

# IEEE 802.11

## 802.11 Wireless Local Area Networks

Bruce Kraemer  
Chair 802.11  
V09

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IEEE-SA Standards Board Operation Manual (subclause 5.9.3)

# Introduction and Agenda

History

Market

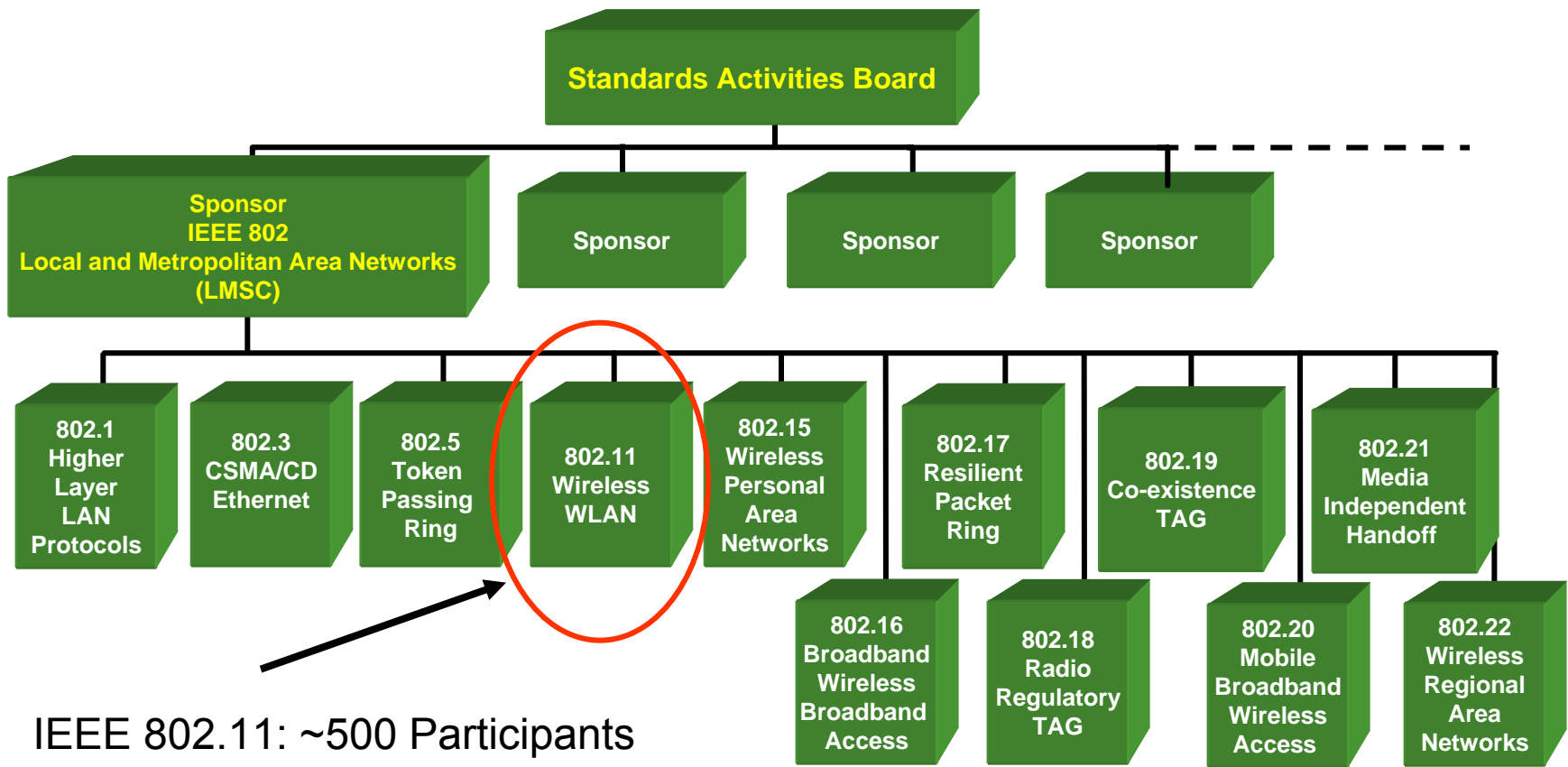
Technical Challenges

Amendment Project details

References

# IEEE 802 Organization

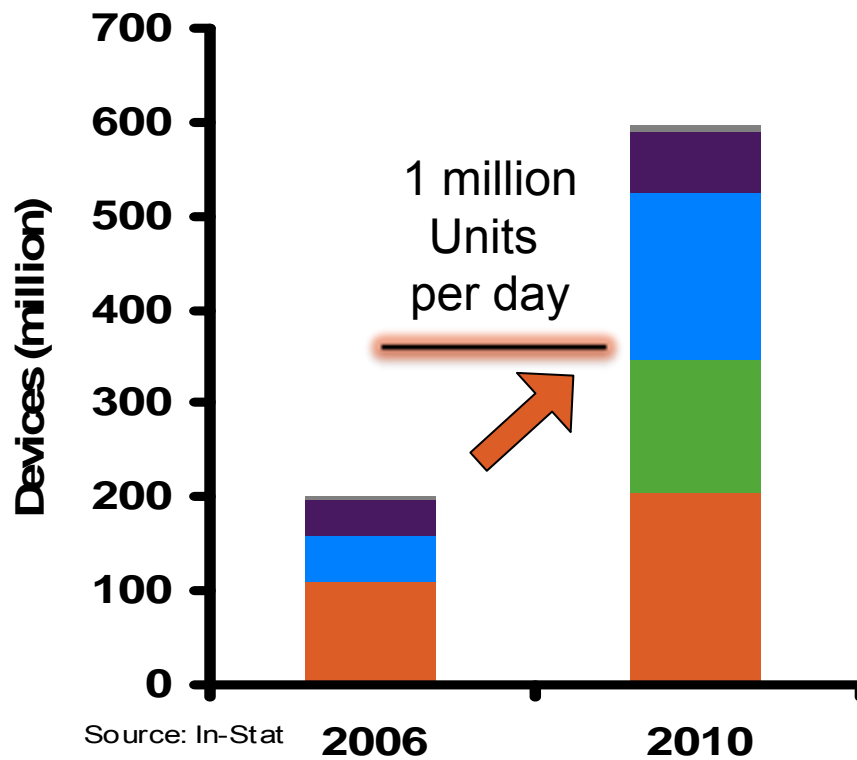
## IEEE Standards Association



IEEE 802.11: ~500 Participants  
Voting Members ~250  
[www.ieee802.org/11](http://www.ieee802.org/11)

# Market Size and Trends

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



- Enterprise APs
- Home/SOHO
- CE
- Phones
- PCs

# 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

# Activity History

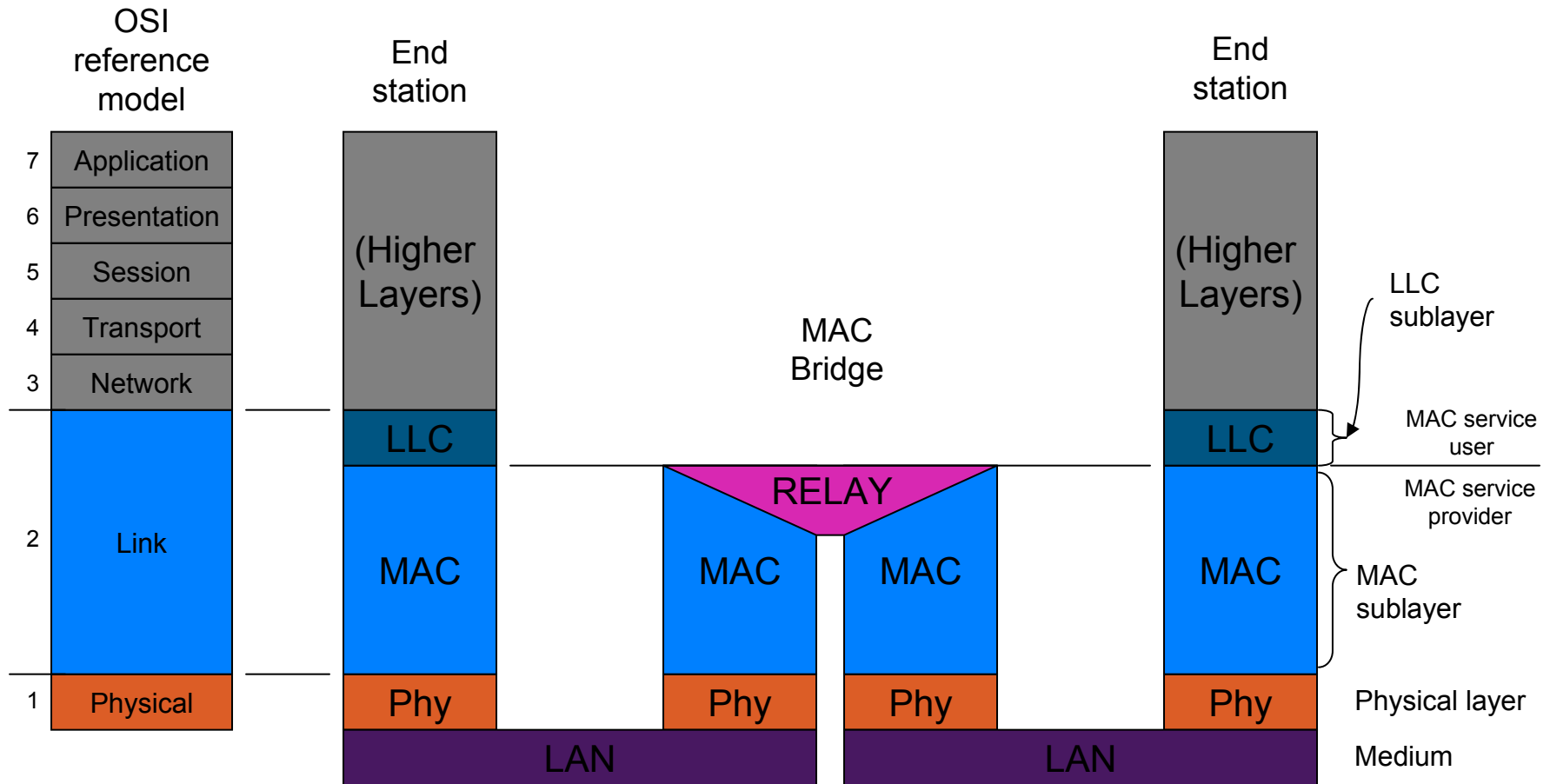
- Feb 14, 1876: Bell files telephone patent
- June 1897: Marconi work- "Signaling through Space without Wires"
- 1970: ALOHAnet operational (Abramson, 9600 baud)
- 1976: Metcalf & Boggs: "Ethernet: Distributed Packet-Switching for Local Computer Networks"
- 1980: Project 802 formed (1 Mbps initially, revised to 20 Mbps 1982) (Feb 1980 , 125+ attendees)
- 1980: Ethernet Bluebook published (September , Digital. Intel, Xerox)
- 1981: FCC issues NOI for unlicensed spectrum
- 1983: First version of 802.3 10Base5 spec completed
- 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



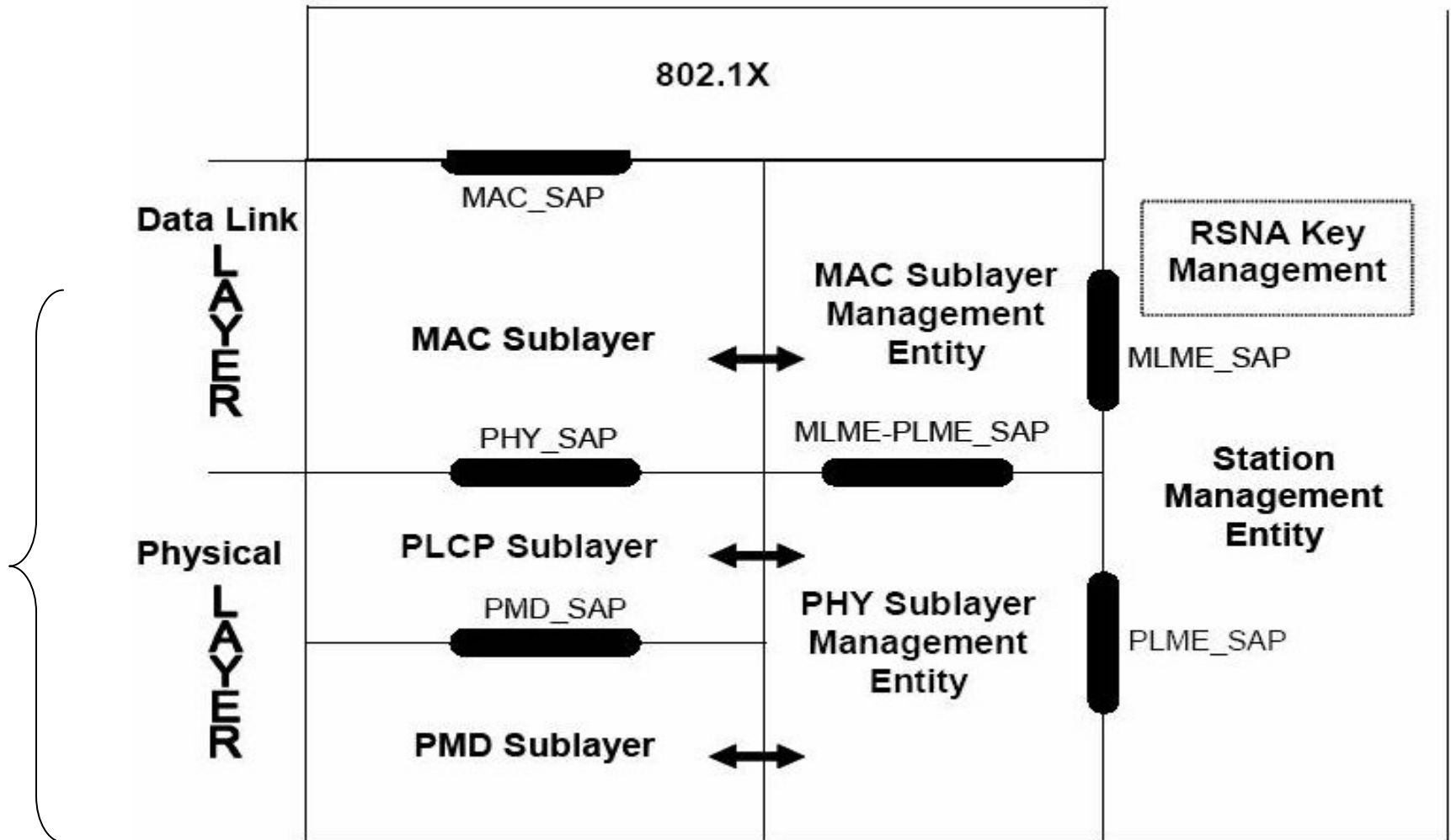
# Activity History

- 1994: 1st wireless radios - Inventory control
- 1997: IEEE 802.11 standard approved (2.4GHz – 1Mbps)
- 1998: UNII (Unlicensed National Information Infrastructure) Band - 5 GHz
- 1999: IEEE 802.11 standard achieved ISO/IEC approval
- 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

# The 802 LAN Architecture



# 802.11 Project Scope (cont.)



# Air is a Poor Substitute for Wire or Fiber

- Large Scale fading
  - Attenuation (distance, obstructions)
  - Delay
- Small scale fading
  - Multipath (Reflections)
  - Doppler
  - Frequency selective fading
- Shared

# 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

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

# Technology Solutions

## PHY

- Multiple Antennas
- Forward Error coding
- Modulation
- Media access

## MAC

- Quality of Service
- Network measurement & Management
- Security

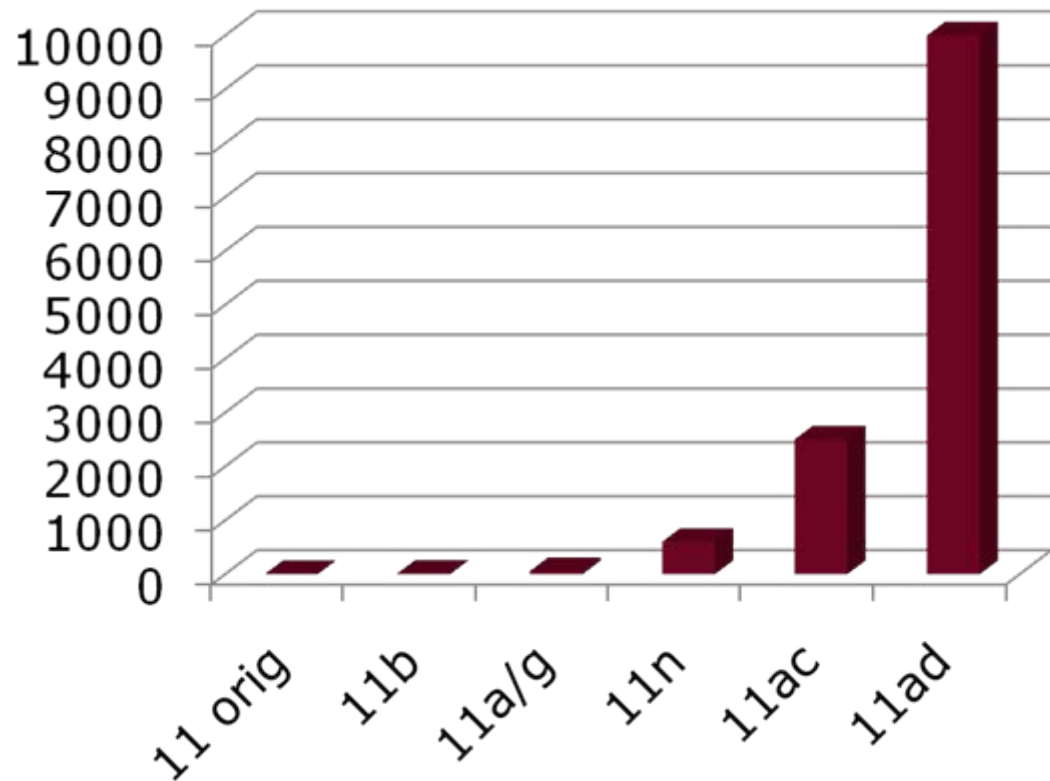
# Summary of Major PHY Projects

- 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

# 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*

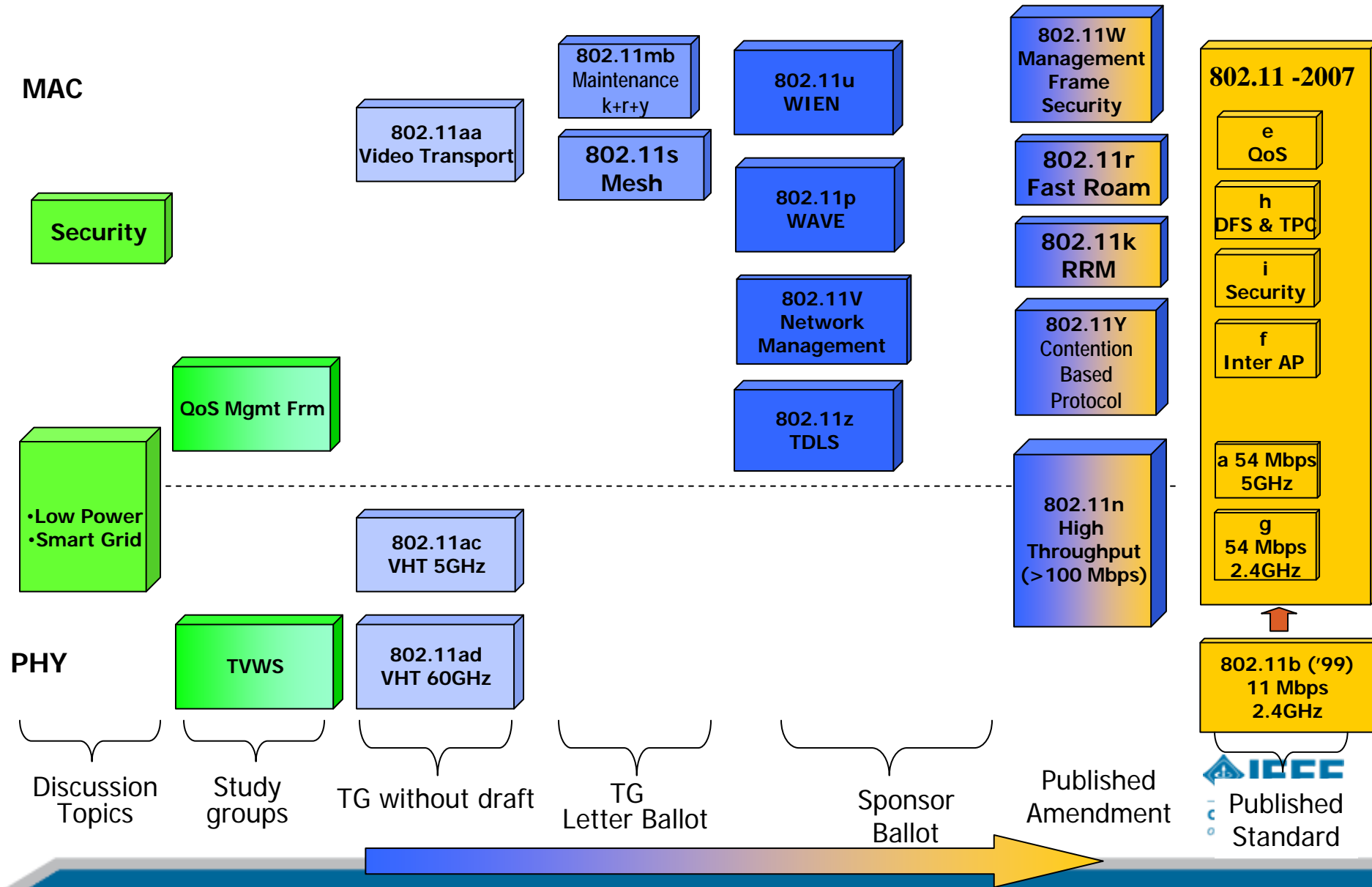




# Summary of Major MAC Projects

- 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 Standards Pipeline



# 802.11n - High Throughput

- 20 & 40 MHz channelization
- 1 to 4 spatial streams
  - 1 stream for Client (Mandatory)
  - 2 stream for Access Point (Mandatory)
- $\frac{1}{2}$  GI
- 56 tones (in 20MHz)
- 5/6 coding
- Green Field preamble

# TGn

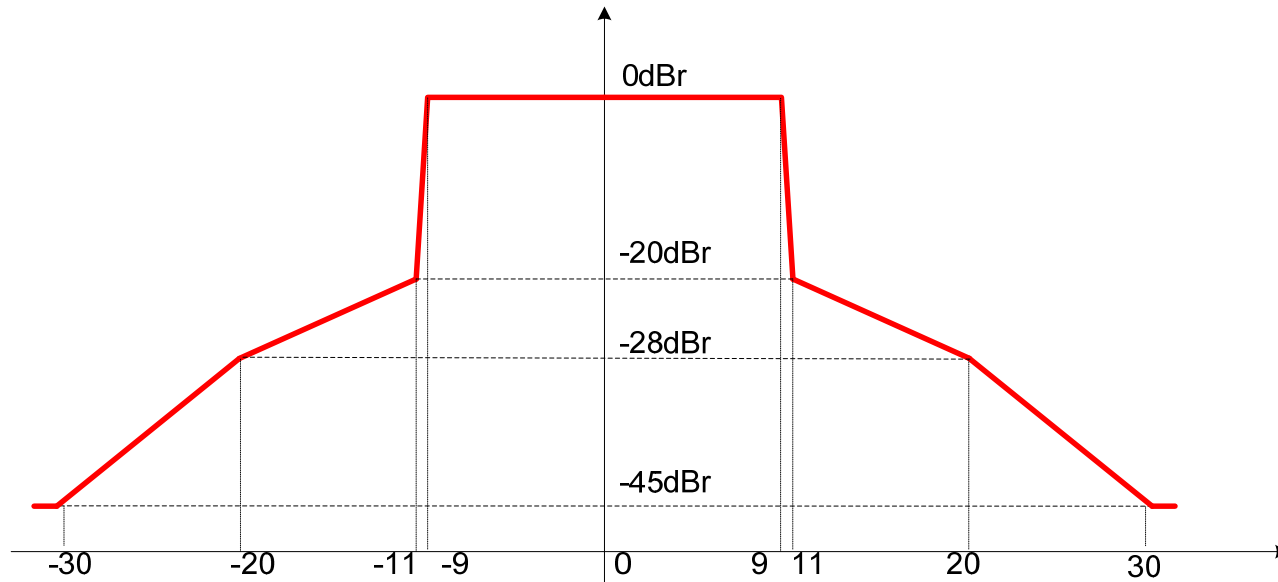
## ■ **Media Access Control Layer Enhancements: Efficiency**

Frame aggregation and block acknowledgements. In legacy 802.11 a/b/g systems an acknowledgment (ACK frame) is sent from the receiving station to the transmitting station to confirm the reception of each frame. If the transmitter does not receive an ACK, it retransmits the frame until an ACK is received. The ACK mechanism is also used in rate adaptation algorithms so that if too many retransmissions are required, the transmitting station drops to a lower data rate. The ACK mechanism adds robustness to 802.11 and ensures that all transmitted frames eventually get to the receiver, but this robustness comes at the price of protocol efficiency since for each transmitted frame, an additional ACK frame is also sent.

# 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%

# 802.11n - 20MHz Channel Mask



- ***New 20MHz spectral mask***
- Same as IEEE 802.11a Mask
- Modified signal floor at 30MHz
  - From -40dBm to -45dBm

# 802.11P Wireless Access in Vehicular Environments

- “Wireless Access in Vehicular Environments” (WAVE) refers to what was previously called Dedicated Short Range Communications (DSRC). The National ITS Architecture has identified DSRC as a primary means of communicating between the roadside and vehicles, and from one vehicle to another.
- 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.

# TGp

## Wireless Access for the Vehicular Environment (WAVE)

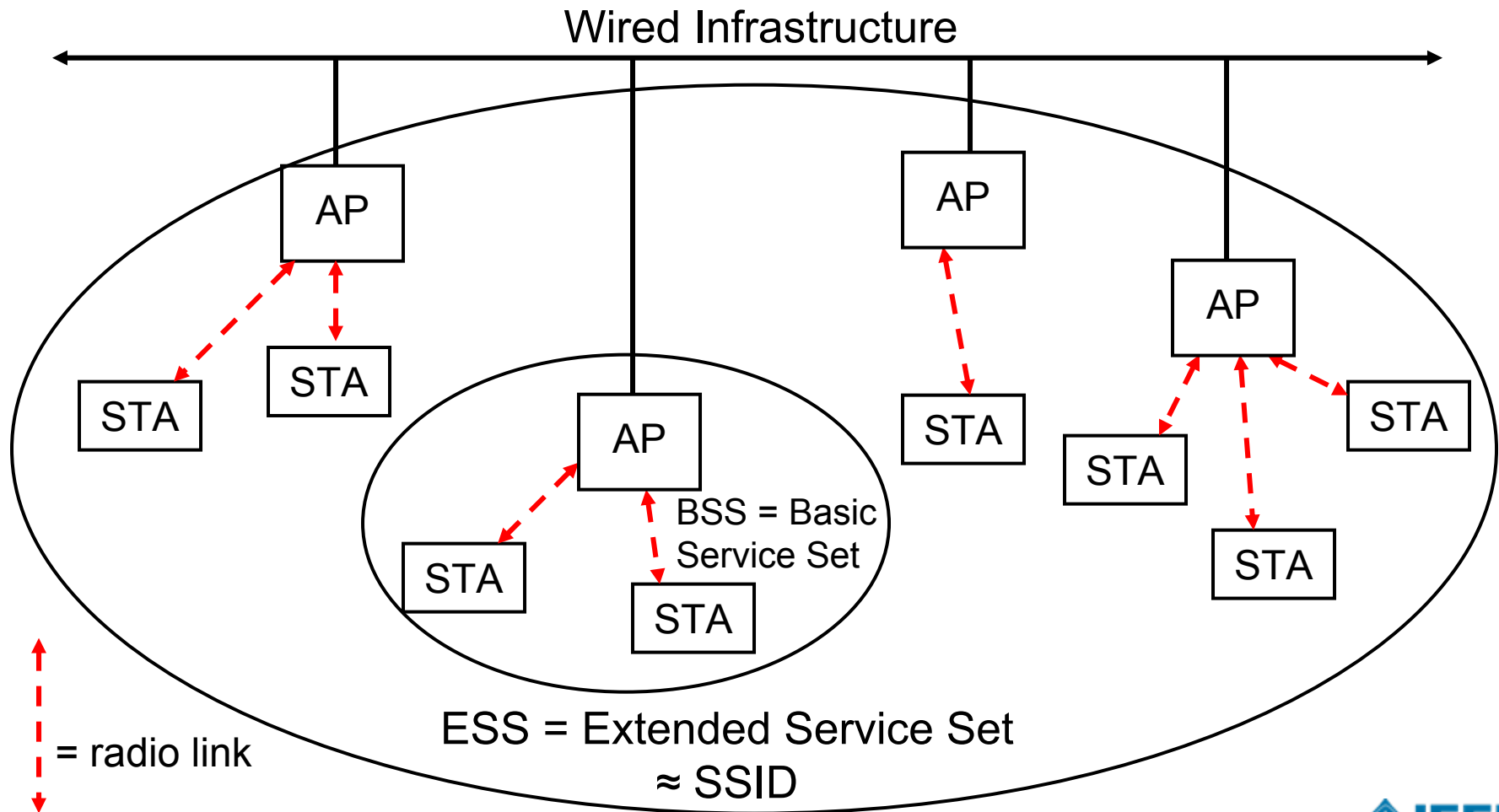
- This Task Group will define enhancements to support data exchange between high-speed vehicles and between these vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz.
- **While there is a priority within North America to support the US National Intelligent Transportation System (ITS) Architecture, the intent is to develop an amendment to IEEE 802.11 that will be applicable on a global basis.**
- **The US DoT, most of the major automobile manufacturers, public agencies throughout North America, DSRC device manufacturers, and many potential service providers have been involved in the DSRC program and actively support it.**



# 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

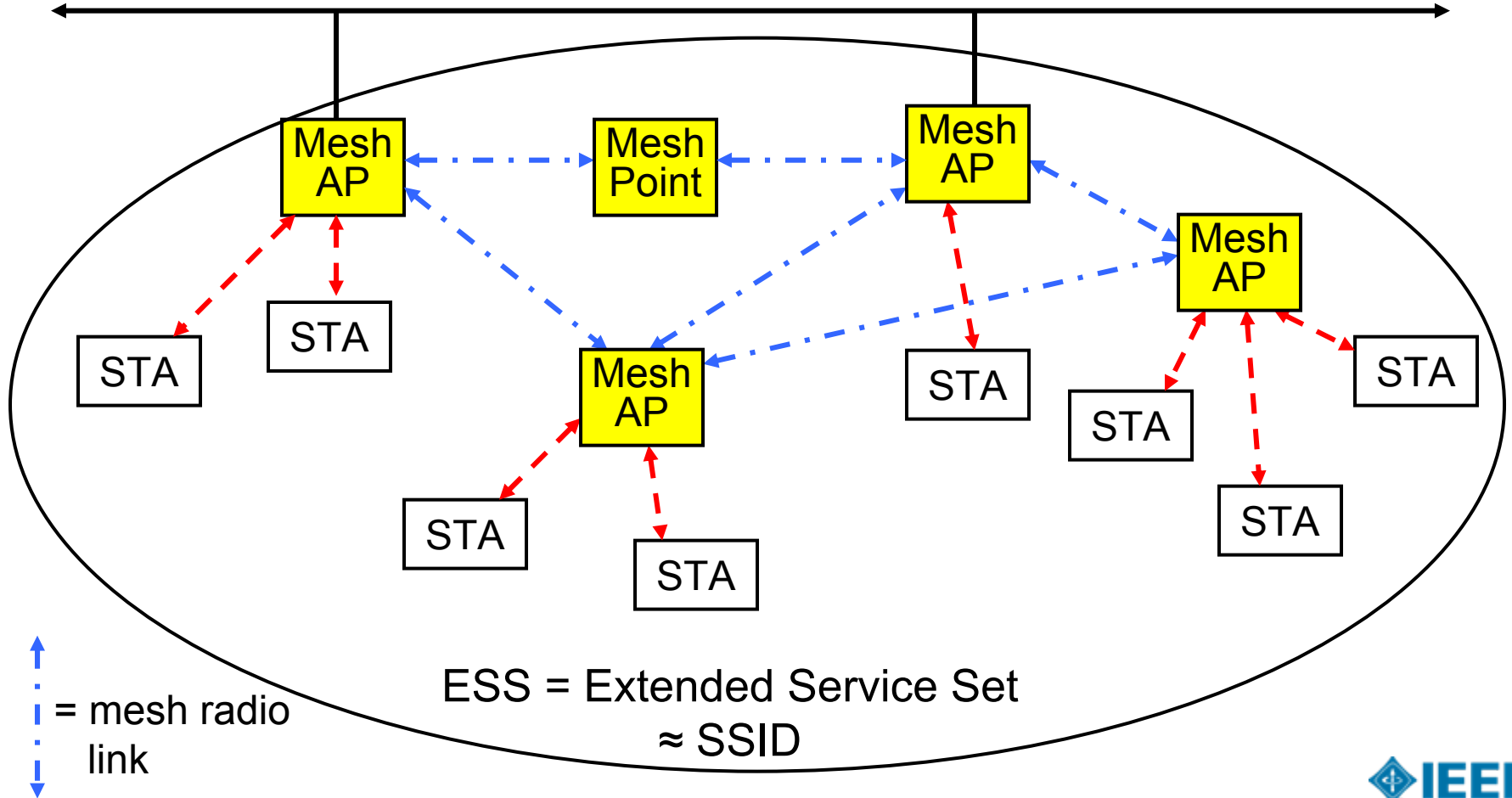
# Classic 802.11 Wireless LAN



Wireless Paradox: WLAN Access Points are Typically Wired

# Unwire the WLAN with Mesh

Wired Infrastructure



# 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

# U Interworking with External Networks

- Hotspot use is currently gaining interest not only with ISPs but also with Cellular operators. It will become an increasing larger issue in public communications and it is felt by many that the interworking of hotspots to external networks must be addressed by IEEE 802.11.
- Interworking will increase the range of services and market reach of IEEE 802.11 devices. This will stimulate more deployments of IEEE 802.11 networks. Additionally it will enable IEEE 802.11 devices to become high-end terminal devices allowing user access to services only available within the cellular communications market. It is felt that both terminal and access point manufacturers will benefit from this expansion.
- Compliance with the amendment will also enable the roaming of IEEE 802.11 terminal equipment into any hotspot throughout the world. Together with the work of 3GPP and 3GPP2, any cellular subscriber with compliant equipment could become a potential user.

# 802.11V Network Management

- Explosive growth of 802.11 wireless LANs
- Maintaining network quality and security requires control
- The need to manage the RF environment is driven by interference from neighboring wireless networks
- The need to secure them by the desire to maintain privacy and prevent unauthorized use.
- In the enterprise these needs are similar, but security is much more than just privacy, it is the control of corporate secrets, customer profiles and other information that may be critical to the survival of the organization.
- Network manageability is also the key to maintaining network flexibility; the ability to shape the network

# TGv

## Objective

- To develop extensions to the 802.11 MAC/PHY to provide network management for STAs
- The current IEEE 802.11 specification implies that stations may be managed via a Simple Network Management Protocol (SNMP). The use of SNMP introduces the following problems:
  - 1. Very few stations in the market include SNMP capabilities.
  - 2. The use of secure SNMP protocol (e.g. SNMPv3) requires significant pre-configuration of the station.
  - 3. Management of a station may be required prior to the establishment of an IP connection.

# TGv Schedule History

- Wireless Network Management SG formed – Jan 2004
- Wireless Networks Management TG formed – Nov 2004
  - ...Enable management of stations...e.g. monitoring, configuring, updating
- Call for proposals – Sept 2005
- Base line accepted - January 06
- Submissions addressing objectives - Started in March 06
- TG Ad-Hoc Draft Internal Review - October 06 to July 2007
- Initial Letter Ballot (1.0) July 2007
  - LB 108 Results: 132 yes -77 no -38 abstain, 63% approval, fails
- Letter Ballot (2.0) Jan 2008
  - LB 123 Results: 126 yes -62 no -34 abstain, 67% approval, fails
- Letter Ballot (3.0) May 2008 - ongoing



# 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. TIM Broadcast
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.

# TGv Content – Station Management

- BSS Transition Management
  - Provides enhanced load balancing capabilities; Enables the AP to direct the station to transition to a specific AP or set of APs.
- Co-located Interference Reporting
  - Station provides information on any collocated interference. AP can use this information to manage communication to the station so that the effect of interference is limited.
- Channel Usage
  - AP can advertise channels for the stations to use for peer-to-peer connections
- Diagnostic Reporting
  - Enables an AP to gather Manufacturer information and Current Configuration, or to request that the station associate/802.1X authenticate to another AP.
- Event Reporting
  - Stations reports Transition, RSNA, Peer to Peer Link and Syslog Events

## TGv Content – New Services

- Location Services
  - Enables enhanced location reporting
- Timing Measurement, to determine location, enable new applications
  - Determine location of Wi-Fi Tags
  - Support audio synchronization for Wi-Fi speakers
- E-911 Location format advertisement
  - Supports E-911 services

# TGv Content – Performance optimization

- Multicast Diagnostics Reporting – Provides feedback to the AP on dropped multicast frames, to improve multicast performance.
- Multiple BSSID Support – Reduces the number of Beacon frames sent when an AP supports multiple BSSIDs (Virtual APs).
- Multiple SSID – Reduces the number of Probe Request frames sent by a station.
- Traffic Generation – Enables a station to indicate the type of traffic it will generate.
  - Application example – voice handsets

# 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

# 802.11z Tunneled 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



# 802.11 AA Video Transport Stream

- The performance of video streaming is not always of acceptable quality.
- A set of enhancements to 802.11 MAC can improve video streaming performance significantly while maintaining data and voice performance.
- Enhancing the 802.11 MAC to address video streaming performance issues will extend the applicability to 802.11 and eliminate the need for proprietary implementation and/or competing standards.
- This amendment defines enhancements to the 802.11 MAC for robust video streaming, while maintaining co-existence with other types of traffic. The MAC enhancements specified in this amendment are:
  - Interworking with relevant 802.1 mechanisms including, but not limited to, 802.1Qat, 802.1Qav and 802.1AS
  - Enabling 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.

# 802.11AC Very High Throughput <6GHz

- 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.

# 802.11AD Very High Throughput

- Market drivers for Very High Throughput wireless LAN, include:
  - Never ending quest for for higher performance computing drives higher processing power. IO and Network speeds needs to grow proportionally to maintain comparable system level performance and cater to a positive user experience.
  - Media appliances are moving to HD content, driving 10X storage capacity and bandwidth requirements, wireless LAN throughput must grow in order to serve those media links at home and in the office.
  - 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.
  - As wireless network density grows, there exists an increasing need for additional capacity and reduced cell sizes. Additional high bandwidth channels are needed for efficient support of high throughput usage.
  - Corporate computing is shifting to a centralized processing model with lower cost “thin” clients that act as “semi-dumb terminals”. With a motivation to reduce Capital and Operational Expenditures, this new model changes the nature of network traffic and drives much higher KVM (Keyboard, Video, Mouse) content, which in turn drives increases in bandwidth and reduction in latencies.

# 802.11ae QoS for 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 the classification and prioritization of management frames
- 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.

# 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.

# Unlicensed Frequency Bands

- ▣ < 700 MHz
- ▣ 900 MHz
- ▣ 2.4 GHz
- ▣ 5 GHz
- ▣ 60 GHz

# Future Projects

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

# Publication Examples

- IEEE Wireless Communications
- IEEE Network
- IEEE Communications Magazine
- IEEE Transactions on Wireless Communications
- IEEE Spectrum
- Proceedings of the IEEE
- IEEE Transactions on Mobile Computing



# Recently Published Papers re 802.11

- Selfishness in Mesh Networks
- MAC Layer Misbehavior in Wireless Networks: Challenges and Solutions
- Designing VoIP Session Management over Interworked WLAN-3G Networks
- The need for Access Point Power Saving in Solar Powered WLAN MESH Networks
- Interworking of WLAN-UMTS Networks
- A Scalable Monitoring System for 802.11 Wireless Networks
- Toward Dependable Networking: Secure Location and Privacy at the Link Layer
- Handover Management in Integrated WLAN and Mobile WiMAX Networks
- Minimum Interference Channel Assignment in Multiradio Mesh Networks
- An Equal-Spacing-Based Design for QoS Guarantee in 802.11e HCCA Wireless Networks
- New MAC Scheme Supporting Voice/Data Traffic in Wireless Ad Hoc Networks
- Improving Security of Real-Time Wireless Networks Through Packet Scheduling
- A Cross-Layer Approach for Per-Station Fairness in TCP over WLANs
- Revisiting the Hidden terminal Problem in a CSMA/CA Wireless Network

# References

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