IEEE 802.11 Overview and Amendments under development

Overview of the 802.11 Working Group

The IEEE 802.11 standard to date

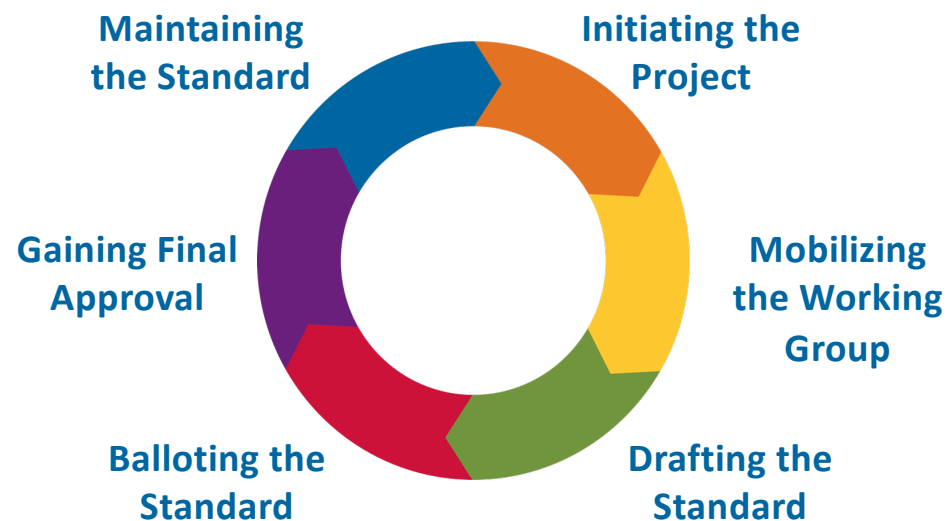**New Amendments: Markets, use cases and key technologies**
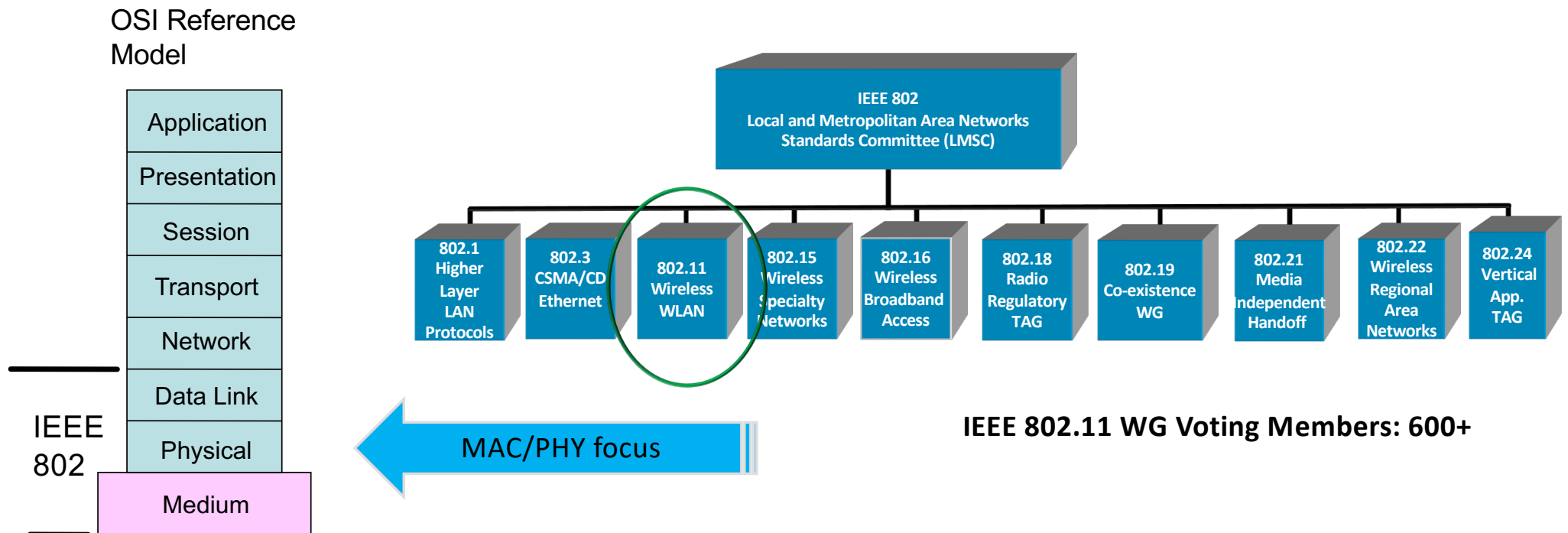
2025 January
Presenter:

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.

Individual membership

7,000+ individual members in 90 countries

Corporate Memberships

390+ member corporations in 23 countries

Standards Developers

~20,000 participants;
all interested parties are welcome

Maintaining the Standard

Initiating the Project

Gaining Final Approval

Mobilizing the Working Group

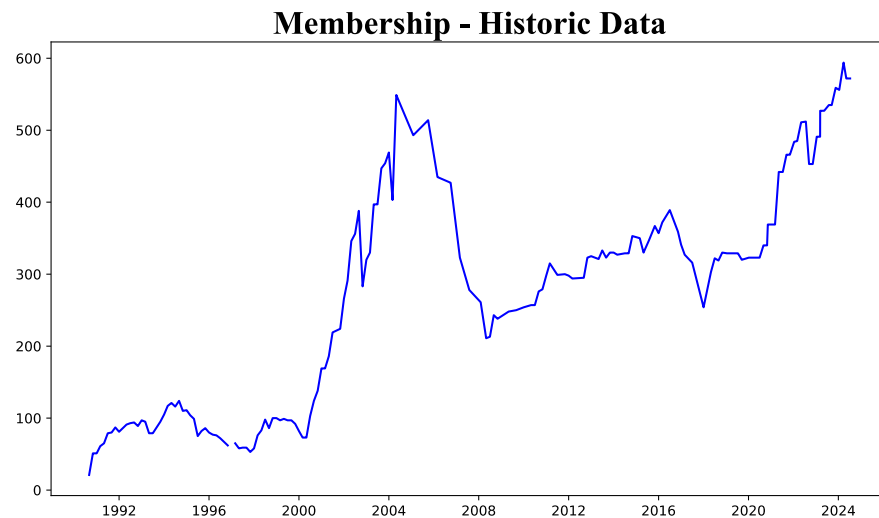Balloting the Standard

Drafting the Standard

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
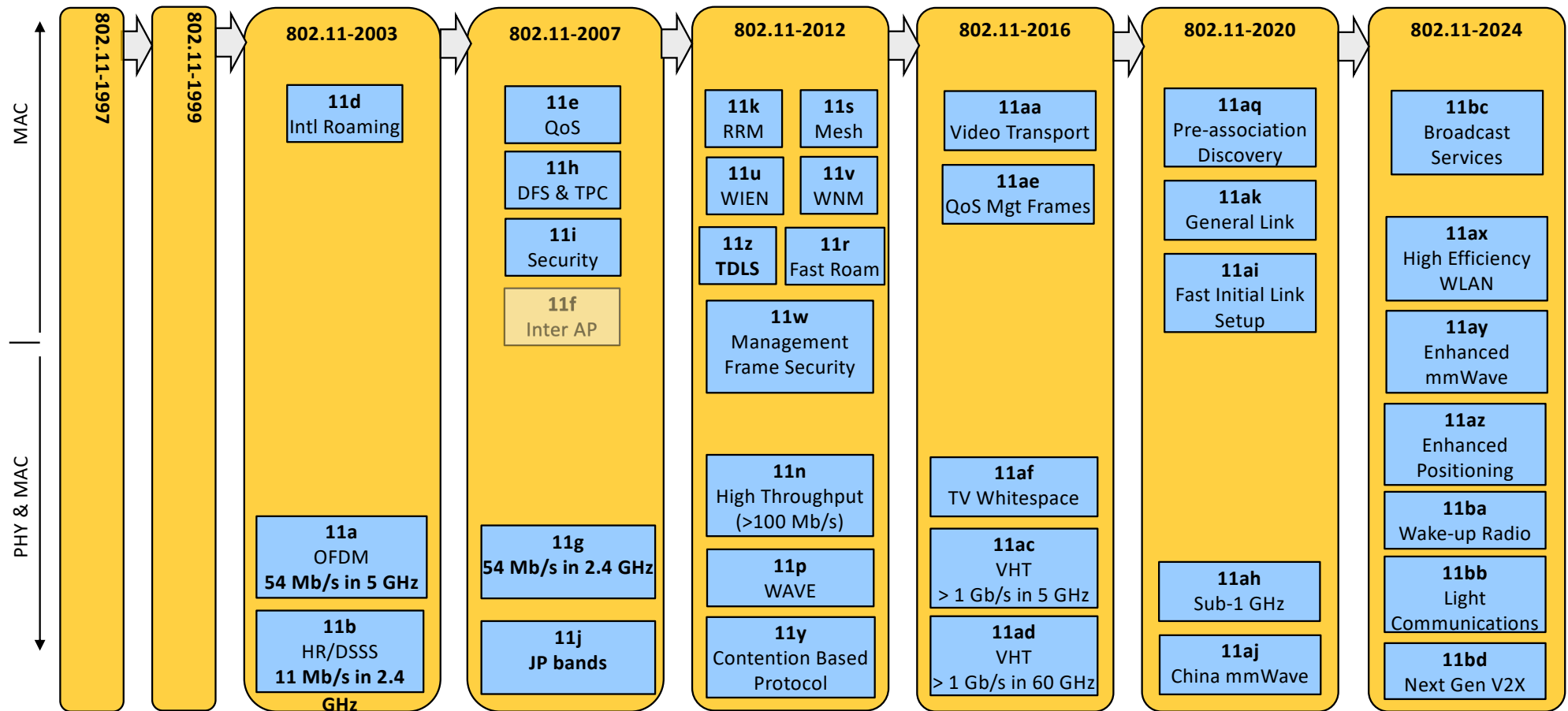- Leverage IETF protocols for upper layers

OSI Reference Model

| Application |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |
| Medium |

IEEE 802

IEEE 802
Local and Metropolitan Area Networks
Standards Committee (LMSC)

802.1 Higher Layer LAN Protocols

802.3 CSMA/CD Ethernet

802.11 Wireless WLAN

802.15 Wireless Specialty Networks

802.16 Wireless Broadband Access

802.18 Radio Regulatory TAG

802.19 Co-existence WG

802.21 Media Independent Handoff

802.22 Wireless Regional Area Networks

802.24 Vertical App. TAG

MAC/PHY focus

IEEE 802.11 WG Voting Members: 600+

IEEE 802.11 Membership

Aspirant	Potential Voter	Voter
99	52	600+

Membership - Historic Data

- 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

MAC

PHY & MAC

802.11-1997

802.11-1999

802.11-2003

11d
Intl Roaming

11a
OFDM
54 Mb/s in 5 GHz

11b
HR/DSSS
11 Mb/s in 2.4
GHz

802.11-2007

11e
QoS

11h
DFS & TPC

11i
Security

11f
Inter AP

11g
54 Mb/s in 2.4 GHz

11j
JP bands

802.11-2012

11k
RRM

11s
Mesh

11u
WIEN

11v
WNM

11z
TDLS

11r
Fast Roam

11w
Management
Frame Security

11n
High Throughput
(>100 Mb/s)

11p
WAVE

11y
Contention Based
Protocol

802.11-2016

11aa
Video Transport

11ae
QoS Mgt Frames

11af
TV Whitespace

11ac
VHT
> 1 Gb/s in 5 GHz

11ad
VHT
> 1 Gb/s in 60 GHz

802.11-2020

11aq
Pre-association
Discovery

11ak
General Link

11ai
Fast Initial Link
Setup

11ah
Sub-1 GHz

11aj
China mmWave

802.11-2024

11bc
Broadcast
Services

11ax
High Efficiency
WLAN

11ay
Enhanced
mmWave

11az
Enhanced
Positioning

11ba
Wake-up Radio

11bb
Light
Communications

11bd
Next Gen V2X

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
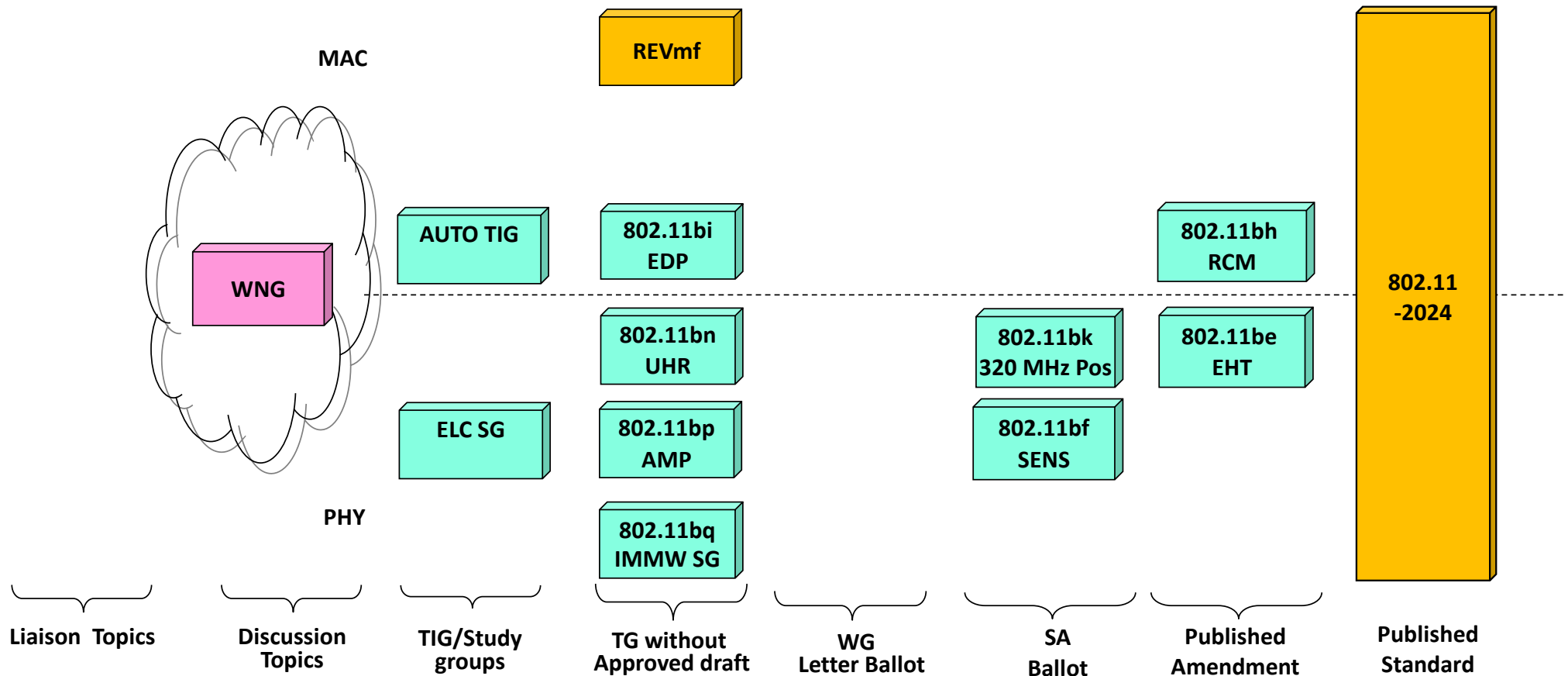
January 2025

8

New <u>802.11 Radio technologies</u> 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
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
802.11be Extremely High Throughput	Wi-Fi 7	Multi-link operation (simultaneous use of multiple channels)
802.11bn Ultra-High Reliability	Wi-Fi 8*	Lower latency, longer range, faster handover

Completed (802.11n, 802.11ac, 802.11ax)

Recently approved (802.11be)

New (802.11bn)

*Expected name; will be decided outside of IEEE 802.11
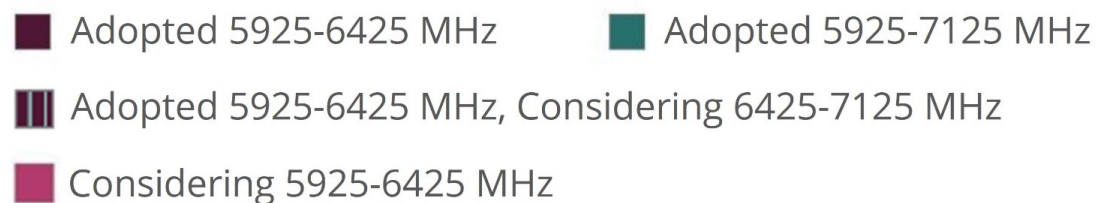
802.11bn: Ultra High Reliability (UHR)

- 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

Work beyond 11be

Longer Range

Higher Throughput

Backwards Compatibility

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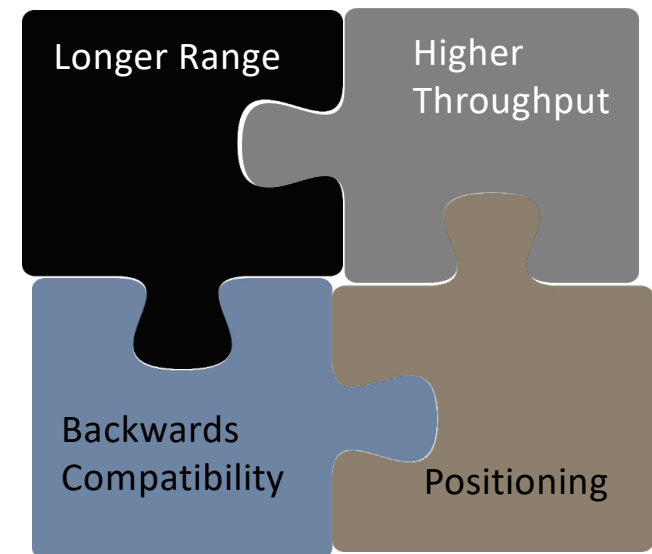
Countries enabling Wi-Fi 6 GHz Operation, see https://www.wi-fi.org/regulations-enabling-6-ghz-wi-fi (as of 2025-01-06)

Legend:
- Adopted 5925-6425 MHz
- Adopted 5925-7125 MHz
- Adopted 5925-6425 MHz, Considering 6425-7125 MHz
- Considering 5925-6425 MHz
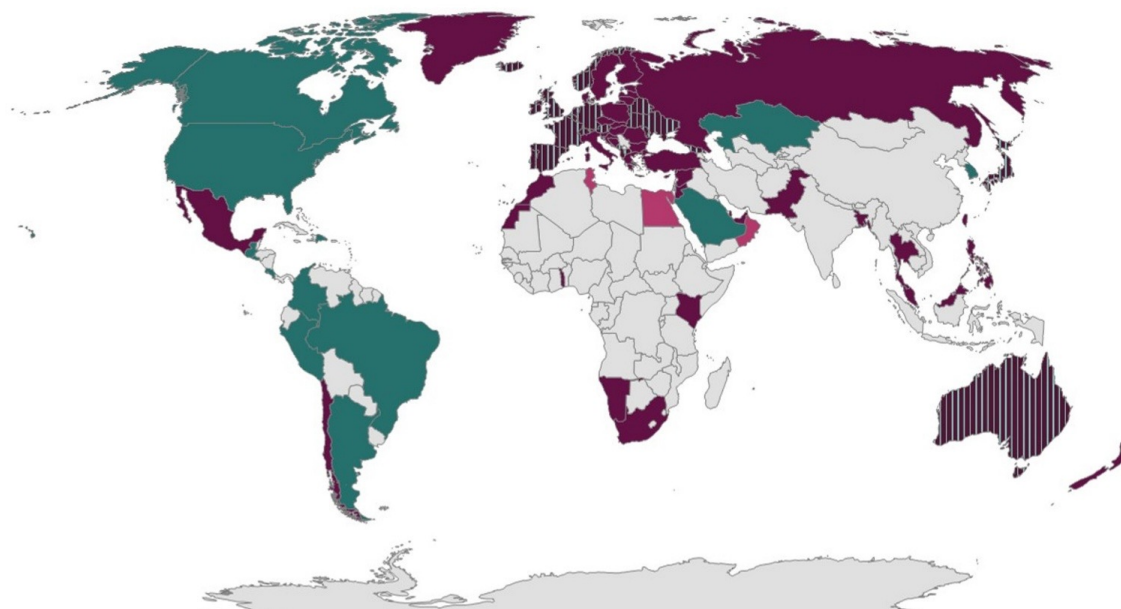
January 2025

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
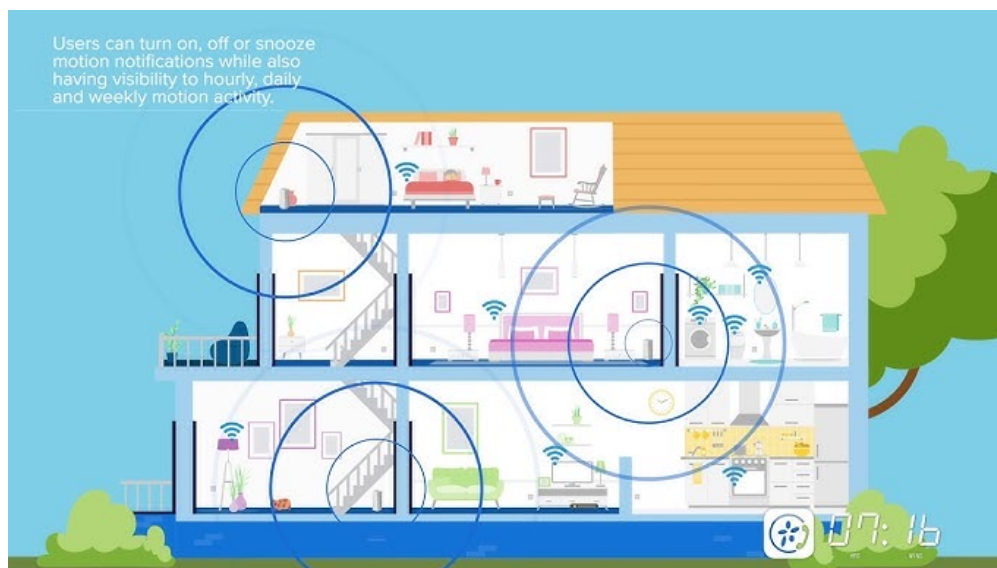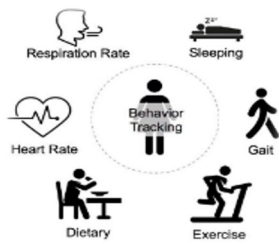

WLAN sensing uses PHY and MAC features of IEEE 802.11 stations to obtain **measurements** that may be useful to estimate **features** of **objects** in an **area of interest**.

- 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
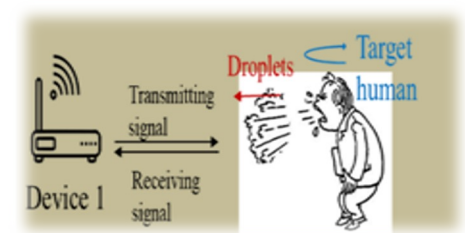
3. Gesture recognition

4. Gaming control

5. Vital signs / Liveness

6. Location in store
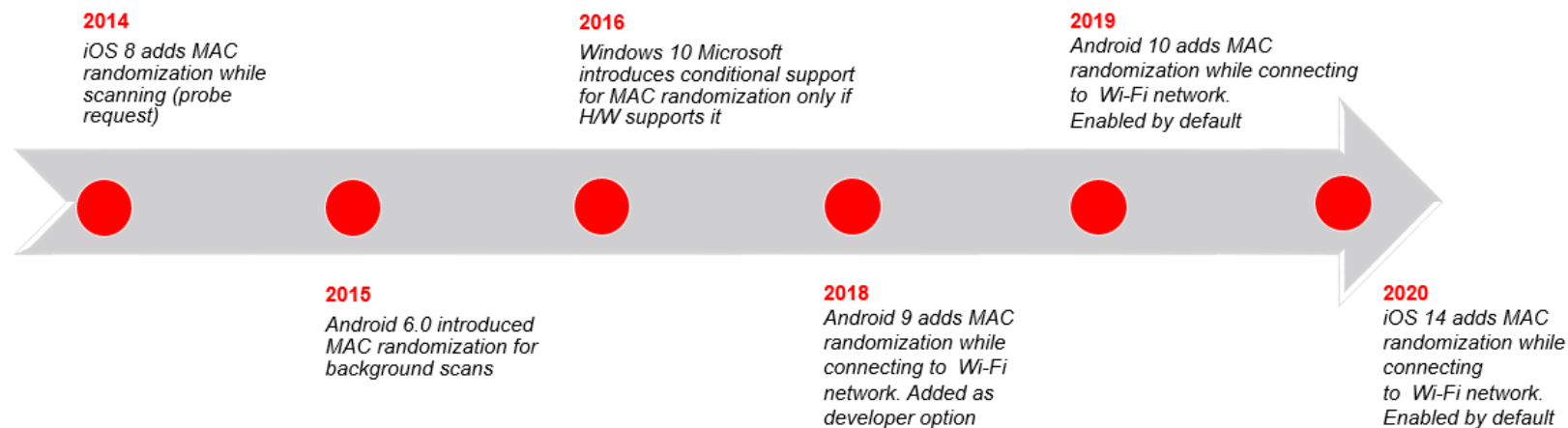
7. Audio with user tracking (Follow-me sound)

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.

2014
iOS 8 adds MAC randomization while scanning (probe request)

2016
Windows 10 Microsoft introduces conditional support for MAC randomization only if H/W supports it

2019
Android 10 adds MAC randomization while connecting to Wi-Fi network. Enabled by default

2015
Android 6.0 introduced MAC randomization for background scans

2018
Android 9 adds MAC randomization while connecting to Wi-Fi network. Added as developer option

2020
iOS 14 adds MAC randomization while connecting to Wi-Fi network. Enabled by default
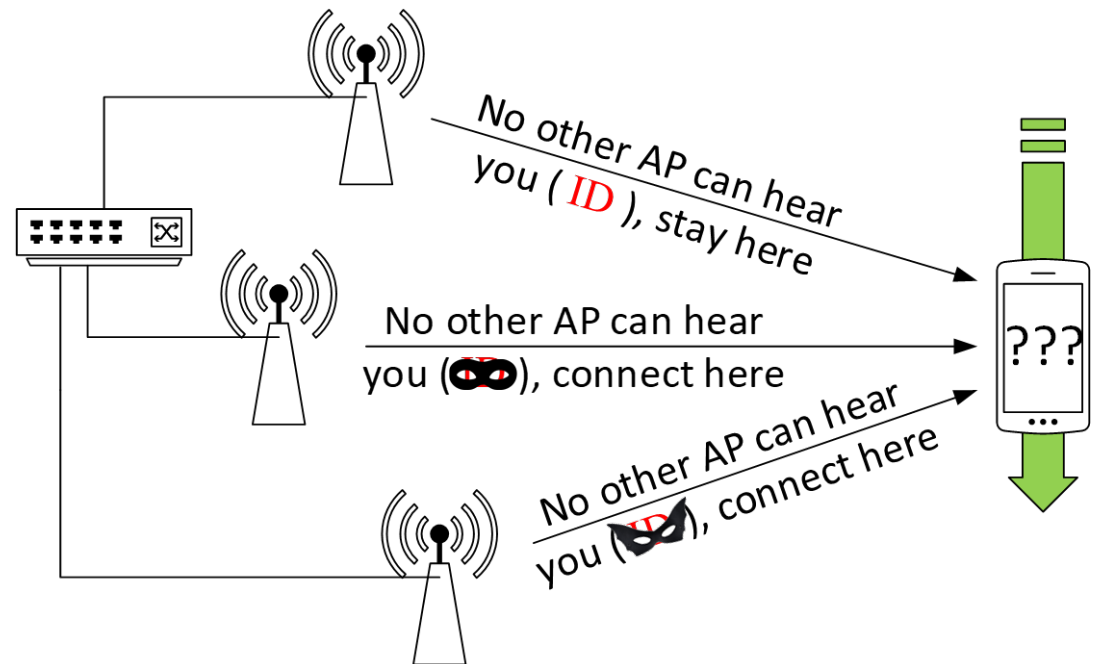
MAC address randomization can undermine the network's ability to steer the device to the best connection point, or to recognize the device and provide differentiated access in secure environments, pay-for-bandwidth scenarios, etc.

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
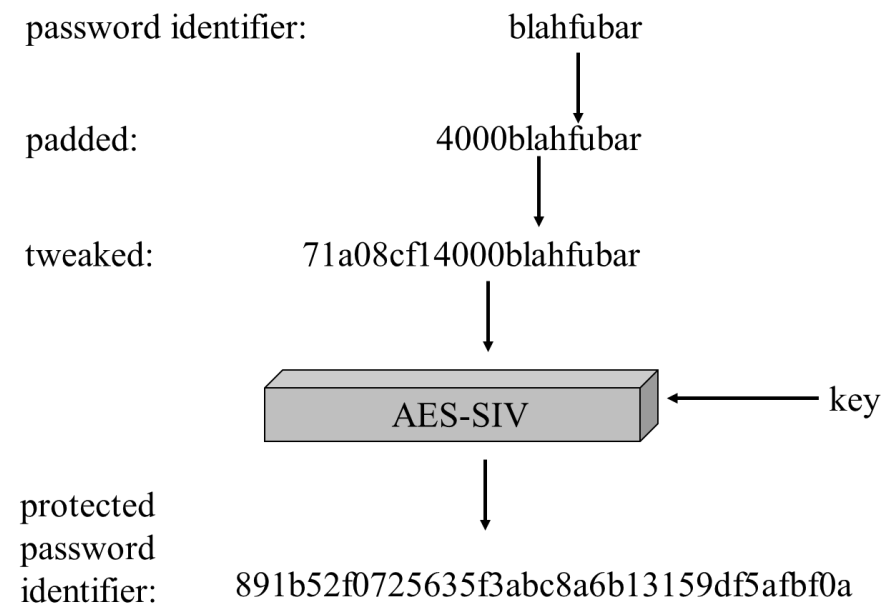
Client Steering Use Case

No other AP can hear you (ID), stay here

No other AP can hear you ( ), connect here

No other AP can hear you ( ), connect here

???

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.

password identifier: blahfubar

padded: 4000blahfubar

tweaked: 71a08cf14000blahfubar

AES-SIV ← key

protected password identifier: 891b52f0725635f3abc8a6b13159df5afbf0a

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
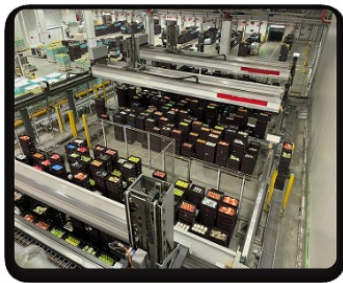
802.11bp Ambient Power Transmission (AMP)

- 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
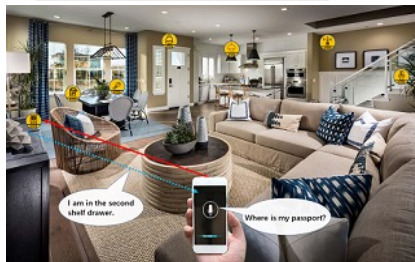

- AMP IoT applications cover various scenarios:
  - Smart manufacturing
  - Logistics/warehouse
  - Close range AMP tag reading
  - Fresh food supply chain
  - Smart home
  - Smart Grid

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)
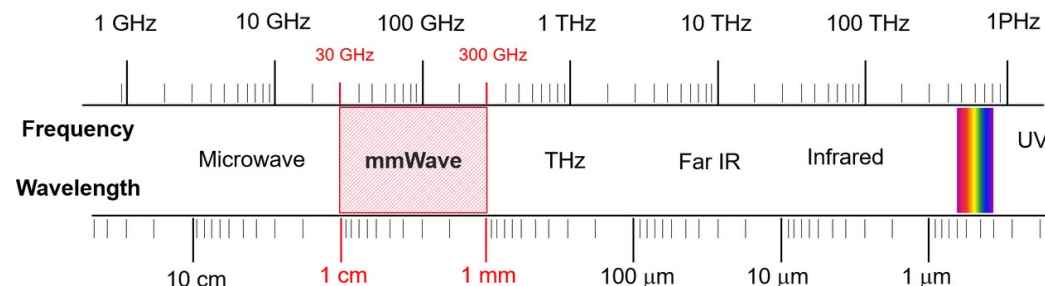
- Expected to start work as task group in February 2025

- 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.
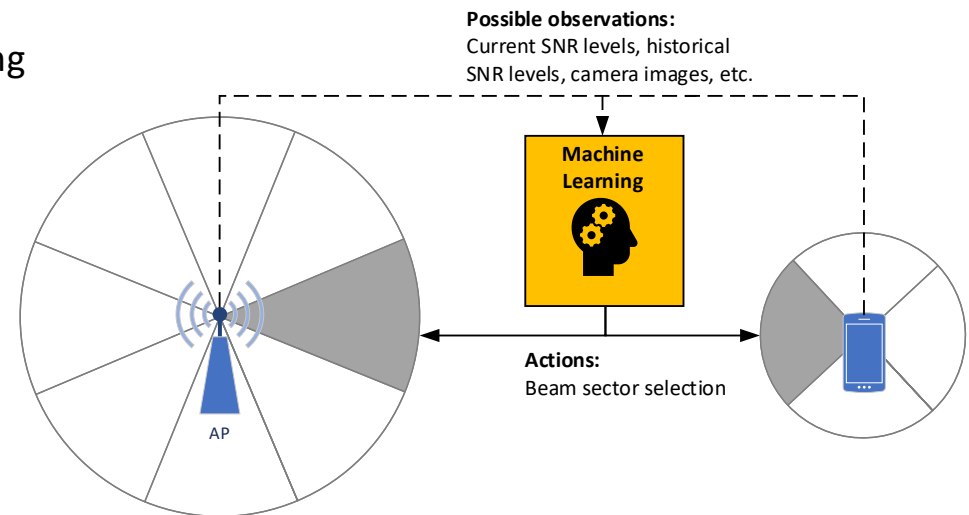 - Alternative solutions
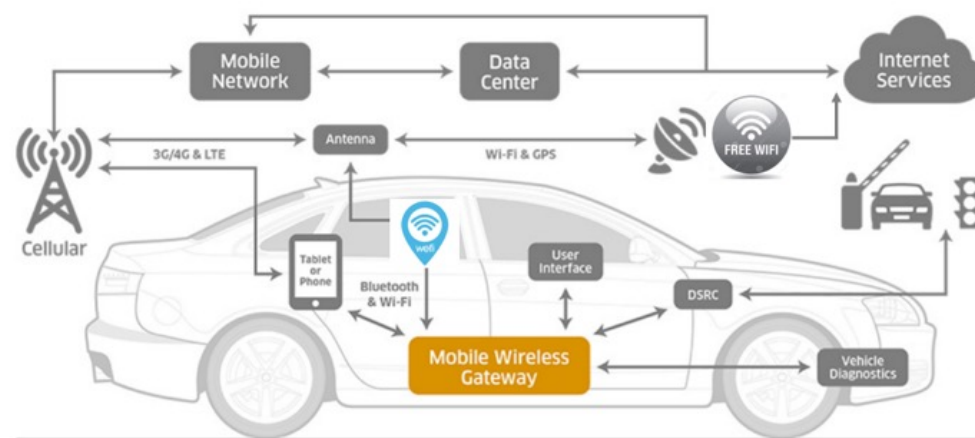
802.11 Enhanced Light Communications (ELC) group

- 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.

Possible observations:
Current SNR levels, historical SNR levels, camera images, etc.

Machine Learning

Actions:
Beam sector selection

AP

Thank You

Questions ?