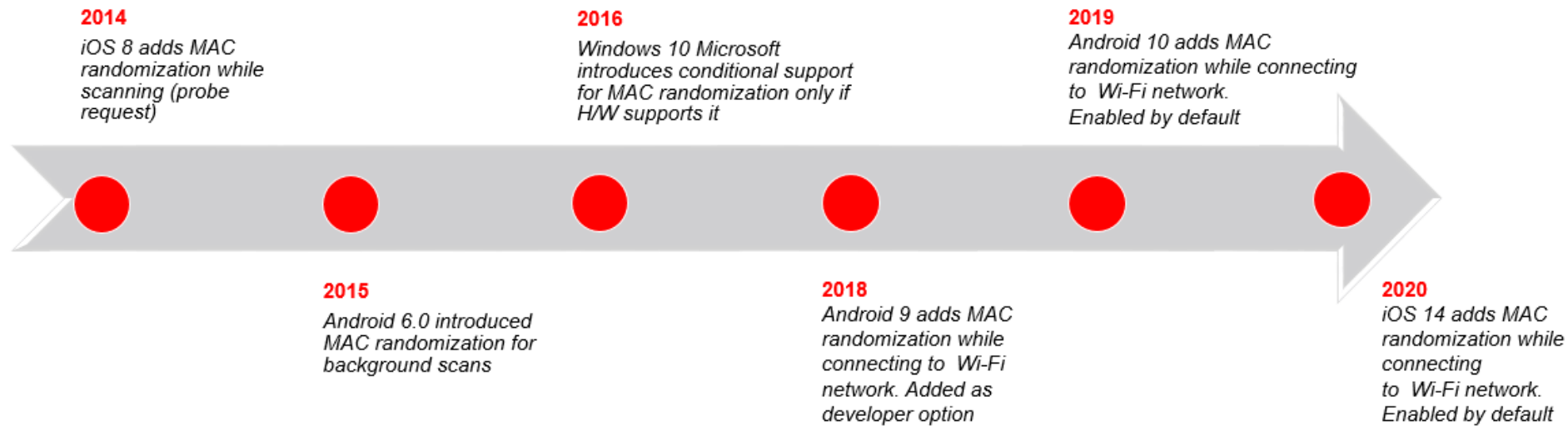
Presence and proximity detection
(Home/Enterprise/Vehicle)

- Note: The specification of applications that make use of WLAN sensing measurements is beyond the scope of P802.11bf.

802.11bh Randomized and Changing MAC addresses (RCM)

A MAC address is a physical hardware identifier that is assigned by the hardware manufacturer to a network device (Ethernet, Wireless, and Bluetooth as examples)

To protect user privacy, there is a growing trend to randomize the client device's MAC address, which can otherwise be "snooped" by third-parties and used to track the user's movements and potentially actions.



- ❖ MAC address randomization can undermine the network's ability to steer the device to the best connection point, or to recognize the device and provide differentiated access in secure environments, pay-for-bandwidth scenarios, etc.

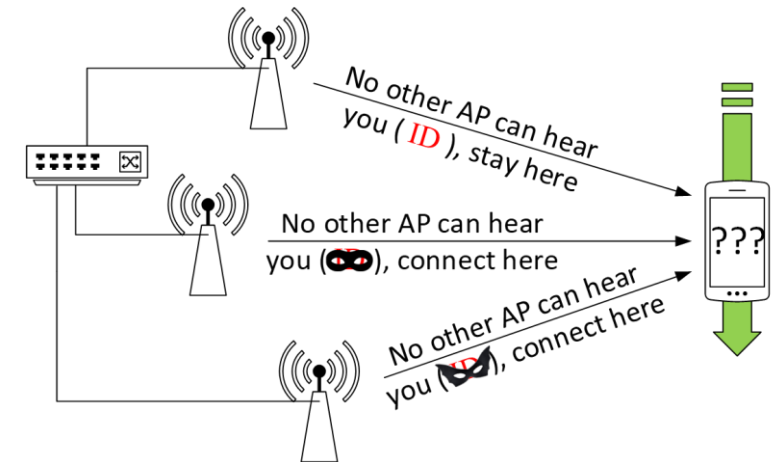
802.11bh Randomized and Changing MAC addresses (RCM)

Impacted use cases include

- Steering a client device to the best connection point
- Recognizing the device, to provide personalized home automation
- Access to pay services, or differentiated levels of service
- Customer support and troubleshooting

- **Draft P802.11bh provides for an optional device identifier* (network defined) and random MAC Address** (STA provided) to enable the network to recognize the STA while providing protection against third party tracking or traffic analysis**
- Identifier is assigned by network to STA
- Network owns ID space, decides on format of ID
- Different networks can use different IDs as they wish
- To the STA, it's just a blob
- STA obtains a blob on first association
- 4way HS updates and produces a new blob that the STA uses on a subsequent association
- STA can "opt out" by just throwing away the blob and getting a new one on the next association if it wants to stop being tracked

Client Steering Use Case



* See <https://mentor.ieee.org/802.11/dcn/22/11-22-0154-00-00bh-opaque-device-id.pptx>

** See <https://mentor.ieee.org/802.11/dcn/23/11-23-0421-01-00bh-irm-proposal.pptx>

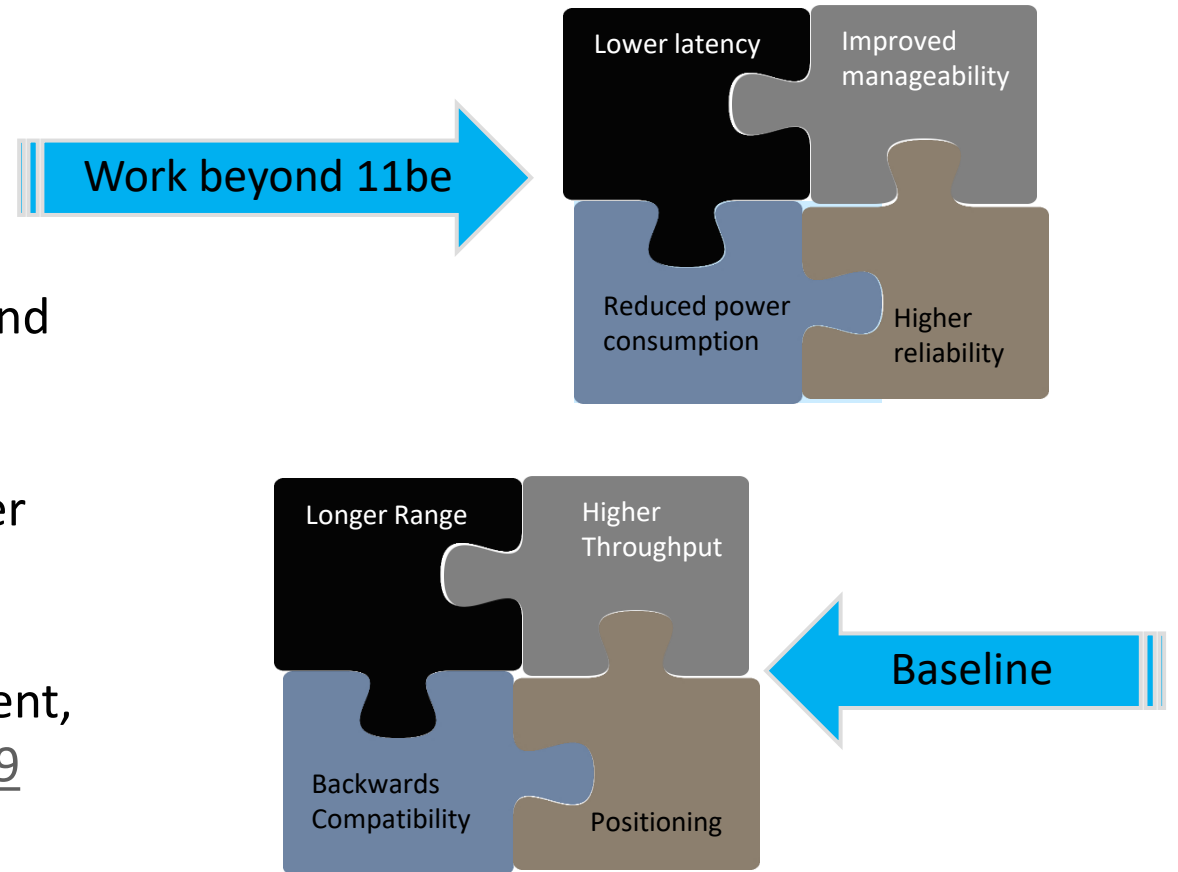
P802.11bn: Ultra High Reliability Task Group was approved in Sept 2023

Define technology to

improve reliability of WLAN connectivity,
reduce latencies,
increase manageability,
increase throughput including at different SNR levels, and
reduce device level power consumption

The Task Group for P802.11bn began work in November 2023

Specification Framework document is under development, see <https://mentor.ieee.org/802.11/dcn/24/11-24-0209>



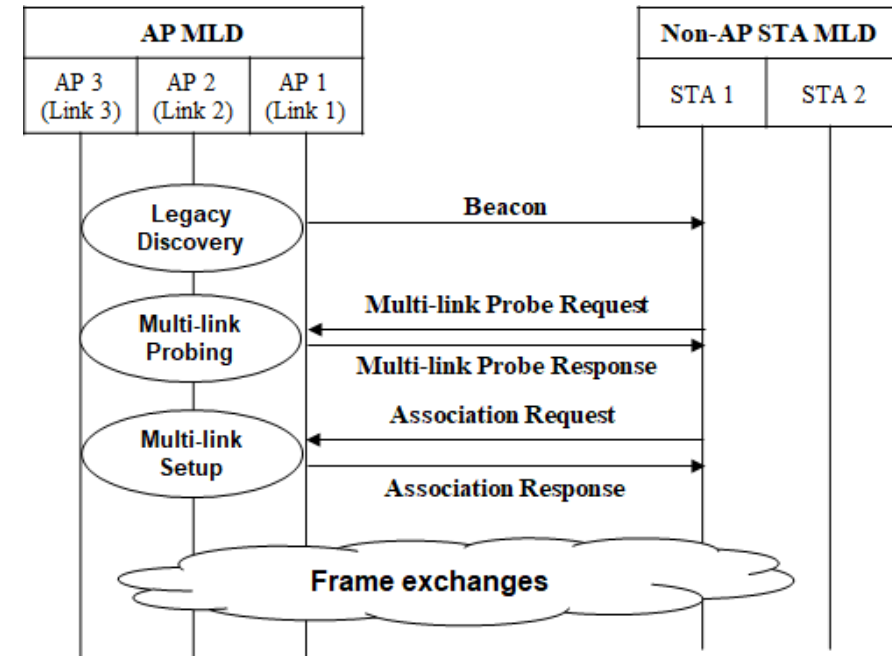
IMMW SG: Integrated Millimeter Wave Study Group

Study Group is developing a proposal for a new amendment
Began work in November 2023

Objective: Simplified integration of mmWave (42-71 GHz) links
with operation in the lower bands

Support very high bandwidth, dense deployment use cases
Address range, mobility and link robustness issues, provide
Coexistence with mmWave operation defined in 802.11ad,
802.11ay

Potential extension and re-use of 802.11be Multi-Link
Operation (MLO) provides efficient discovery, association,
authentication mechanisms



See <https://mentor.ieee.org/802.11/dcn/23/11-23-1905-00-immw-high-level-thoughts-on-immw.pptx>
<https://mentor.ieee.org/802.11/dcn/24/11-24-0459-00-immw-multi-link-operation-for-immw.pptx> and
<https://mentor.ieee.org/802.11/dcn/24/11-24-0116-02-immw-immw-draft-proposed-par.docx>

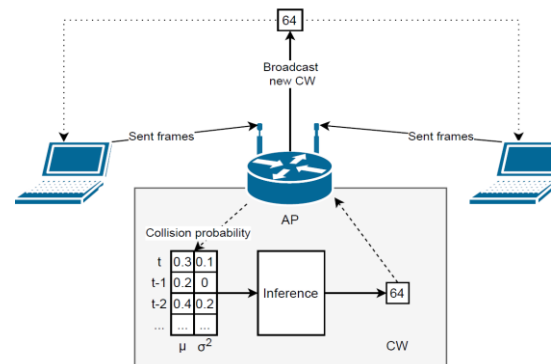
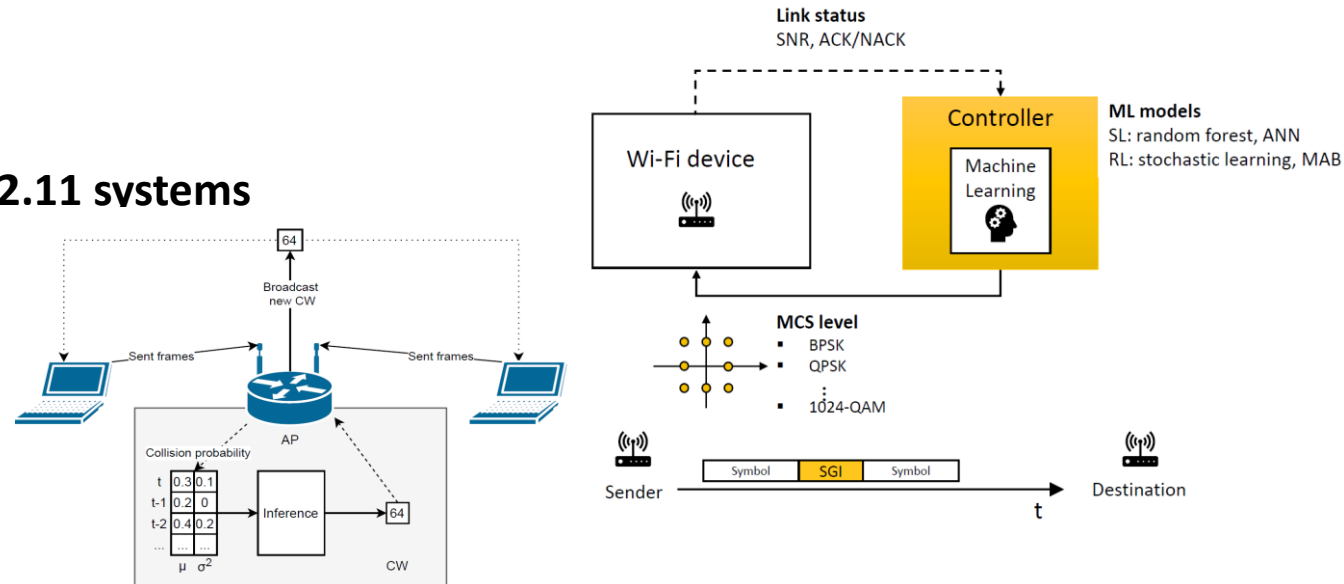
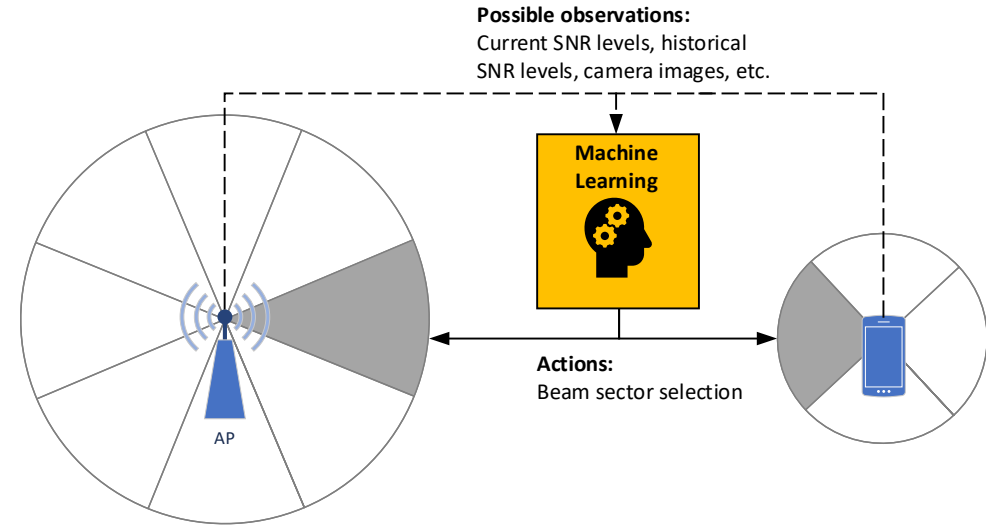
AIML Standing Committee: Investigate WLAN support of Artificial Intelligence/ Machine Learning

Use of AIML for 802.11 applications is an active area of work in the research community. See [Applying ML to 802.11: Current Research and Emerging Use Cases](#) and [Current Report](#)

Current applications focus on performance improvement parameter selection for channel access control and link adaptation, multi-user parameters, contention window sizes, channel usage, improved BSS transition

Work underway:

- Describe use cases for AI/ML applicability in 802.11 systems
- Investigate the technical feasibility of features enabling support of AI/ML.

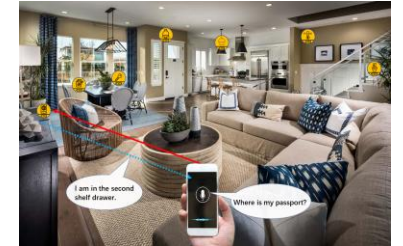


P802.11bp: Develop an 802.11 amendment for WLAN support of Ambient Power Communication

Research into ambient power (energy harvesting) and prototype development has been ongoing using 802.11 based devices

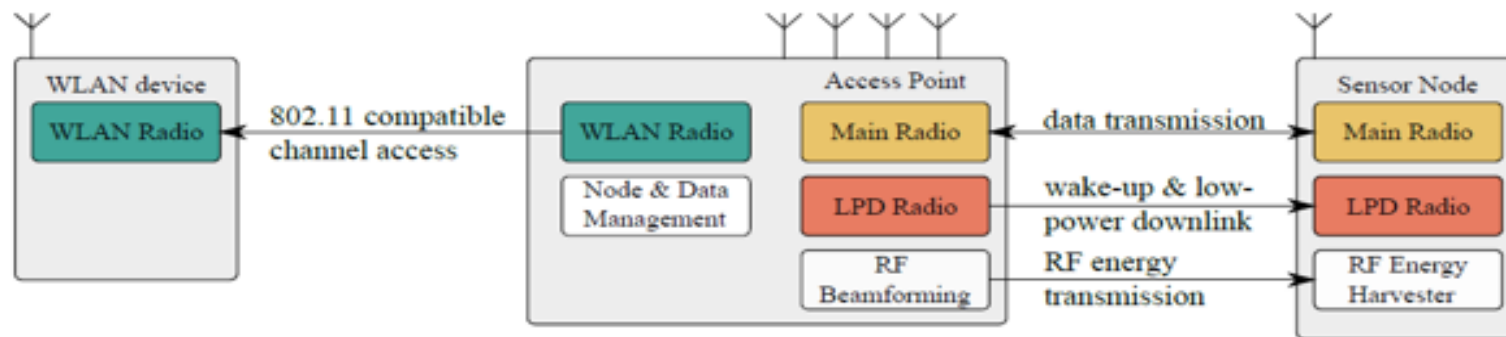
Optimizing M2M Energy Efficiency in IEEE 802.11ah, IEEE GLOBECOM 2015

“the battery dependency of an 802.11ah sensor is significantly lowered by energy harvesting provided that the sensor size and energy harvesting efficiency are sufficient for the utilized ambient energy source.”



Low-Power Downlink for the Internet of Things using IEEE 802.11-compliant Wake-Up Receivers, IEEE INFOCOM 2021

Use Cases include Smart Home, Logistics/Warehouse/Inventory, Industrial Wireless Sensor Networks



See <https://mentor.ieee.org/802.11/dcn/23/11-23-2203-01-0amp-updated-technical-report-on-support-of-amp-iot-devices-in-wlan.docx>

Completed: Meet expanding market needs and leverage new technologies



802.11az – 2nd generation positioning features (Published 2023)

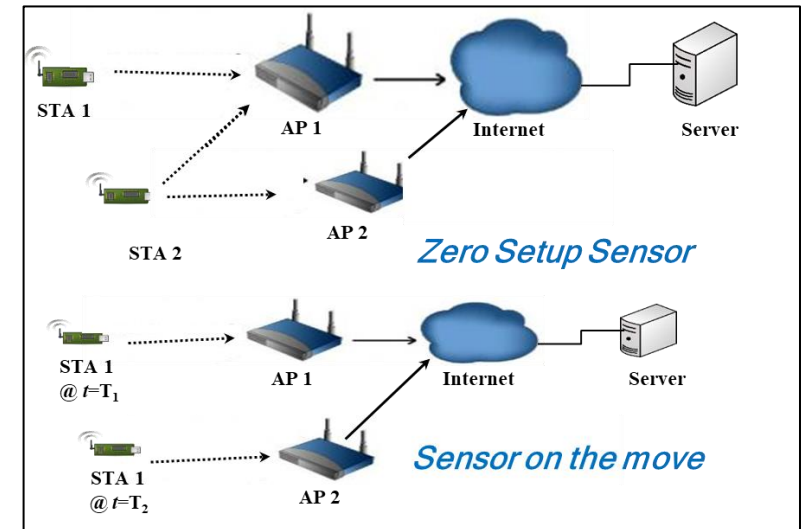
802.11bb – Light Communications (Published 2023)

802.11bc – Enhanced Broadcast Service (2024 publication)

802.11bd – Enhancements for Next Generation V2X (Published 2023)

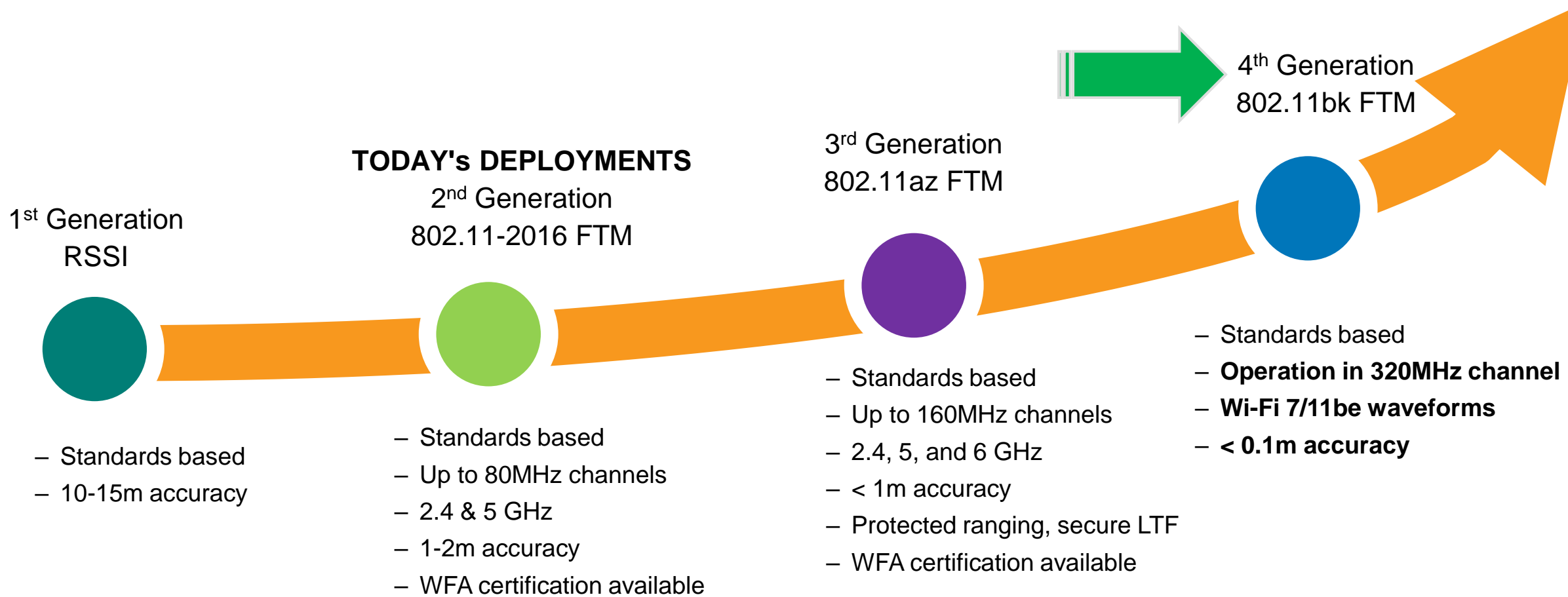
See IEEE Webinar re: 802.11bb, 802.11bc

See Wi-Fi Now tutorial on 802.11az

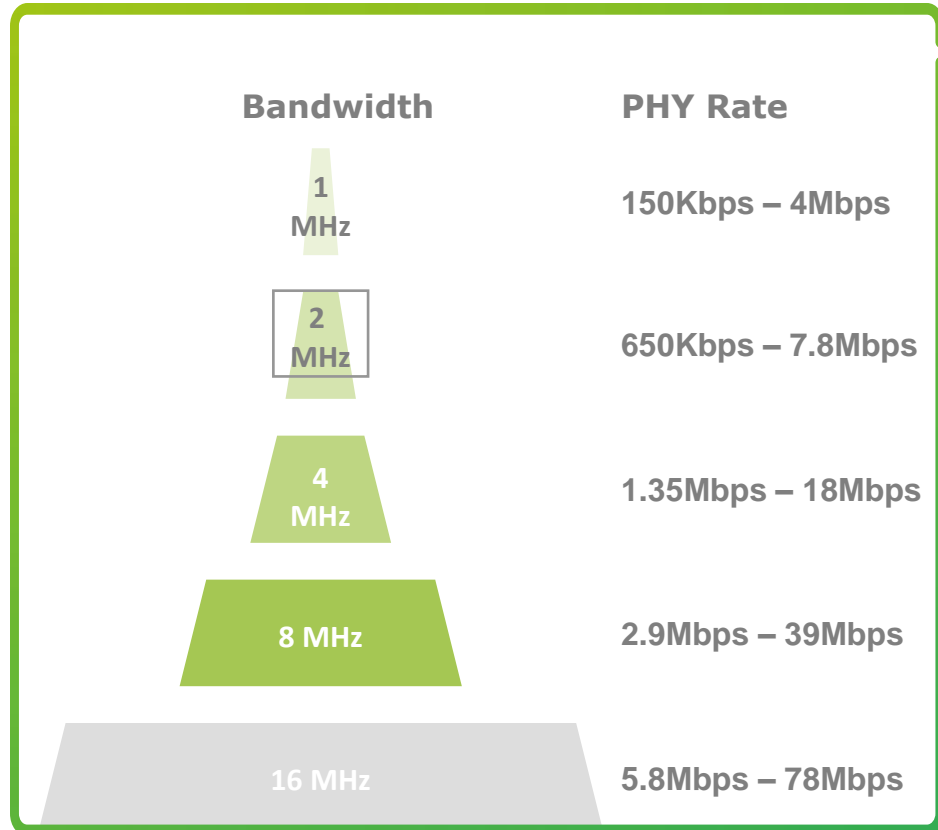


The Evolution of Wi-Fi Location-based Services

Each generation enables greater accuracy



Completed: IEEE Std 802.11ah-2016 enables Wi-Fi for M2M and IoT applications with products now coming to market



Long range indoor/outdoor connectivity up to 1 km
Robust connections for superior penetration through walls and other obstacles in home and industrial environments

Low power consumption for multi-year battery operation
Bidirectional monitoring and control of IoT client devices enable over the air software updates

Moderate data rates **support IETF TCP/IP, discovery protocols**

WFA **Wi-Fi Certified HaLow** certification program

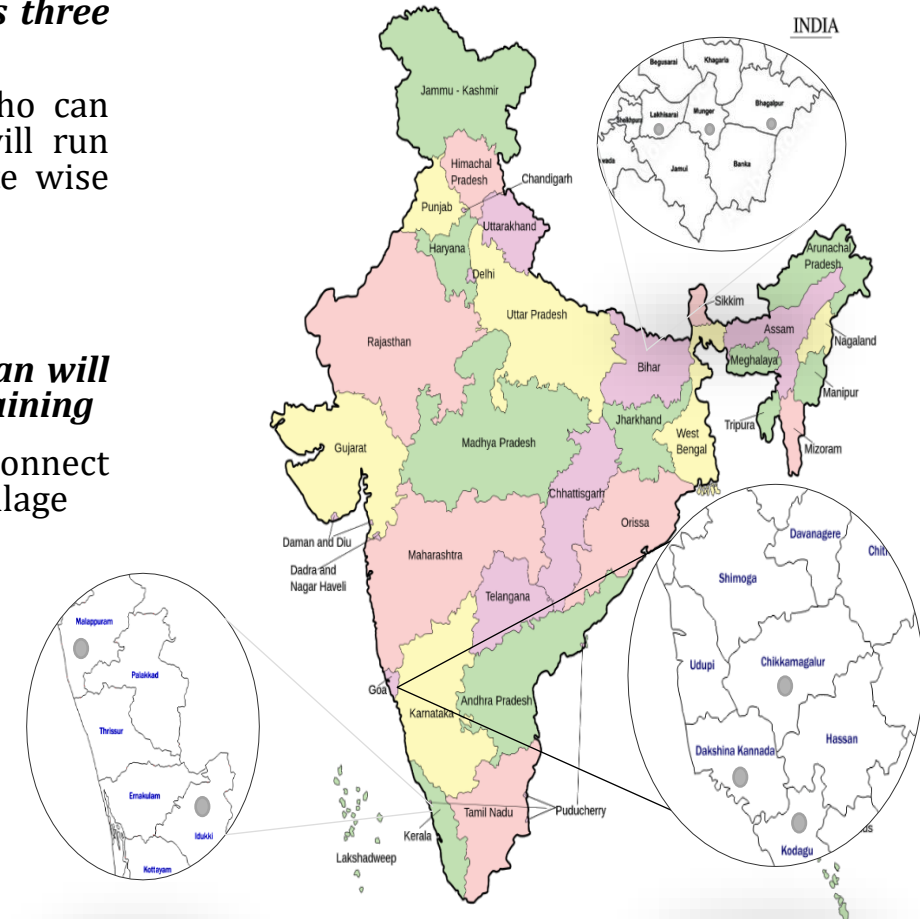
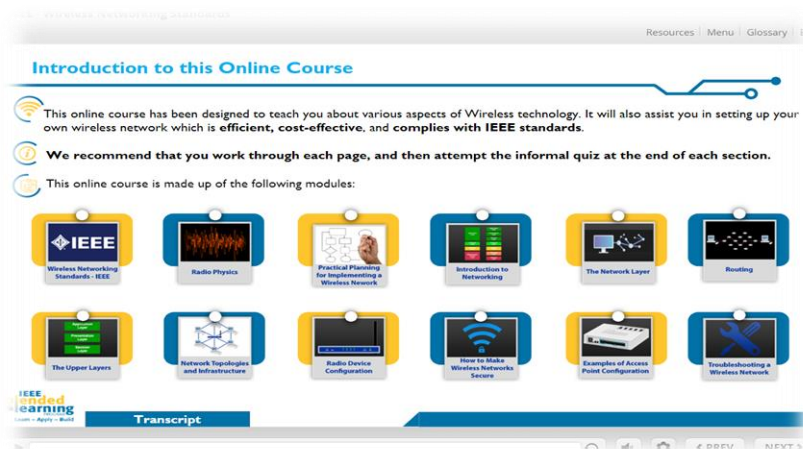
Japan: **802.11ah Promotion Council**

New market entrants emerged to develop the technology

<https://www.wi-fi.org/signal/episode-47-wi-fi-halow-empowers-iot-connections-with-kevin-daly-and-david-halasz-of-morse>

IEEE 802.11 based products are an essential component for connecting the unconnected: IEEE & ISOC Initiative for Building Wireless Community Networks (BWCN)

- **Use cases: Hotspot access, Community Wi-Fi using satellite, optical for backhaul**
- **Installation of the internet in 200 villages and Installation of 100 digital class across three states (Karnataka, Kerala and Bihar)**
 - Internet: will be provided to schools in the villages through service provider who can provide last mile connectivity Digital classroom : 65-inch touch screen which will run through Android and Windows, prefilled with global level syllabus and later state wise syllabus is installed in partnership with state government
- **BWCN course will be translated to 5 languages to benefit more people**
- **250 VLEs / VLTs (Village Level Technicians / Entrepreneurs) and 500+ junior technician will be trained extensively and the BWCN course, BLP platform will be used to deliver the training**
 - Entrepreneurs are trained to deploy, repair, troubleshoot internet so that they can reconnect internet service with the help of service provider after any disaster situation in the village



IEEE 802.11 Working Group Standards development and Wi-Fi Alliance Interoperability Certification ecosystem enable a robust market ecosystem

Wi-Fi Alliance: a 25-year success story

Interoperability Certification

Market Advocacy

Regulatory Advocacy

Podcast Series: <https://www.wi-fi.org/signal>

Blog Series: <https://www.wi-fi.org/beacon>

<https://www.wi-fi.org/beacon/the-beacon/wi-fi-by-the-numbers-technology-momentum-in-2023>www.wi-fi.org/beacon

Wi-Fi Alliance® surpasses 80,000 certifications

Austin, Texas and Prague, Czech Republic – October 17, 2023 – Wi-Fi Alliance® has surpassed 80,000 certified products, bringing a momentous number of high-quality, **Wi-Fi CERTIFIED™** devices to users worldwide.

Wi-Fi CERTIFIED helps ensure products meet high standards for interoperability and security. Achieving this milestone comes at a time of incredible momentum for the Wi-Fi® industry, including the addition of **new Wi-Fi CERTIFIED 6E testing** to support authorization of 6 GHz standard power devices and Wi-Fi 7 certification coming in the first quarter of 2024. Wi-Fi products can be certified for core functionality like the various Wi-Fi generations, and different applications such as **multiple access point Wi-Fi systems** and **seamless connectivity experiences** while mobile. Certifying a product through Wi-Fi Alliance demonstrates a company is committed to providing the highest quality devices and bringing the best experience for their customers.



Wi-Fi CERTIFIED products offer benefits across the Wi-Fi ecosystem. Certified interoperability supports lower return rates, reduced support costs, higher customer satisfaction, and increased sales volumes. Retailers and service providers request Wi-Fi CERTIFIED products to offer customers high quality, secure devices that deliver good user experiences.

Learn more about the value of Wi-Fi CERTIFIED in our **video** or visit www.wi-fi.org/certification for more information.

About Wi-Fi Alliance® | www.wi-fi.org

THANK YOU

QUESTIONS

Wi-Fi connects vehicles and international infrastructure in space

NASA astronauts install the ninth Wi-Fi® access point outside Space Station

December 1, 2022 by Chatwin Lansdowne

This access point (AP) is the first to be installed on the International Space Station's port truss.

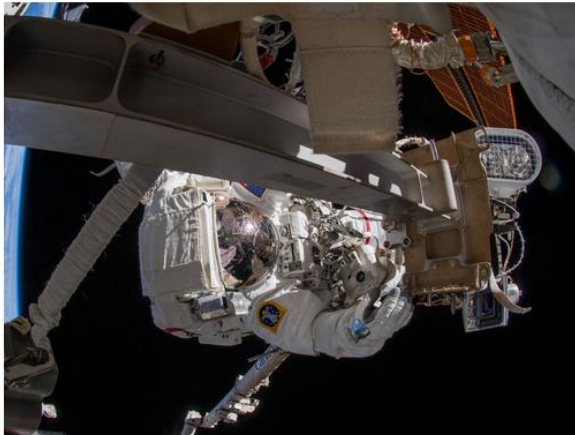


Figure 1: NASA astronaut Raja Chari connects an Ethernet cable to a wireless high-definition camera assembly on the main truss of the International Space Station, converting it to operate as a Wi-Fi access point. (Source: NASA)

During a seven-hour spacewalk on **March 23, 2022**, NASA astronaut **Raja Chari** and ESA astronaut **Matthias Maurer** installed a Wi-Fi CERTIFIED™ access point (AP) on the port side of the International Space Station's main truss. The access point is the first to be sited on the port truss, and from this vantage, the newest AP provides not only a great camera view but also an open Wi-Fi® line-of-sight for the port side of the Russian segment and the **Japanese Experiment Module External Facility (JEM-EF) experiment porch**. The station's solar panels partially block radio signals but the new access point is close enough to penetrate the port solar panels enough to reach the worksite where **astronauts recently installed additional panels (iROSA)**.

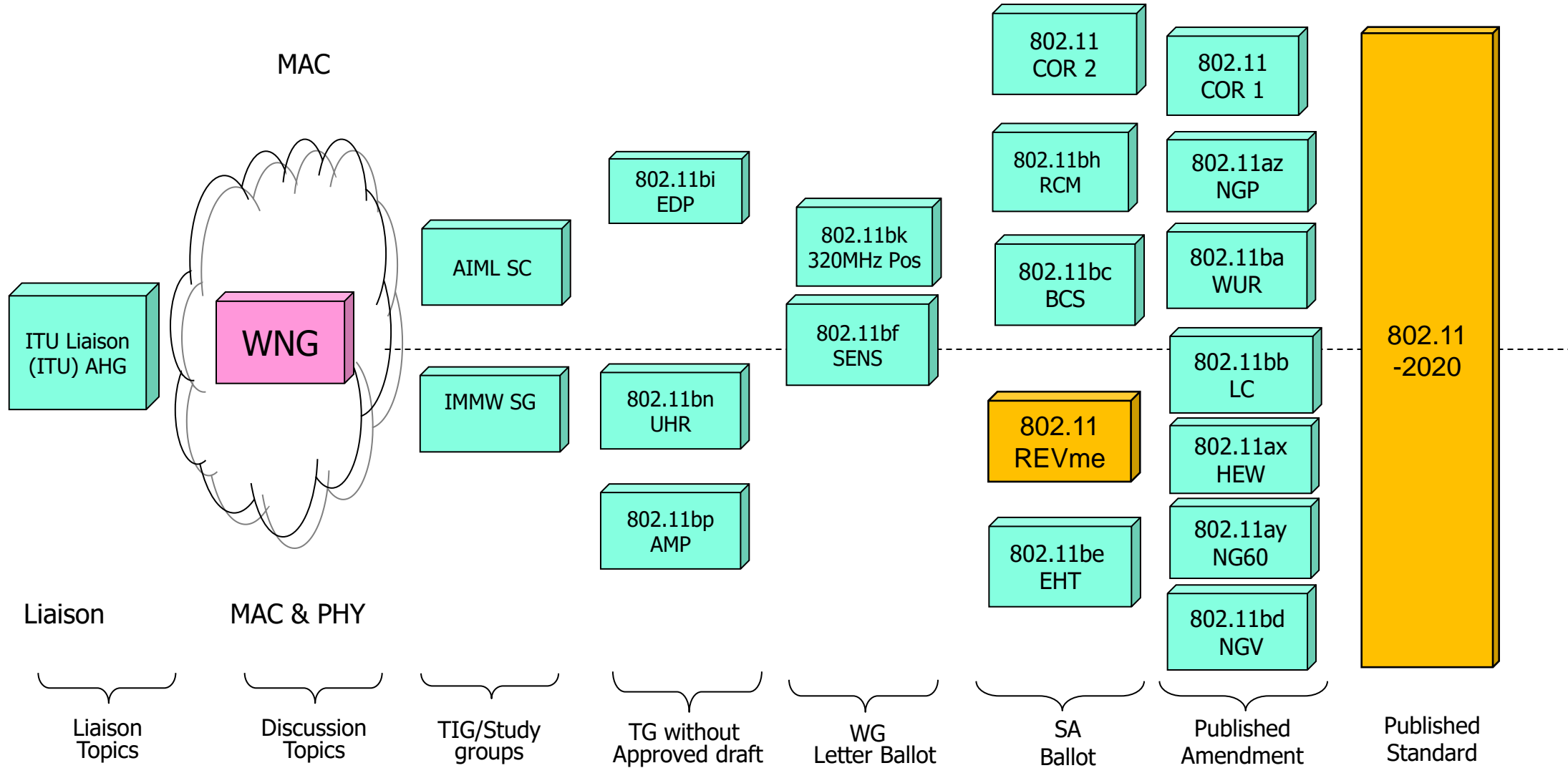
Wi-Fi in Space: Wi-Fi enables next generation space exploration, 9th Access Point Installed. Plans for Artemis/moon.

“The first Wi-Fi network in space was installed in January 2008 using Wi-Fi 4, the IEEE 802.11n standard.”

“In May 2020, Wi-Fi connected vehicles in space for the first time when the Japanese HTV-9 cargo transfer vehicle—operated by the Japan Aerospace Exploration Agency(JAXA)—demonstrated a high-definition, live video streaming application using Wi-Fi during its final approach to the Space Station.

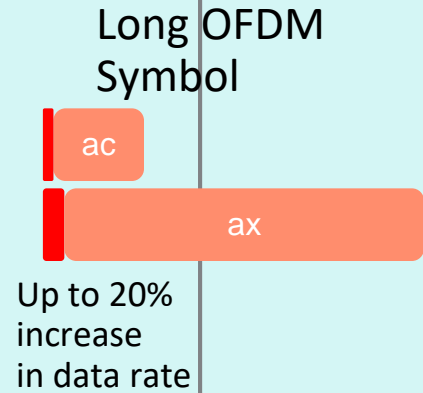
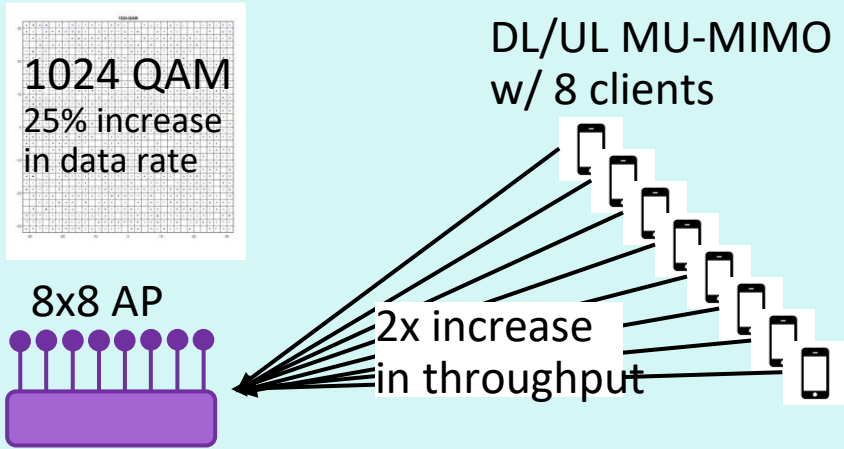
“..it is hard to imagine the Space Station without Wi-Fi.” Chatwin Lansdowne, Subsystem manager for the IEEE 802.11-based wireless communications system, International Space Station

IEEE 802.11 Standards Pipeline/Roadmap

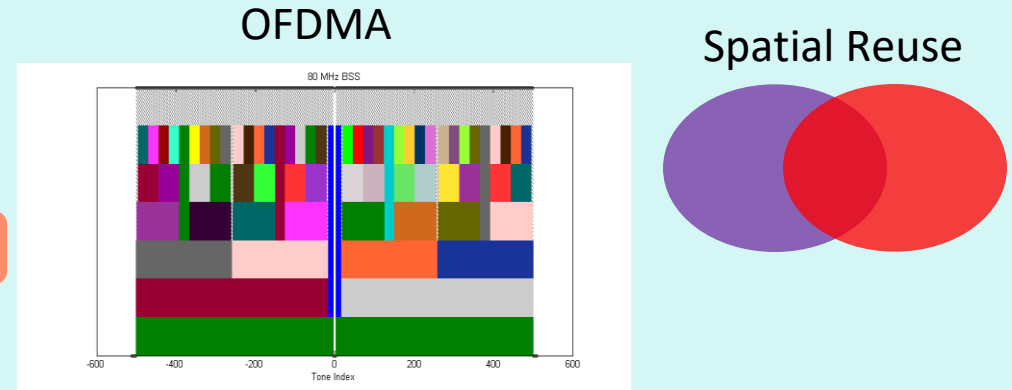


Products implementing 802.11ax-2021 are in the market now: Wi-Fi 6, 6E
 2022: 2.3 Billion Wi-Fi 6 devices, 350 Million Wi-Fi 6E, 4.4 Billion devices total

Spectral Efficiency & Area Throughput

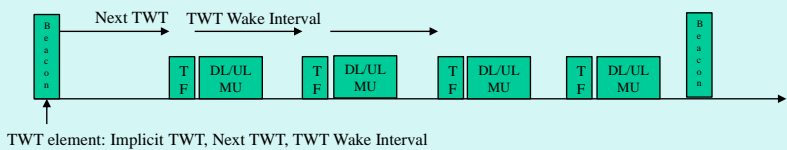


High Density



Power Saving

Scheduled sleep and wake times



20 MHz-only clients

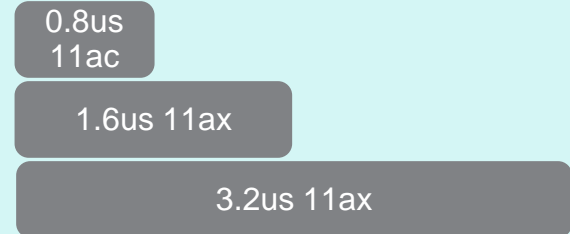


Outdoor / Longer range

Extended range packet structure



Enhanced delay spread protection - long guard interval



IEEE 802.11ax meets the MAC/PHY requirements for 5G IMT-2020 Indoor Hotspot and Dense urban test environments defined by ITU-R

Simulation conforming to the ITU-R evaluation methodology shows that performance of IEEE 802.11ax systems meet or exceed MAC and PHY requirements for the 5G Indoor Hotspot and Dense Urban test environments

	Metric (Indoor Hotspot)	ITU-R Evaluation Method	Minimum Requirement	802.11ax Performance
1	Peak data rate	Analytical	DL/UL : 20/10 Gbps	DL/UL : 20.78 Gbps
2	Peak spectral efficiency	Analytical	DL/UL : 30/15 bits/s/Hz	DL/UL : 58.01 bits/s/Hz
3	User experienced data rate	Analytical for single band and single layer; Simulation for multi-layer	Not applicable for Indoor Hotspot	Not applicable
4	5 th percentile user spectral efficiency	Simulation	DL/UL : 0.3/0.21 bits/s/Hz	DL/UL : 0.45/0.52 bits/s/Hz
5	Average spectral efficiency	Simulation	DL/UL : 9/6.75 bits/s/Hz/TRxP	DL/UL : 9.82/13.7 bits/s/Hz/TRxP
6	Area traffic capacity	Analytical	DL : 10 Mbit/s/m ²	Required DL bandwidth = 170 MHz with 3 TRxP/site
7	Mobility	Simulation	UL : 1.5 bits/s/Hz	UL : 9.4 bits/s/Hz
8	Bandwidth	Inspection	100 MHz, scalable	20/40/80/80+80/160 MHz
9	User plane latency	Analytical	DL/UL : 4 ms	DL/UL : 80 us

Completed: 802.11bd Next Generation V2X Use Cases

5.9 GHz band mainly, and optionally 60 GHz; Completion in 2022, published 2023

http://www.ieee802.org/11/Reports/tgbd_update.htm

V2X Use Cases:

- Support all defined DSRC/802.11p use cases, including Basic safety message (safety, range, backward compatibility, fairness)
- Sensor sharing (throughput)
- Multi-channel operation (safety channel + other channels)
- Infrastructure applications (throughput)
- Vehicular positioning & location (LoS and NLOS positioning accuracy)
- Automated driving assistance (safety, throughput)
- Aerial vehicle IT application (video)
- Train to train (high speed)
- Vehicle to train (high speed, long range)

Key additions :

- Backward compatibility with 11p
- Higher throughput (2x) than 802.11p
- Longer range (3dB lower sensitivity level)
- Support for positioning

Useful Links

- 802 home page: <http://www.ieee802.org/>
- 802.11 home page: <http://ieee802.org/11/>
- Help if you want to contribute: <http://www.ieee802.org/11/help.html>
- 802.11 document server: <https://mentor.ieee.org/802.11/documents>
- Wi-Fi Alliance <http://www.wi-fi.org/>
- Get 802.11 standards:
 - <http://standards.ieee.org/about/get/802/802.11.html>
 - <http://www.techstreet.com/ieee>