

Demystifying IEEE 802.11 Standards

Beijing Workshop

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802.11 Chair

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IEEE-SA Standards Board Operation Manual (subclause 5.9.3)

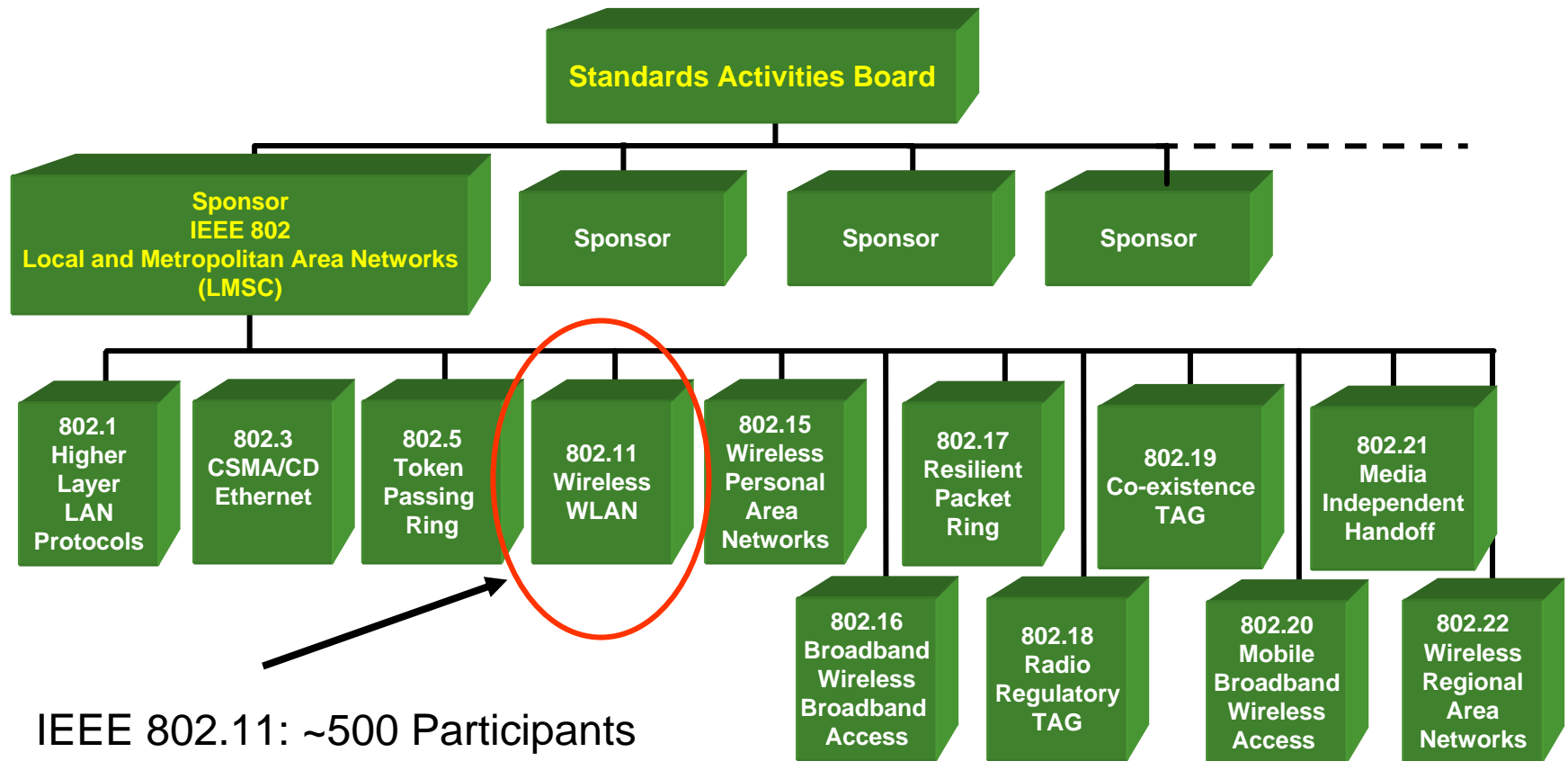
Acknowledgements

- ▣ Bruce Kraemer – chair 802.11
- ▣ Adrian Stephens – vice chair 802.11

Context

IEEE 802 Organization

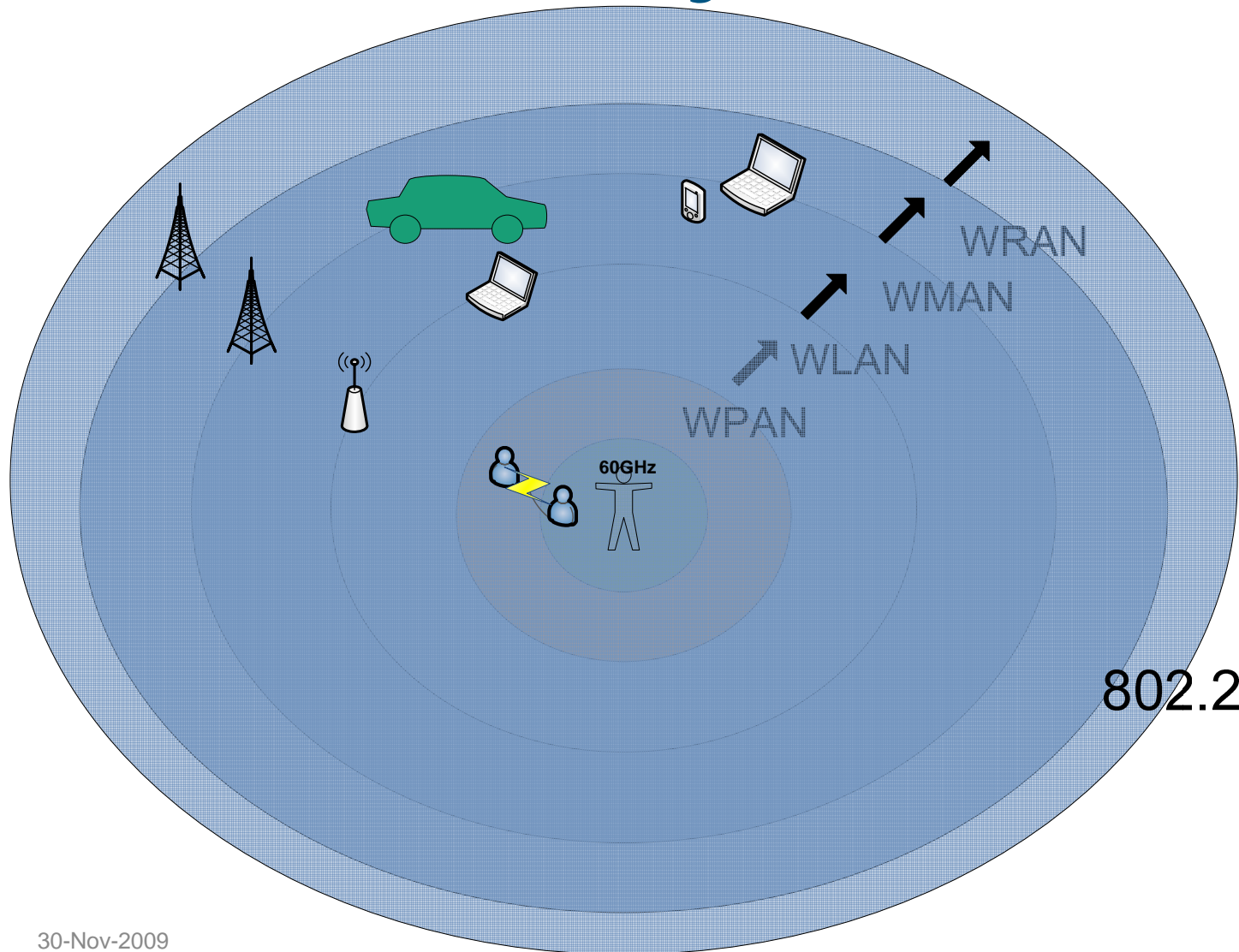
IEEE Standards Association



IEEE 802.11: ~500 Participants
Voting Members ~250

www.ieee802.org/11

802 Wireless Ecosystem



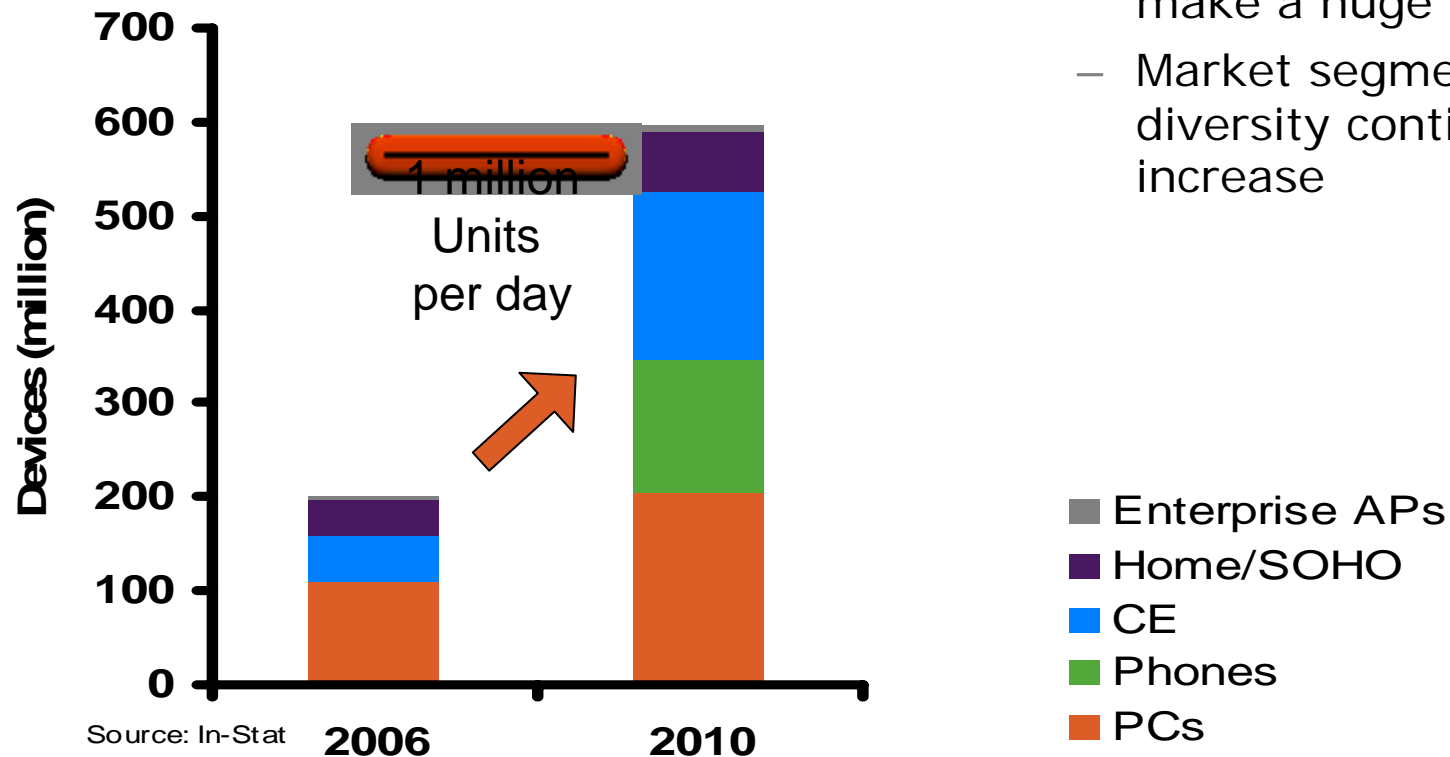
Wireless

802.20

Market Acceptance

Market Size and Trends

- Both Consumer Electronics and Voice (VoIP) are forecast to make a huge impact
- Market segment diversity continues to increase



Wi-Fi Hotspot Public Access

- 280K+ hot spots in 132 countries
 - *Source: JiWire (2009)*
- 1.2 Billion connects
 - *Source: In-Stat*
- 87% of US hotels offer Wi-Fi
 - *Source: American Hotel & Lodging Assn*



Expanding Uses - Airline Examples

- Airline Example
 - American Airlines
 - Lufthansa
 - Virgin America
 - Google
 - Aircell GoGo Inflight Internet
- Smart Grid

Science Challenge

Air is a Poor Substitute for Wire or Fibre

- Large Scale fading
 - Attenuation (distance, obstructions)
 - Delay
- Small scale fading
 - Multipath (Reflections)
 - Doppler
 - Frequency selective fading
- Shared Medium
 - Cannot disregard legacy devices
 - In unlicensed bands - cannot control who else is using the medium

Characteristics unique to wireless

- Propagation Characteristics
- Limited spectrum
 - Lansford's Law: "Moore's law does not apply to spectrum."
- Must meet National Regulations
- Licensed / lightly licensed / unlicensed bands
- Protection of incumbents/primary users
 - DFS, TVWS

Wireless Constraints

■ Shannon-Hartley

$$C = BW \times \log_2 \left[1 + \frac{S}{N} \right]$$

C= channel capacity (bits/sec)

BW= channel bandwidth (Hz)

S = Signal
N = Noise } watts (not dB)

■ Friis path loss

$$P_{rx} = \frac{G_{tx} G_{rx} c^2}{(4\pi d)^2 f_c^2} \times \frac{1}{\sigma N_f} P_{tx}$$

History

Early Development History

- Feb 14, 1876: Bell files telephone patent
- **June 1897: Marconi work- "Signaling through Space without Wires"**
- 1970: ALOHAnet operational (Abramson, 9600 baud)
- 1976: Metcalf & Boggs: "Ethernet: Distributed Packet-Switching for Local Computer Networks"
- 1980: Project 802 formed (1 Mbps initially, revised to 20 Mbps 1982) (Feb 1980, 125+ attendees)
- 1985: **FCC opens ISM Band- spread spectrum allowed**
- 1985: First version of 802.3 published (10 Mbps)
- 1987: **Project 802.4L – Wireless Token Bus begins**
- 1989: ISM frequency Bands 900MHz, 2.4GHz and 5GHz allowed
- 1990: **IEEE 802 drops 802.4L starts 802.11 project**
- 1990: 802.3 10BASE-T (802.3i) released
- 1997: **IEEE 802.11 standard approved (2.4GHz – 1Mbps)**
- 1999: **IEEE 802.11 standard achieved ISO/IEC approval**

Amendment History

- 1999: IEEE 802.11a (5GHz – 54Mbps) - approved
IEEE 802.11b (2.4GHz- 11Mbps)- approved
- 1999: Formation of WECA (now Wi-Fi Alliance)
- 2001: IEEE 802.11d Regulatory Domains - approved
- 2003: IEEE 802.11g (Higher rate 2.4GHz PHY) – approved
IEEE 802.11i (Security) - approved
IEEE 802.11h (Spectrum Mgmt) - approved
IEEE 802.11f (interaccess point protocol) – approved
- 2005: IEEE 802.11e (MAC enhancements – QoS) – approved

Standard Revision Process

802.11-1999

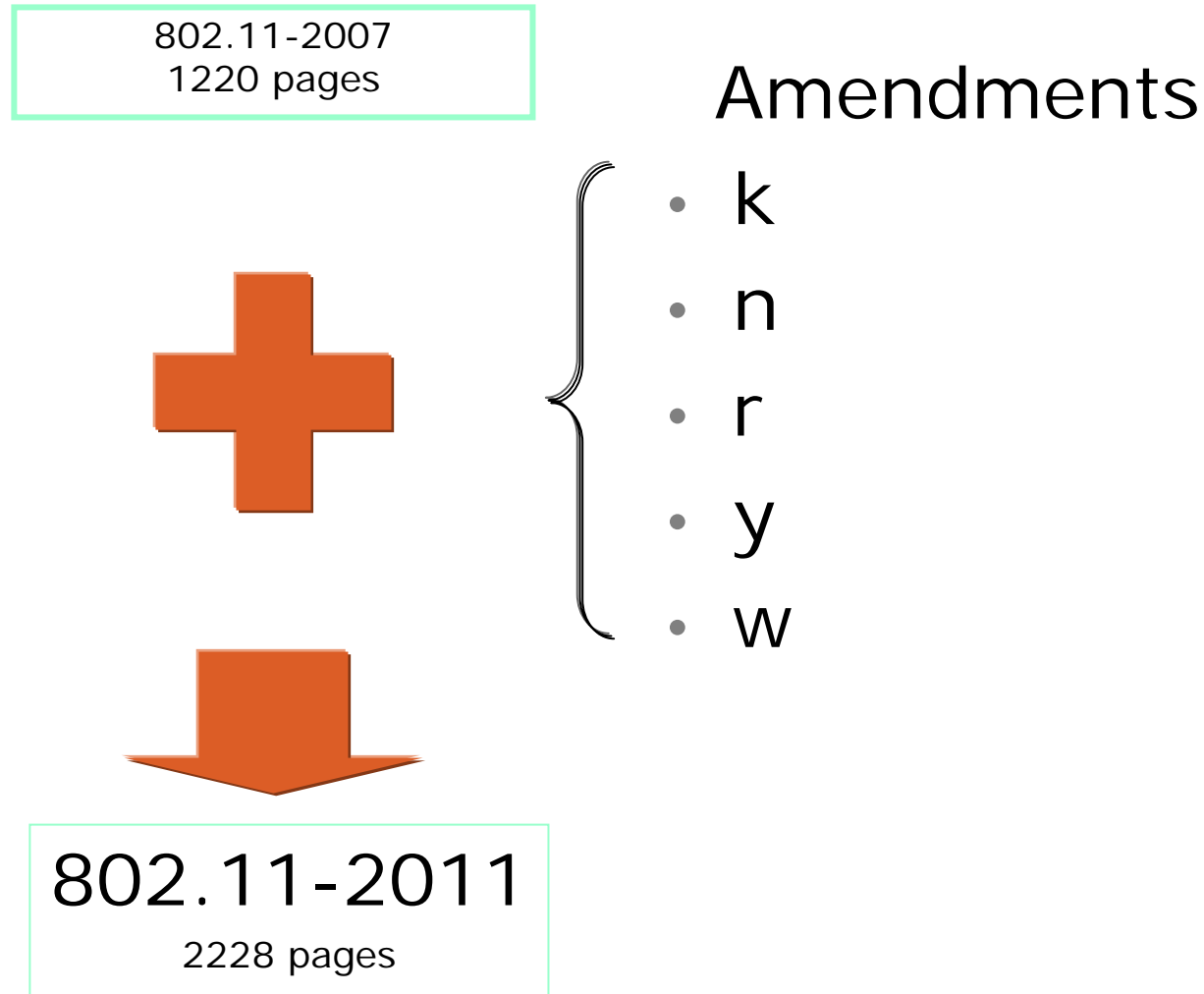


802.11-2007

Amendments

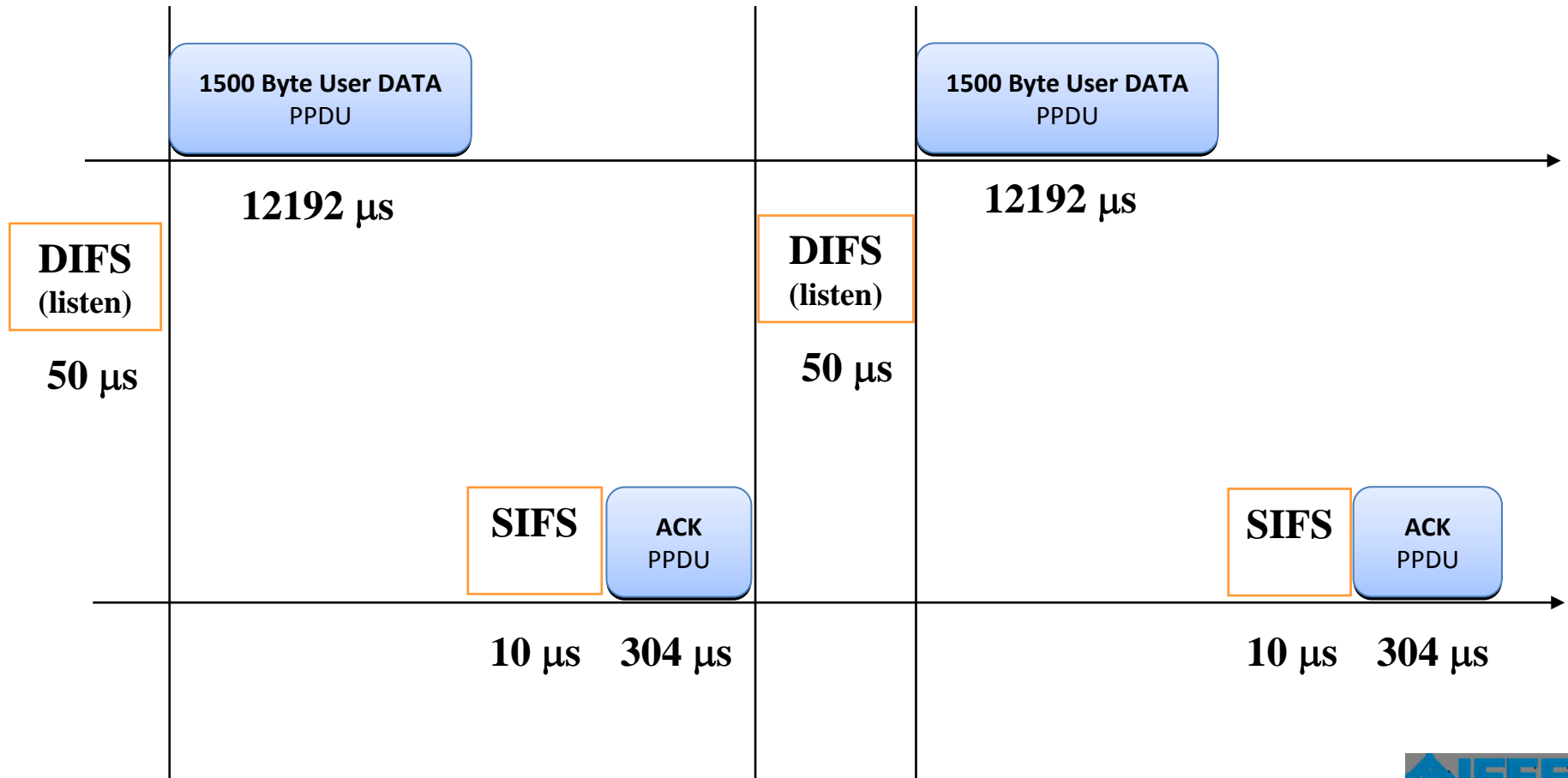
- a
- b
- d
- e
- g
- h
- i
- j

Standard Revision Process

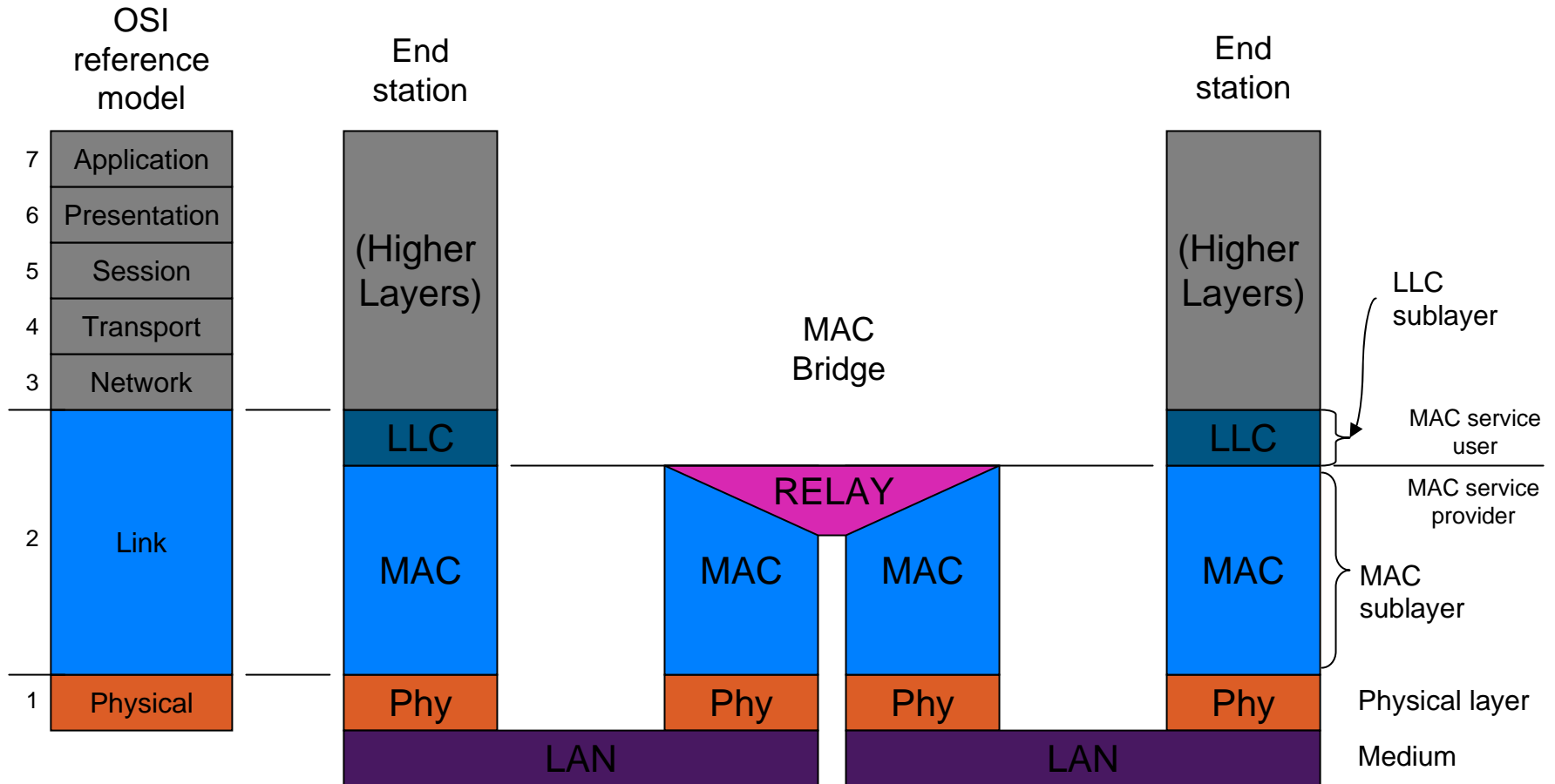


Standard Baseline

Basic Service Protocol - Listen Before Talk 1Mbps example



The 802 LAN Architecture



Standard Extensions

Overview of Project Objectives

PHY (.11, a, b, g, j, n, ac, ad)

- Change data rate options
- Change spectrum
- Project examples (.11, a, b, g, j, n, y, ac, ad, af, S1G)

MAC

- Security (i, w)
- Measurement and Management (k, v)
- Flow control and QoS (e, aa, ae)
- Time required to establish connection (p, r, FIA)
- Spectral Efficiency
- Regulatory behavior (d, h)
- Radio node connection topology (s, z)
- Connection with other networks (u)

Summary of Major PHY Projects

- A - 20 MHz BW, 5GHz
 - B - 20 MHz BW, 2.4 GHz
 - G - 20 & 40 MHz BW, 2.4 GHz
 - N - 20 & 40 MHz BW, 2.4 & 5GHz
-
- AC – 20 to 160 MHz BW, 5GHz
 - AD – 2 GHz BW, 60 GHz

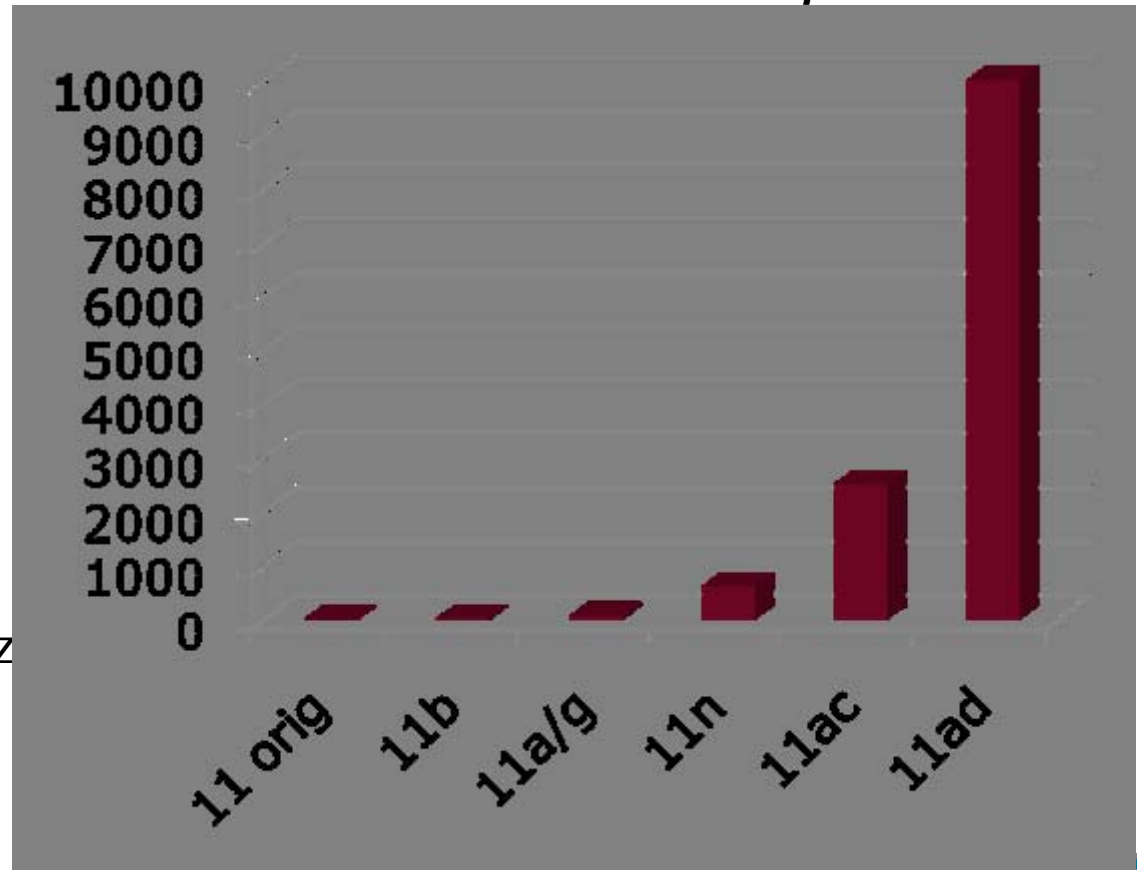
Summary of Major MAC Projects

- ▣ D – Country information
- ▣ E - QoS
- ▣ F – Inter AP communication
- ▣ H – DFS,TPC Spectrum sharing with radars in 5GHz
- ▣ J – Japan spectrum @ 4.9 GHz
- ▣ K – Radio Measurement
- ▣ P – Vehicular Environments
- ▣ R – Fast roaming
- ▣ S – MESH Networking
- ▣ U – Inter-Networking
- ▣ V – Network Management
- ▣ W – Secure Management Frames
- ▣ Z – Tunneled Direct Link
- ▣ AA – Video Transport
- ▣ AE – QoS for Management Frames

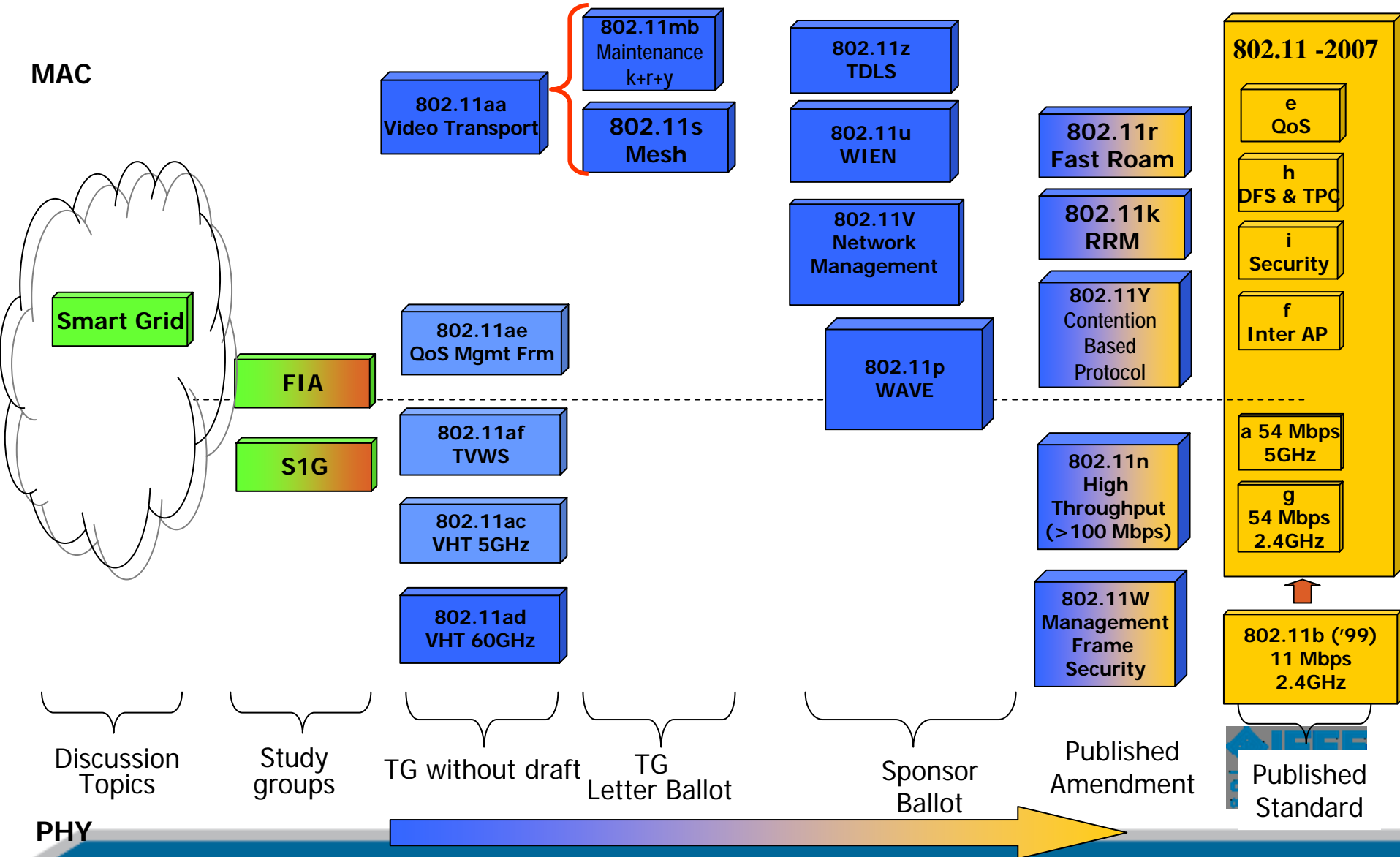
IEEE 802.11 – Key Technical Attributes

- Specifications for the Physical and MAC Layers
- Backward compatibility with legacy 802.11 standard
- Maximize spectral efficiency and performance
- Co-existence with other device sharing the 2.4GHz and 5GHz frequency bands

*802.11 Physical layer
Data Rates – Mbps*



IEEE 802.11 Standards Pipeline



Details on Recent Amendments

802.11n - High Throughput

- 20 & 40 MHz channelization
- 1 to 4 spatial streams
 - 1 stream for Client (Mandatory)
 - 2 stream for Access Point (Mandatory)
- ½ Guard Interval
- 56 tones (in 20MHz)
- 5/6 coding
- Green Field preamble
- Block aggregation
- Maximum PHY throughput of 600Mbps

- Status: Published

TGn Throughput

| | | Potential TCP throughput Improvement over legacy abg | | | |
|------|--------|--|--------|----------------|--------|
| | | No A-MPDU | | A-MPDU Enabled | |
| | | 20 MHz | 40 MHz | 20 MHz | 40 MHz |
| 1 SS | No SGI | 18% | 50% | 123% | 350% |
| | SGI | 22% | 54% | 145% | 381% |
| 2 SS | No SGI | 45% | 68% | 322% | 700% |
| | SGI | 50% | 73% | 363% | 727% |
| 3 SS | No SGI | 59% | 77% | 509% | 1000% |
| | SGI | 59% | 77% | 564% | 1095% |

802.11P Wireless Access in Vehicular Environments

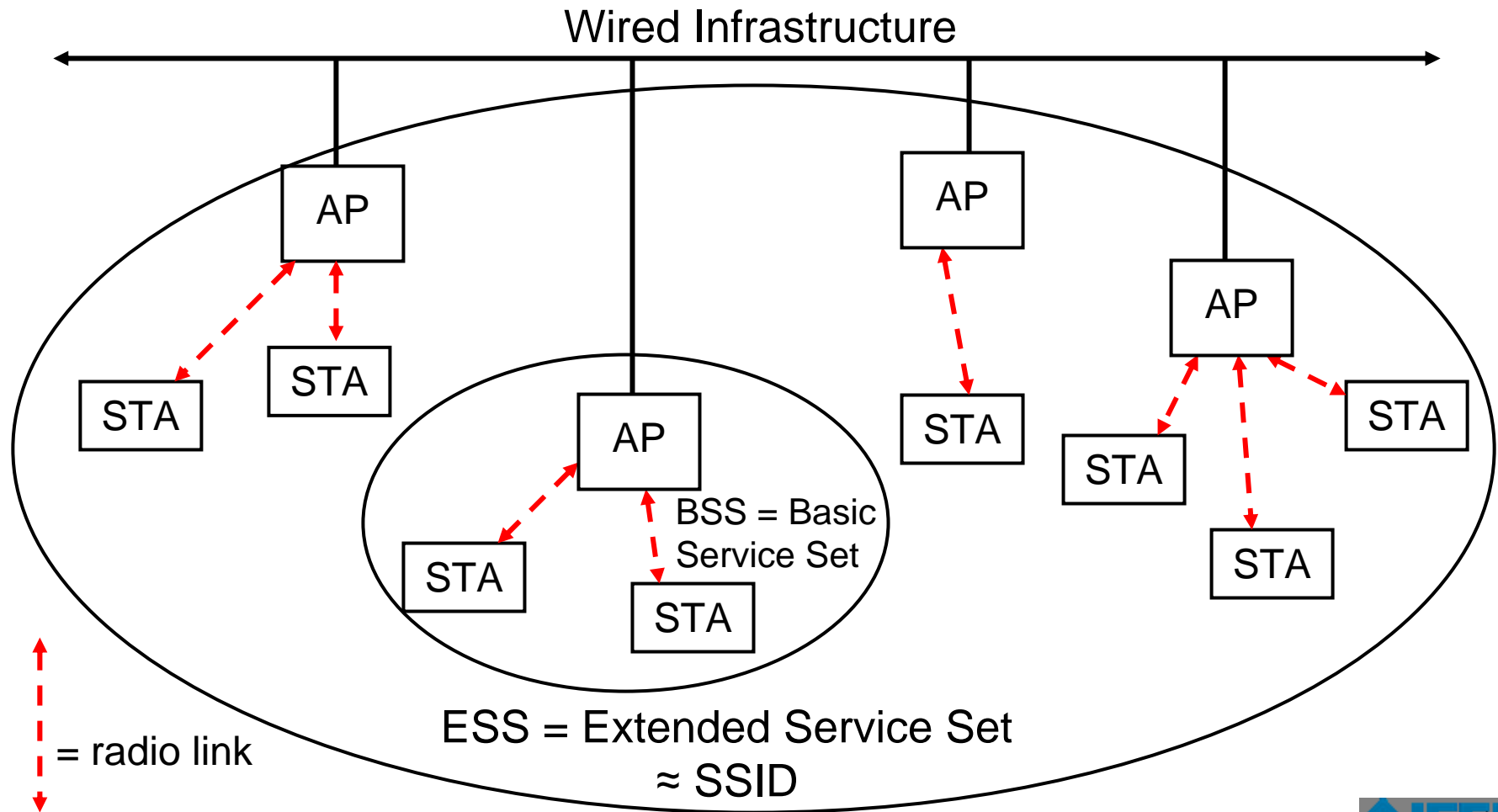
Wireless Access for the Vehicular Environment (WAVE)

- This Task Group will define enhancements to support data exchange between high-speed vehicles and between these vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz.
- Applications planned within the ITS domain (ITS services), including:
 - collision avoidance
 - traveller information
 - toll collection
 - commercial vehicle operations
 - transit operations
 - traffic management
 - connecting the vehicle to the Internet.
- Status: Produced draft 11.0 – preparing to go to publication

802.11s MESH

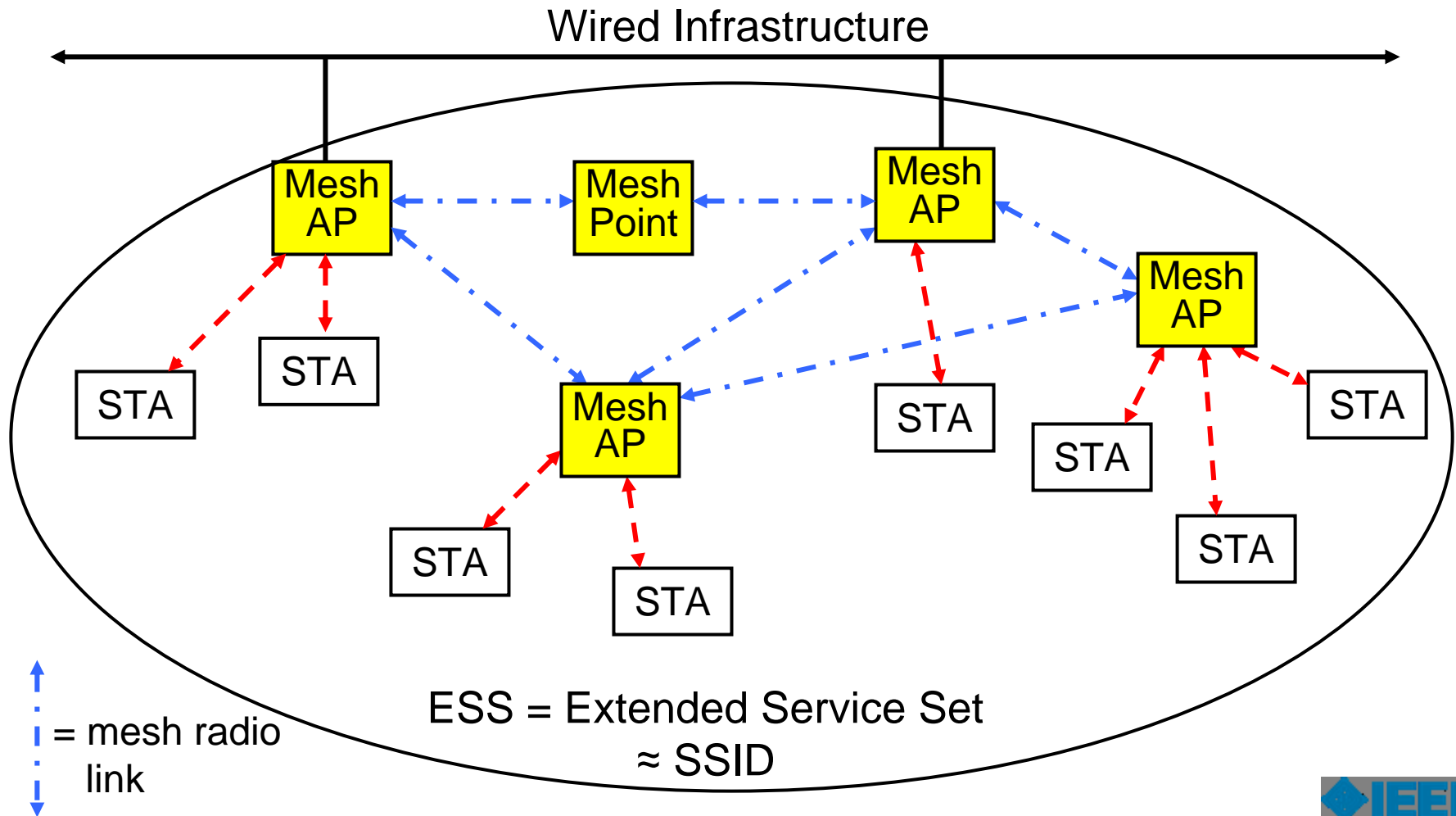
- An amendment to create a [Wireless Distribution System](#) with automatic topology learning and dynamic wireless path configuration.
 - Target number of packet forwarding nodes: ~32
 - Support unicast and broadcast/multicast traffic
 - Use 802.11i security or an extension thereof
 - Extensible routing to allow for alternative forwarding path selection metrics and/or protocols
 - Use the 802.11 four-address frame format or an extension
 - Interface with higher layers and connect with other networks using higher layer protocols
- Status: Produced draft 4.0 – preparing to go to Sponsor Ballot
 - Publication early 2011

Classic 802.11 Wireless LAN



Wireless Paradox: WLAN Access Points are Typically Wired

Unwire the WLAN with Mesh



Tgu – Wireless Interworking

Background

- As IEEE 802.11 hotspot deployment has become more widespread throughout the world, several problem areas have emerged with the way in which the hotspot behaves regarding its connection to external networks (e.g. the internet, cellular networks) which could be solved by standardization.
- As the diversity of hotspots have proliferated, users have started to become frustrated with the non uniformity of interworking systems (e.g. poor service definition, disparate registration procedures, non-ubiquitous roaming).
- Within the IEEE 802.11 community it was felt that an amendment to the IEEE 802.11 standard would be in order to address these problem areas. Generically these issues have been referred to as interworking, which refers to the functionality and interface between an IEEE 802.11 access network and any external network.

Objectives

- The primary objective of IEEE 802.11u, is to create an amendment to address interworking issues between an IEEE 802.11 access network and any external network to which it is connected.
- Interworking, is actually a collection of different functionalities:
 - Online Enrolment
 - Network Selection
 - Security
 - Authorization from Subscriber Network
 - Media Independent Handover Support
- Status: Produced draft 9.0 – preparing to go to publication

802.11V Network Management

- Explosive growth of 802.11 wireless LANs emphasized the need to
 - Maintain network quality and security
 - Manage the RF environment
 - largely driven by interference from neighbouring wireless networks
 - Secure the network to maintain privacy and prevent unauthorized use.
- Optimize the Network
 - improve the ability to shape the network
- Status: Produced draft 10.0 – preparing to go to publication

TGv D3.0 Content

1. BSS Transition Management
2. Channel Usage
3. Co-located Interference Reporting
4. Diagnostic Reporting
5. Event Reporting
6. Location Services
7. Maximum Multicast Rate Processing
8. Multicast Diagnostic Reporting
9. Multiple BSSIDs
10. Proxy ARP
11. WNM-Sleep Mode
12. Traffic Management
13. Timing Measurement
14. Traffic Filtering Service
15. Traffic Generation

TGv Content – Increased Station Power Saving

- Traffic Filtering Service
 - Enables the AP to filter traffic for the station, and deliver only frames of a specified type.
- WNM-Sleep Mode
 - Provides an additional, extended power save mode.
 - When used with the Traffic Filtering Service, can provide significant station power savings, and provide a “Wake on WLAN” service.
- Flexible Broadcast/Multicast service
 - Enables multicast frames to be sent at longer delivery intervals and higher data rates, improving performance of multicast applications, and reducing station “awake time”
- Proxy ARP
 - Enables stations to remain in power save mode longer
- TIM Broadcast – Enables stations to check for queued traffic without receiving a full Beacon frame.

Example TGv Based Applications

- “Wake on WLAN” Service– Stations sleep and are “awakened” when specific frames are received
 - Example application: User leaves corporate desktop in “sleep mode”, goes home, uses VPN from home to corporate LAN, wakes up and uses desktop remotely
 - Reduces power consumption of end devices, even stationary ones
- Improved client power saving
 - Proxy ARP, TIM Broadcast, FBMS, Sleep Mode, Traffic Filtering
- “Wireless Speakers” – Use Location services timing measurements to support audio synchronization
- Improved Multicast Performance
- Network Diagnostic Analysis/Troubleshooting
 - Co-located Interference Reporting, Diagnostic Reporting, Event Reporting, Multicast Diagnostics Reporting

802.11w – Protected Management Frames

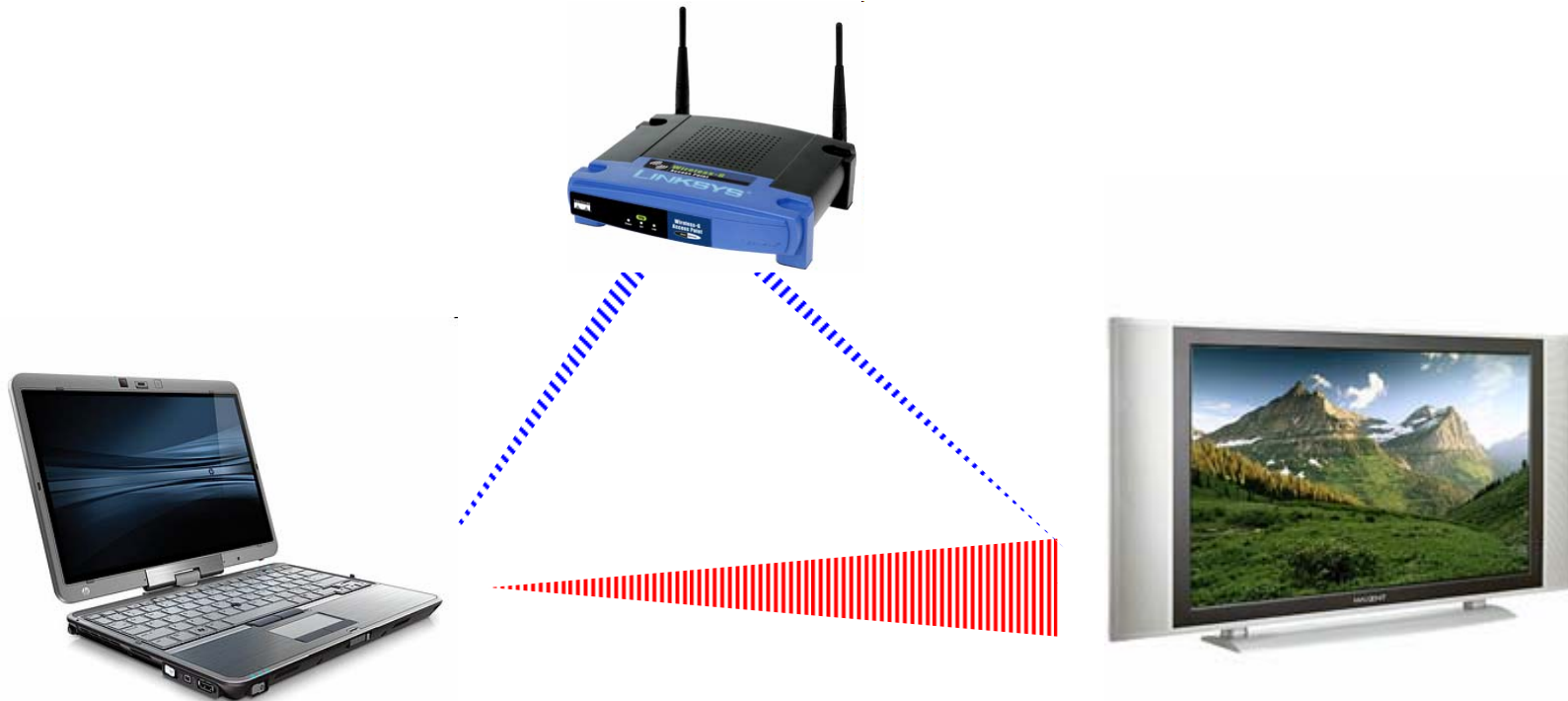
- One of the frame types defined in 802.11 is “Action” sub-type “Management”
- Management frames were previously less well protected than data frames.
- The objective of this was to improve the security by providing data confidentiality of action management frames, deauthentication and disassociation frames
- This standard protects networks from attack by malicious systems that forge disassociation requests that appear to be sent by valid equipment
- Status: Published

802.11z Tunnelled Direct Link

- The purposes of this amendment are to create a new DLS mechanism which:
 - a) Does not require access point upgrades (i.e. supports DLS operation with the non-DLS capable access points),
 - b) Which supports power save mode (when associated with either DLS or non-DLS capable access points), and
 - c) Continues to allow operation of DLS in the presence of existing DLS capable access points
- **Status: Produced draft 8.0 – preparing to go to publication**

P802.11z example

- Access Point maintains control over network connection air times
- However, device pairs can optimize their conversation and use modes not supported by the access point



802.11 AA Video Transport Stream

- A set of enhancements to 802.11 MAC to improve video streaming performance significantly while maintaining data and voice performance.
- Enhancements to the 802.11 MAC for robust video streaming offer:
- Interworking with relevant 802.1 mechanisms including, but not limited to, 802.1Qat, 802.1Qav and 802.1AS
- Graceful degradation of video streams when there is insufficient channel capacity.
- Increasing robustness in overlapping BSS environments, without the requirement for a centralised management entity.
- Modifying EDCA timing and parameter selection for video transport
- Improving Multicast/Broadcast video streams for link reliability with low delay and jitter.
- Status: Produced draft 0.05 – preparing to go to ballot

802.11AC Very High Throughput <6GHz

- Goal: A multi-user BSS peak aggregated throughput of at least 1Gbps as measured at the MAC data service access point (SAP)
- Robust and flexible bandwidth management: native support for simultaneous multiple bandwidth operation (within a given frequency band)
- Add optional outdoor compatible delay spread resistance
- Below 6GHz carrier frequency operation excluding 2.4GHz operation and ensuring backward compatibility with legacy IEEE802.11a/n devices in the **5GHz unlicensed band**.
- Status: Working on First draft – planning to begin balloting in November

802.11AD Very High Throughput

- **60 GHz PHY**
- **2GHz channel bandwidth**
- **4Gbps data rates**

- Market drivers for Very High Throughput wireless LAN, include:
 - Never ending quest for for higher performance computing drives higher processing power.
 - Media appliances are moving to HD content, driving 10X storage capacity and bandwidth requirements.
 - Mainstream **Wired** LAN products have shifted to Gigabit per second speeds. The trend for a purely wireless campus drives the need for wired equivalent multi-Gigabit per second wireless solutions.

- Aggregate capacity increase using reduced cell sizes.

- Status: Working on technology submissions for first draft – planning to begin balloting in September

802.11ae QoS for Management Frames

- This project will consider the classification and prioritization of management frames
- All IEEE 802.11 MAC management frames are transmitted at the highest priority.
- IEEE 802.11 amendments 'k', 'y', 'w', 'v', and 'u' have introduced features that rely on management frames, which are essential for network operation.
- In some cases, the management traffic will contend with network data traffic and reduce the performance of certain WLAN applications.
- Providing a mechanism to prioritize management frames will enable improved performance of IEEE 802.11 networks
- This project will consider management frames that are used in both pre- and post- association.
- Management frames of subtype Action will be considered. Other management frame types may be considered.
- These mechanisms should allow for administrative configuration of priorities.
- Status: Working on first draft preparing to go to first ballot in November

802.11af Operation in the TV White Spaces

- With the global transition to Digital TV (DTV), sub-Gigahertz RF spectrum is becoming available, much of it for unlicensed, license exempt and/or lightly licensed use. This project will make the necessary MAC and PHY changes to enable 802.11 products to take advantage of this additional spectrum.
- On November 4, 2008, the United States FCC approved Report & Order 08-260, allowing unlicensed use of TV band spectrum, in accordance with Part 15. Subpart H of FCC rules. Ofcom (UK) is in the process of making this Digital Dividend band available, and the EU has conducted a consultation on the band. Other regulatory domains are expected to follow.
- Status: Produced draft .02 – preparing to go to first ballot in May

S1G – Study Group

- Project proposes to use spectrum below 1 GHz.
- Lower frequency will increase range
- Channel bandwidths have typically been 20 MHz or more, lower channel bandwidth will be required.
- Status: Study Group – planning to begin amendment in September

FIA

- Project goal is to reduce initial association time to allow fast connection and data transfer in situations where users are very dense and highly mobile.
- Status: Study Group – planning to begin amendment in September

Fast Initial Authentication (FIA) (11-10-0371r3)

- New Study Group Approved March 19
- Chair pro tem, Hiroshi Mano , Root Inc
- Speed of moving devices is limited by the 14 step authentication process
- Authentication and Key Management time can be much larger than data exchange (for short status or location updates)
- Initial secure authentication and association process is very inefficient
- Building a secure, fast initial authentication **that**
- **a) is suitable for users experiencing a small dwell time in a cell (due to high mobility or small cell sizes users)**
- **b) scales for large number of simultaneously occurring initial authentications**

Future Projects

- Security
- Low power consumption
- Higher speed
- Longer range
- Spectral efficiency
- QoS
- Spectrum Sharing/ Cognitive Radio/ SDR
- Beamforming/ Smart Antennas

802.11 References

- <http://grouper.ieee.org/groups/802/11>