
IEEE 802.11 Overview and Amendments under development

Overview of the 802.11 Working Group

The IEEE 802.11 standard to date

New Amendments: Markets, use cases and key technologies

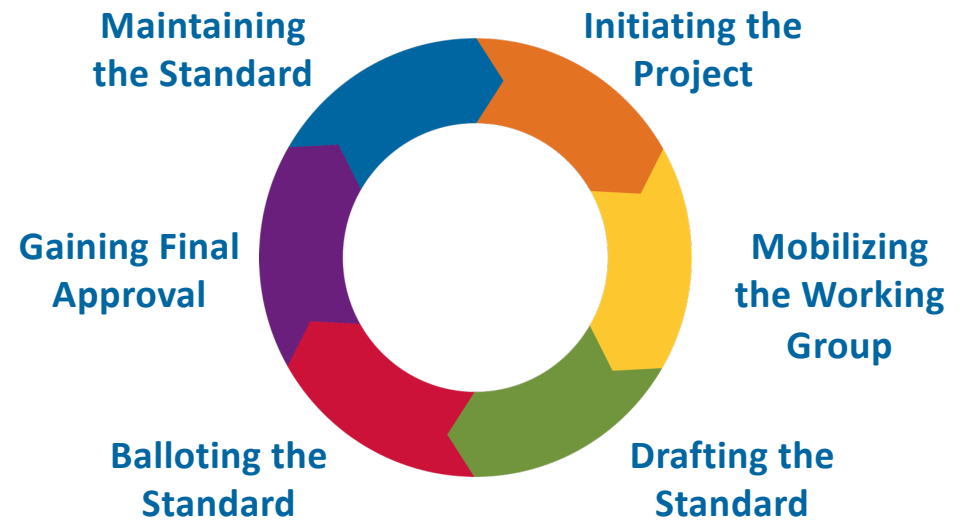
2025 January

Presenter:

“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)

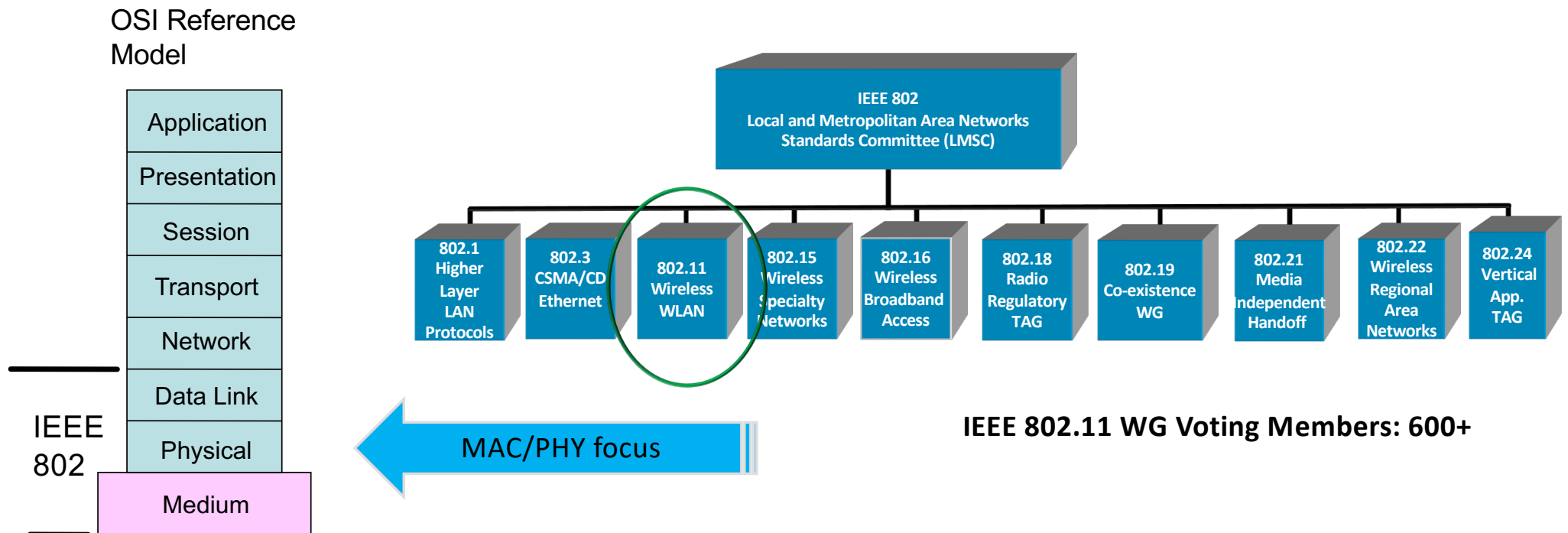
IEEE Standards Association

IEEE Standards drive the functionality, capability, and interoperability of a range of products and services that affect the way people live, work, and communicate.



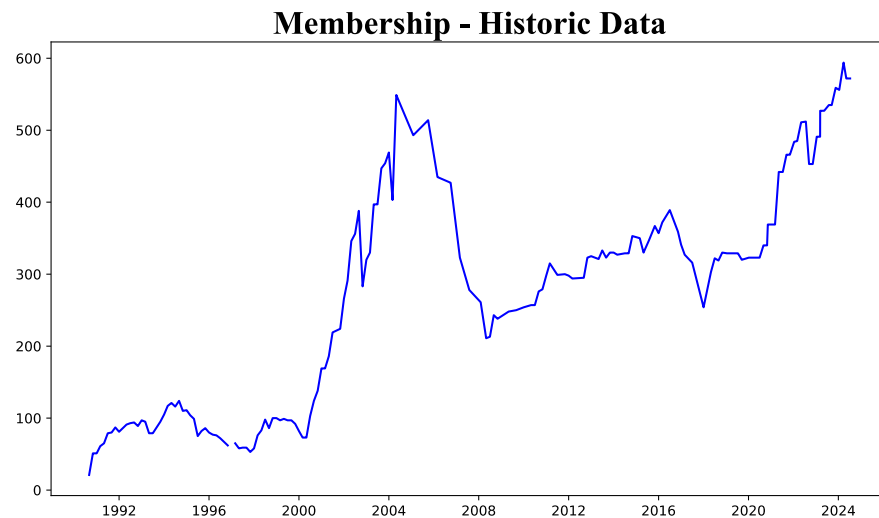
The IEEE 802.11 Working Group is one of the most active WGs in 802

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



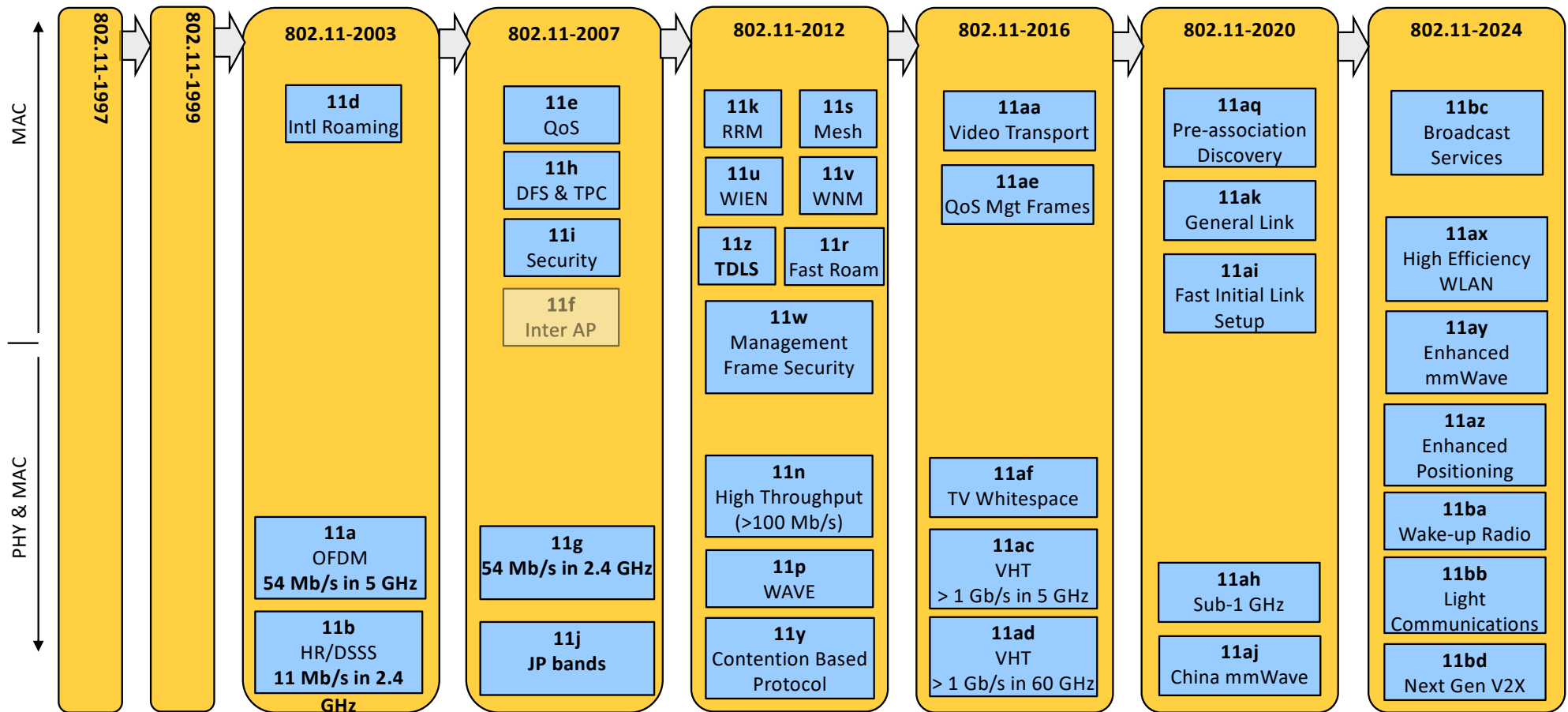
IEEE 802.11 Membership

Aspirant	Potential Voter	Voter
99	52	600+



- Membership is at an historic high
- We shifted from in-person to remote attendance during pandemic
- This enabled easy attendance from anywhere in the world
- We now run meetings with both in-person and remote attendance
- Membership is gained by attendance
- Membership is maintained through attendance and ballot participation

Development of the IEEE 802.11 Standard is ongoing since 1997



New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies. **Completed standards**

IEEE Std 802.11-2020 Revision project

IEEE Std 802.11ax-2021 – Increased throughput & efficiency in 2.4, 5 (and 6) GHz bands

IEEE Std 802.11ay-2021 – Support for 20 Gbps in 60 GHz band

IEEE Std 802.11az-2022 – 2nd generation positioning features

IEEE Std 802.11ba-2021 – Wake up radio. Low power IoT applications

IEEE Std 802.11bb-2023 – Light Communications

IEEE Std 802.11bc-2023 – Enhanced Broadcast Service

IEEE Std 802.11bd-2022 – Enhancements for Next Generation V2X

IEEE Std 802.11be-2024 – Enhancements for extremely high throughput (EHT)

IEEE Std 802.11bh-2024 – Operation with Randomized and Changing MAC Addresses

Market demands and new technology drive IEEE 802.11 innovation

- **Demand for throughput**

- Continuing exponential demand for throughput ([802.11be](#) and [802.11bn](#))
- Most (50-80%, depending on the country) of the world's mobile data is carried on 802.11 (Wi-Fi) devices

- **New usage models / features**

- Dense deployments ([802.11be](#)), Indoor Location ([802.11az](#), [802.11bk](#)),
- Automotive ([802.11bd](#), [AUTO](#))
- WLAN Sensing ([802.11bf](#))

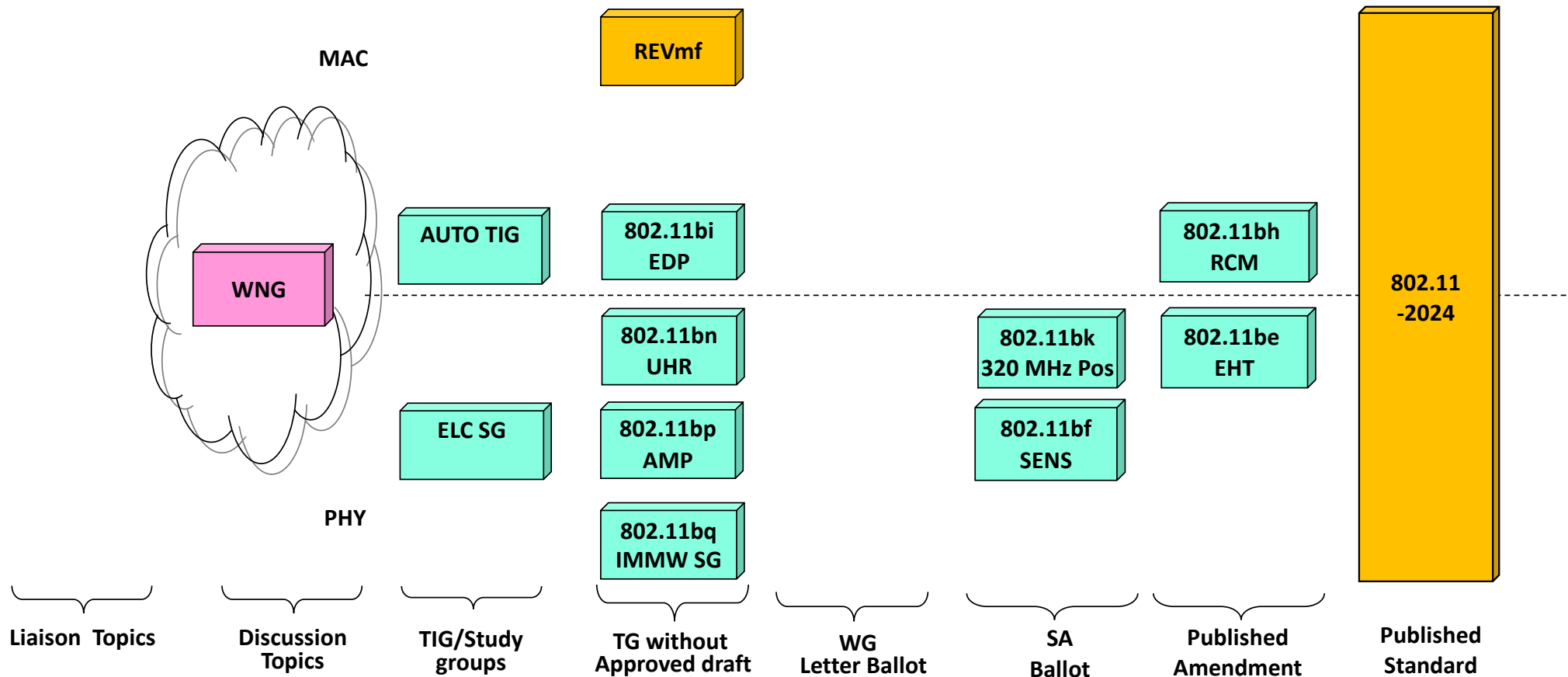
- **Technical capabilities**

- Millimetric (42-71 GHz) radios ([802.11bq](#))

- **Changes to regulation**

- 6 GHz ([802.11be](#))
- Coexistence and radio performance rules (e.g., ETSI BRAN, ITU-R)

IEEE 802.11 Standards Pipeline – January 2025



January 2025

New 802.11 Radio technologies are under development to meet expanding market needs and leverage new technologies.

802.11bf – WLAN Sensing

802.11bi – Enhanced Data Privacy

802.11bk – 320 MHz Positioning

802.11bn – Ultra High Reliability

802.11bp – Ambient Power for IOT

802.11bq – Integrated Milli Metric Wave

ELC – Enhanced Light Communication Study Group

AUTO – Automotive Topic Interest Group

AI / ML – Artificial Intelligence / Machine Learning Group



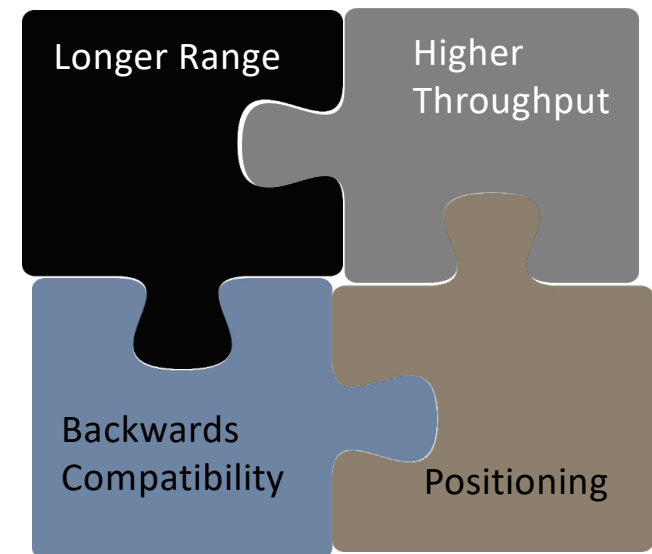
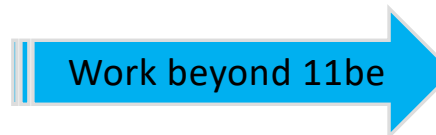
Wi-Fi standard evolution: 802.11bn is now under development

	Project	Industry Name	Defining features
Completed	802.11n High Throughput	Wi-Fi 4	Spatial multiplexing, 40 MHz channels, beamforming, A-MPDU
	802.11ac Very High Throughput	Wi-Fi 5	80 MHz & 160 MHz channels, beamforming that works Enabled broad support for 5 GHz band operation
	802.11ax High Efficiency	Wi-Fi 6 and 6E	Multi-user operation, 320 MHz channels, 6 GHz band operation
Recently approved	802.11be Extremely High Throughput	Wi-Fi 7	Multi-link operation (simultaneous use of multiple channels)
New	802.11bn Ultra-High Reliability	Wi-Fi 8*	Lower latency, longer range, faster handover

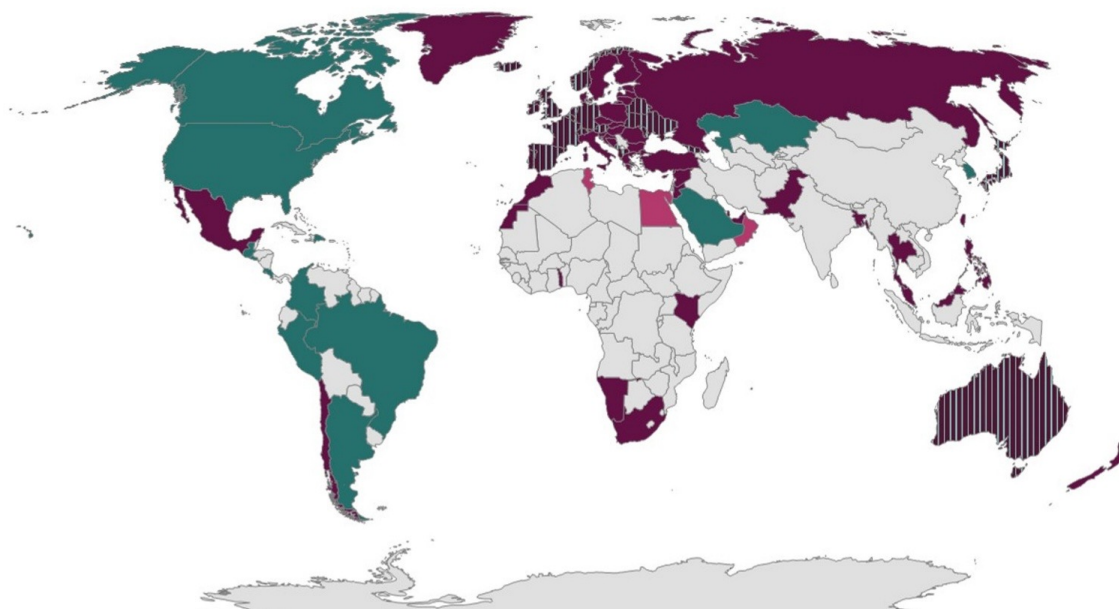
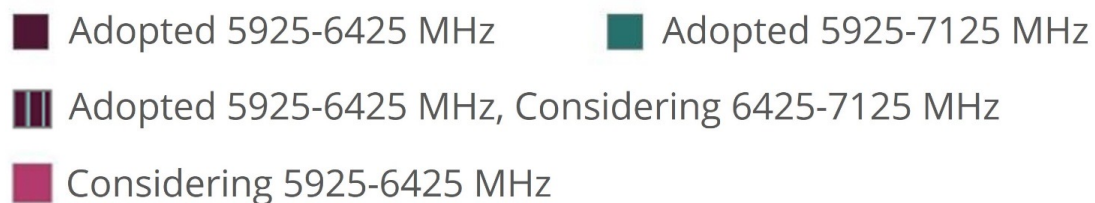
*Expected name; will be decided outside of IEEE 802.11

802.11bn: Ultra High Reliability (UHR)

- Expected to be the basis for Wi-Fi 8
- Currently developing their specification framework document (SFD) :
Expected improvements:
 - Reduce tail latency
 - Reduce roaming latency by taking advantage of multi-link features
 - Allow access on secondary channel while primary channel is busy
 - AP power save
 - Security enhancements, e.g., Control frame protection
 - Extend range by reducing sensitivity gap between client and AP
 - Multi-AP coordination



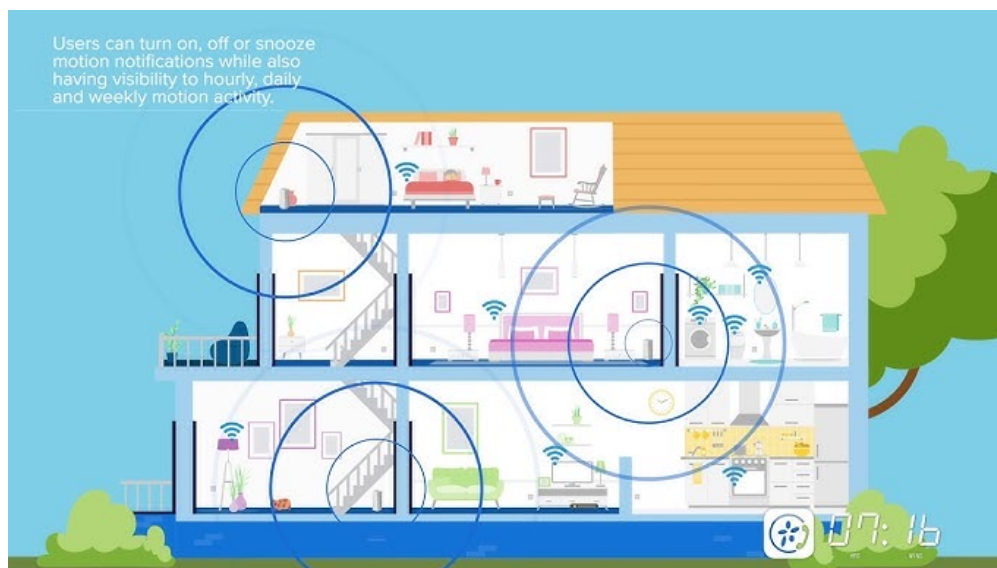
Countries enabling Wi-Fi 6 GHz Operation, see <https://www.wi-fi.org/regulations-enabling-6-ghz-wi-fi> (as of 2025-01-06)



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802.11bf Sensing

- 802.11bf is developing a protocol for environmental sensing
- Measurements that can be used to monitor environmental conditions and changes
- E.g., people movement, number of people present, room occupancy, etc.
- Built on sounding (beamforming) waveforms
- Does not define use of the measurements; just defines the sounding exchange and transfer of channel state information

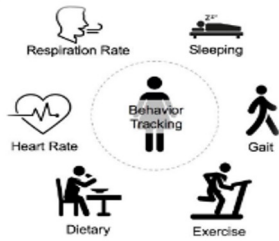


WLAN sensing uses PHY and MAC features of IEEE 802.11 stations to obtain **measurements** that may be useful to estimate **features** of **objects** in an **area of interest**.

- Features = Range, velocity, angular, motion, presence or proximity, gesture, etc.
- Objects = Human, animal, etc.
- Area of interest = Room, car, enterprise, etc.

802.11bf Sensing

Use cases:



1. Smart home



2. Presence and proximity detection



3. Gesture recognition



4. Gaming control



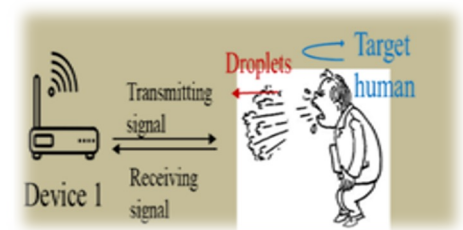
5. Vital signs / Liveness



6. Location in store



7. Audio with user tracking (Follow-me sound)

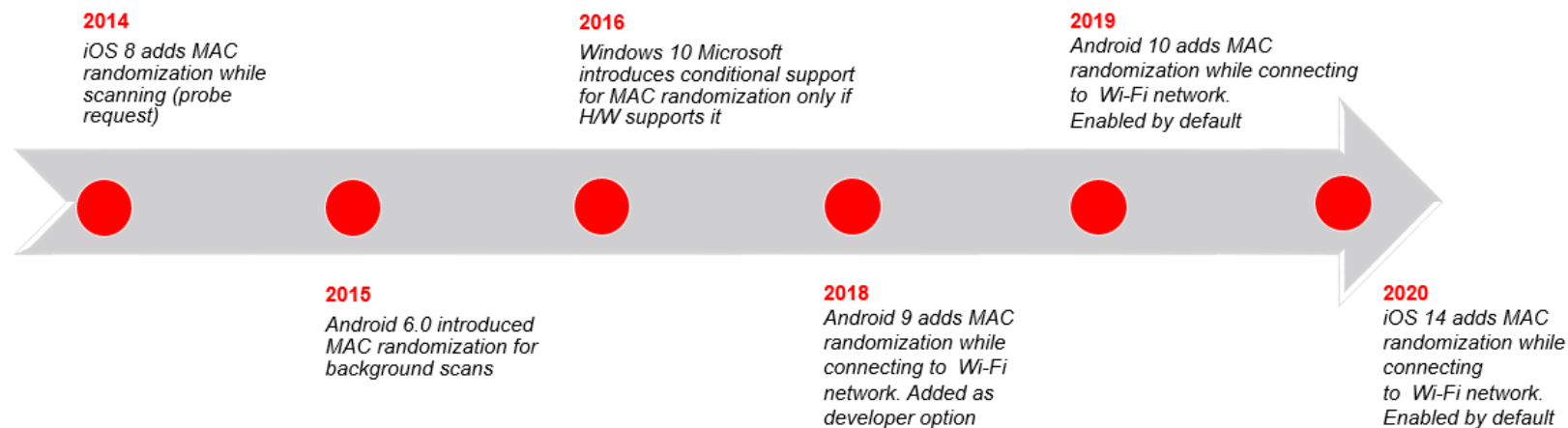


8. Sneeze sensing

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.



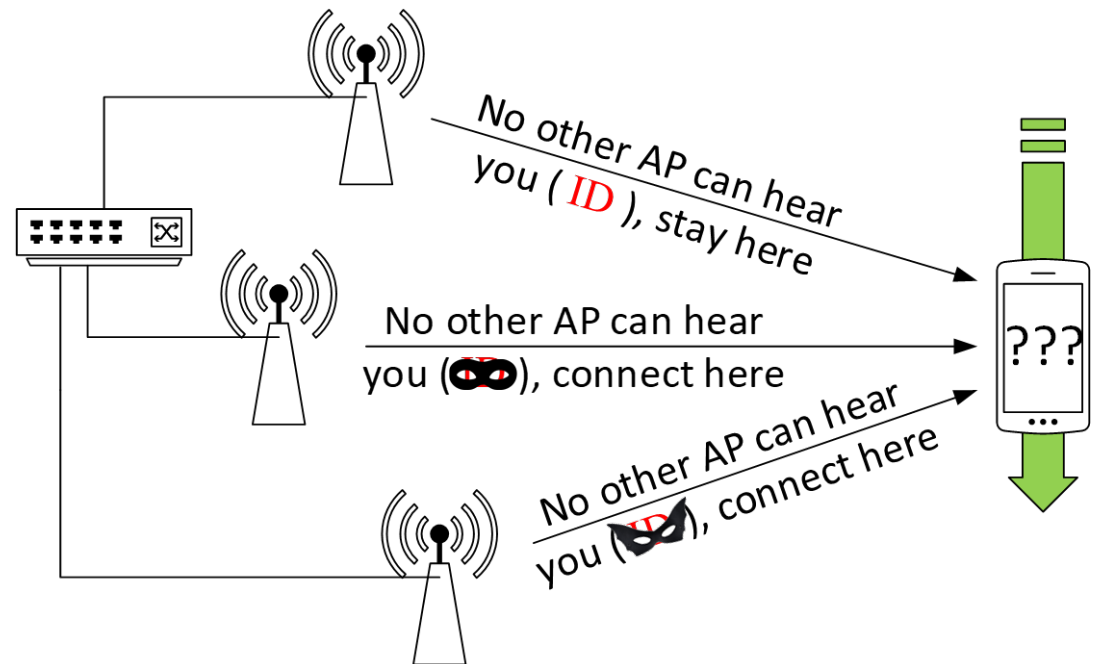
MAC address randomization can undermine the network's ability to steer the device to the best connection point, or to recognize the device and provide differentiated access in secure environments, pay-for-bandwidth scenarios, etc.

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

Client Steering Use Case

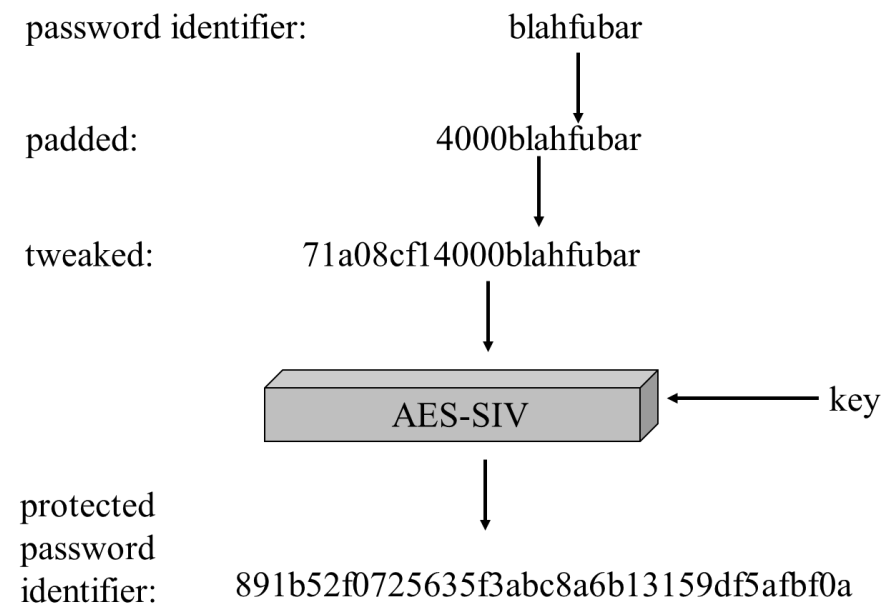


802.11bi Enhanced Data Privacy (EDP)

Defines new mechanisms to improve user privacy

- Today, IEEE Std 802.11aq-2018 defines MAC address randomization and specific requirements to prevent device tracking using passive observation of PHY, MAC protocol fields.
- To ensure continued growth and support for IEEE Std 802.11, this project is investigating additional enhancements for user privacy solutions applicable to 802.11.

✓ Privacy of Password (WPA3)
Privacy of Password **Identifier**



802.11bk 320 MHz Positioning (320P)

- Increase the accuracy of 802.11 based location and proximity determination
- WLAN standardization roadmap towards 0.1m accuracy levels in real world scenarios
- Based on P802.11be 320 MHz channelization and waveforms, reuses the 802.11be PHY
- Takes advantage of WLAN spectrum availability in the <7GHz band and the superior 802.11 link budget
- Attractive for device-to-device, improved self-locating network accuracy, keyless entry and engine-start use cases

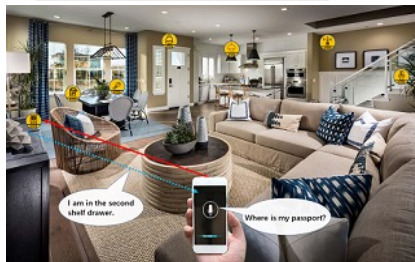
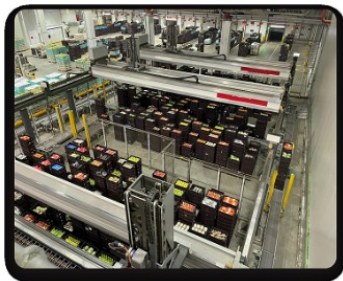


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802.11bp Ambient Power Transmission (AMP)

- AMbient Power (AMP) Communication provisions a mechanism enabling battery-free applications which is especially important to low-power IoT applications. This will not only help users within home, enterprise and public access markets, but also assist manufacturers and operators to provide common components and services for IEEE 802.11 customers



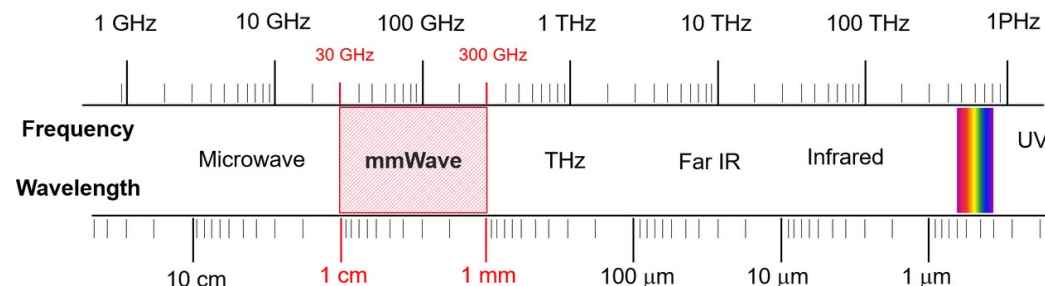
- AMP IoT applications cover various scenarios:

- Smart manufacturing
- Logistics/warehouse
- Close range AMP tag reading
- Fresh food supply chain
- Smart home
- Smart Grid

802.11bp Ambient Power Transmission (AMP)

- 802.11bp defines MAC/PHY enhancements from mainstream 802.11 standards and amendments to provide an ambient power communication solution in WLAN by:
 - defining ambient power transmission in both S1G and 2.4 GHz bands.
 - defining wireless power transmission protocol in S1G
 - supporting both bistatic and monostatic transmission
 - defining mechanisms for coexistence between 802.11bp compliant devices and legacy 802.11 devices.
- A technical report on AMP in WLAN was developed by an earlier AMP group.

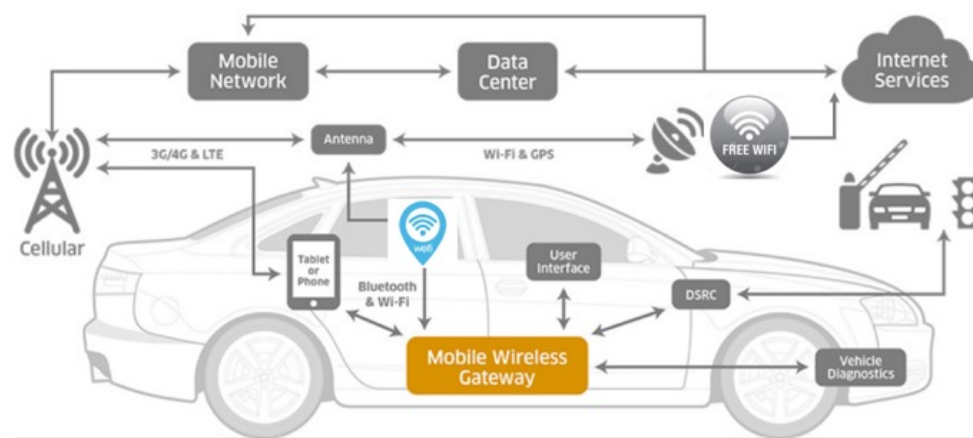
802.11bq Integrated mmWave (IMMW)



- Expected to start work as task group in February 2025
- Simplify 42-71 GHz band operation to reduce implementation cost
- Previous generations (802.11ad/ay/aj) assumed stand alone operation
 - Re-design with multi-band support in mind
- Improvements expected:
 - More architectural reuse from low band PHY
 - Eliminate control PHY by taking advantage of multi-link; e.g., sector sweep beamforming directed through low band channel
- This project is particularly relevant to China where 6 GHz band operation is not available

802.11 AUTomotive group

- The AUTO TIG is developing a report on the automotive use of Wi-Fi
- The automotive industry wants to use Wi-Fi opportunistically to
 - Update software, maps, etc.
 - Get updates on traffic conditions
 - Serve internet connectivity to occupants using Wi-Fi
 - Connect to mobile devices
- The report will provide
 - Use cases and requirements
 - Key performance indicators
 - Technical approaches and 802.11 standard gaps in the areas such as protocols in association & authentication, seamless AP handover, optimized roaming algorithm etc.
 - Alternative solutions



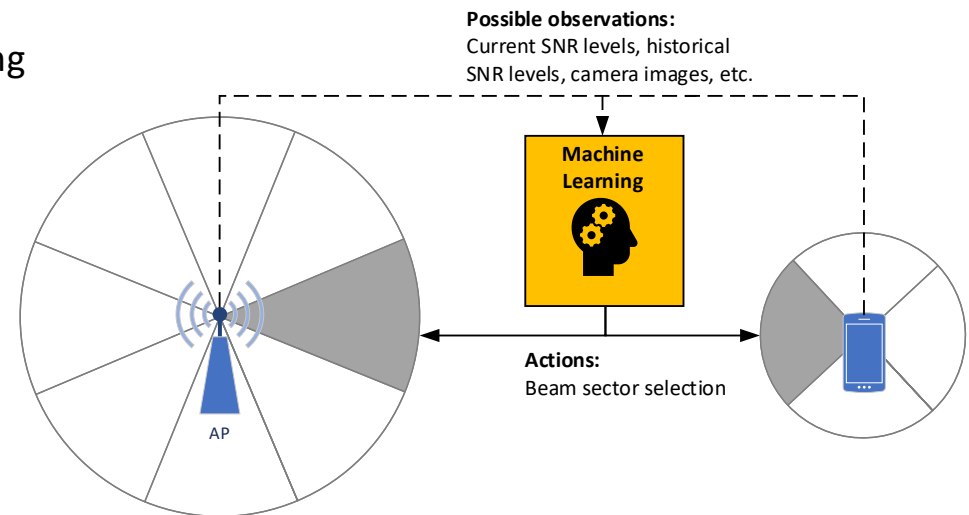
802.11 Enhanced Light Communications (ELC) group

- IEEE Std 802.11bb-2023 added light communications (LC) to 802.11
- The ELC study group is preparing a project outline to enhance this work
- For example,
 - Add multi-link support
 - Support for underwater operation
- With approval a task group is expected to start work in May 2025



802.11 AI / ML Artificial Intelligence/ Machine Learning group

- Use of AI/ML for 802.11 applications is an active area of work in the research community.
- Current applications focus on performance improvement parameter selection for channel access control and link adaptation, multi-user parameters, channel usage
- Focus of the 802.11 AIML group is to:
 - Describe use cases for Artificial Intelligence/Machine Learning (AI/ML) applicability in 802.11 systems and investigate the technical feasibility of features enabling support of AI/ML.



Thank You

Questions ?