

# IEEE 802.11 WLANS - WiFi Evolutions -

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#### Wi-Fi Evolution – Long-Range Extension

- □ IEEE 802.11af-2013
- □ IEEE 802.11ah







## IEEE 802.11af: TV White Space (TVWS)

Motivation

- TV channels (e.g., 54–698 MHz in Korea) are not utilized for 24 hours a day
- Superior propagation characteristic of low frequency band
- □ Super WiFi (or 802.11af) defines TVWS spectrum sharing
  - Among unlicensed 802.11af devices and licensed services (TV broadcast)

□ PHY

- Based on 802.11ac PHY
- Utilizes (non-adjacent) 6-8 MHz TV channels
- □ MAC
  - Geo-location Database (GDB)-based channel access







## IEEE 802.11ah: Sub 1 GHz

- Motivation
  - Superior propagation characteristic of low frequency band
  - Unlicensed spectrum available at ~900 MHz
- Operation at sub 1 GHz excluding TVWS
- □ Large-scale low-rate applications (e.g., smart grid)
  - Support of more stations (~8,191 stations)
  - Deep power saving
- □ Scarcity of available bandwidth
  - 10 times down-clocking 802.11ac's PHY (2~16 MHz & extra 1 MHz channel support)







#### IEEE 802.11ah: Sub 1 GHz

 $\Box$  Transmission range w/ tx power = 200 mW

- Only consider path loss effect
- Based on minimum input level sensitivities to determine successful decoding



Weiping Sun, Munhwan Choi, and Sunghyun Choi, "IEEE 802.11ah: A Long Range 802.11 WLAN at Sub 1GHz," Journal of ICT Standardization, vol 1, issue 1, May 2013.





## Capacity vs. Coverage

□ Various rates and coverage due to different spectrum

- Low frequency spectrum  $\rightarrow$  long range
- High frequency spectrum → high rate







#### Wi-Fi Evolution – Greater Ease of Use

- □ IEEE 802.11ai
- □ IEEE 802.11aq
- □ Wi-Fi Direct & Wi-Fi Display
- □ Passpoint







## IEEE 802.11ai: Fast Initial Link Setup

- Motivation
  - Initial link setup is slow and burdensome to users
- Aims at Fast Initial Link Setup (FILS) (< 100 ms)</p>
- □ Approach
  - Optimizations in AP/network discovery, concurrent cross-layer configuration
  - Passive scanning
    - FILS Discovery frame delivers partial information of beacon more frequently
  - Active scanning
    - Adaptively omit or delay probe frames





## IEEE 802.11aq: Pre-Association Discovery

- Motivation
  - Diversified service categories of Wi-Fi
    - Internet access, 3D printer, video streaming, free or not
  - Find "right" AP become more complex
- □ 802.11aq enables **pre-association service discovery** 
  - By delivering more considerate information to users before association
- Consider how to utilize existing service discovery/description schemes
  - UPnP, Bonjour, ANQP





## Wi-Fi Alliance Certification Programs

- □ Connectivity
  - Interoperable connectivity (Wi-Fi CERTIFIED a/b/g/n/ac)
  - Wi-Fi Direct
- □ Security
  - WPA2 (government-grade security mechanism)
  - EAP (for enterprise)
- $\Box$  Access
  - Passpoint, Wi-Fi Protected Setup, Wi-Fi Aware
- Applications and Services
  - Miracast, Voice-Enterprise & Voice-Personal
- Optimization
  - TDLS, WMM





## Wi-Fi Direct & Miracast

- Direct Wi-Fi (based on Wi-Fi P2P spec) communication without infrastructure (AP)
- □ Mimic former 802.11 WLAN BSS architecture
  - P2P Group Owner (GO): AP-like device
  - P2P Client: station-like device
- $\square$  GO power saving
  - Opportunistic power saving
  - Notice of Absence (NoA)
- Wi-Fi Direct Services
  - Platform interface to encourage more Wi-Fi Direct applications
- Miracast (based on Wi-Fi Display spec) on top of Wi-Fi Direct









## Wi-Fi Direct Services (WFDS)

- Define architecture, protocol and functionality for interoperability of Wi-Fi Direct Services
- Address solution requirement areas
  - Send, play, print, display, enable, application service platform



![](_page_11_Picture_5.jpeg)

#### Passpoint

- Motivation
  - Network access in hotspot area is complicated
    - Search and choose a network
    - Request connection
    - (Re)enter authentication credentials
- □ Passpoint automates entire network access process
  - By enabling a seamless connection between hotspot networks and mobile devices
  - Implemented based on IEEE 802.11u and Hotspot 2.0 specs

![](_page_12_Figure_9.jpeg)

![](_page_12_Picture_10.jpeg)

WIRELESS NETWORKING, 430.752B, 2020 SPRING SEOUL NATIONAL UNIVERSITY

![](_page_12_Picture_12.jpeg)

#### Wi-Fi Aware

- Motivation
  - Growing proximity-based applications
  - Need for energy-efficient always-on discovery mechanism
- Neighbor awareness networking (NAN) "cluster"
  - Operation in a predefined channel (e.g., ch. 6 for 2.4 GHz band)
  - Discovery window (DW)
    - Time period where NAN devices converge
    - Service Discovery frame and Synchronization Beacon transmissions
  - Discovery Beacon broadcast outside DW for NAN cluster discovery

![](_page_13_Picture_10.jpeg)

![](_page_13_Figure_11.jpeg)

![](_page_13_Picture_12.jpeg)

![](_page_13_Picture_14.jpeg)

#### Wi-Fi Evolution in the Future

- □ Wi-Fi for IoT
- Needs for more spectrum
- □ Future of Wi-Fi
- □ Wi-Fi vs. LTE?

![](_page_14_Picture_5.jpeg)

![](_page_14_Picture_6.jpeg)

![](_page_14_Picture_8.jpeg)

## Wi-Fi: An Ideal Technology for IoT

- □ Standards-based, interoperable technology
- Legacy compatibility
- Proven security
- □ Ease of deployment and use
- Pervasive connectivity
- Precise location awareness

![](_page_15_Figure_7.jpeg)

Wi-Fi Alliance White Paper, "Connect your life: Wi-Fi and the Internet of Everything," Jan. 2014.

![](_page_15_Picture_9.jpeg)

![](_page_15_Picture_11.jpeg)

## Wi-Fi Innovation Continues

More methods for device pairing

- The Wi-Fi Protected Setup is expanding in 2014 to include NFC token authentication
- □ Pre-association service discovery
  - Wi-Fi Alliance is developing a "neighbor-aware" networking mechanisms
    - Enabler for proximity and location services in dense environments
- □ Improvements in spectral efficiency (802.11ax HEW)
  - As the number of devices continues to grow, spectral efficiency will be a critical area

![](_page_16_Picture_8.jpeg)

![](_page_16_Picture_10.jpeg)

## Low-Power Wi-Fi Platform

□ For instance, Qualcomm Atheros QCA4002/4004

- A new chip family launched on Sep. 2013
- Low-power Wi-Fi solutions designed for Internet of Everything
- Target Applications
  - Major home appliances, Consumer electronics, Sensors
  - Smart plugs for home lighting, security and automation systems
- Include Green TX technology
  - A dynamic power adjustment
    - Reduce TX power by up to 1/2 in close proximity of another device or AP
  - Sleep mode consuming less than 1 mW
    - onboard wake-up manager that enables self-wake and sleep management
  - Wake from suspend: four times faster than other products
    - Reduces total power profile and system latency

Qualcomm, "Qualcomm Unveils Low-Power Wi-Fi Platform for Major Home Applications and Consumer Electronics," Sept. 2013.

![](_page_17_Picture_15.jpeg)

![](_page_17_Picture_17.jpeg)

## Power Consumption Measurement Study

- □ One for smartphones and the other for PCs
  - Fair comparison is not guaranteed due to different measurement methods
- □ Broadcom BCM4330 combo chip
  - IEEE 802.11n, 1x1 SISO
  - 2.4 GHz, 5 GHz band, 20 MHz channel
  - Used in Galaxy Nexus, Galaxy S2, Galaxy S3, ...
- Qualcomm Atheros QCA9880
  - IEEE 802.11ac, up to 3x3 MIMO
  - 5 GHz band, up to 80 MHz channel bonding
  - Used in many laptop PCs

![](_page_18_Picture_11.jpeg)

Monsoon power monitor

![](_page_18_Picture_13.jpeg)

![](_page_18_Picture_15.jpeg)

## Power Consumption Measurement Results

#### □ Idle & RX states

• Wider bandwidth  $\rightarrow$  More power consumption (RX power is more sensitive to BW)

![](_page_19_Figure_3.jpeg)

![](_page_19_Figure_4.jpeg)

#### □ TX state

- Wider BW  $\rightarrow$  similar power
- Major consumption at power amp
- DAC power << ADC power</li>
- Observation
  - Room to reduce power for IoT (RX?)

![](_page_19_Figure_11.jpeg)

![](_page_19_Picture_12.jpeg)

![](_page_19_Picture_14.jpeg)

## Wi-Fi Forward

- Motivation
  - Ever-increasing demand for data and overloaded spectrum
- Wi-Fi Forward
  - A group of companies, organizations and public sector institutions
  - For protecting existing unlicensed spectrum designations
  - For freeing up new unlicensed spectrum, including low, medium, and high frequency bands
  - For establishing (investment) friendly, transparent and predictable rules that encourage growth and deployment

![](_page_20_Picture_8.jpeg)

#### Envisioning Future of Wi-Fi

□ Will all Wi-Fi ecosystem be possible in the future?!?

![](_page_21_Figure_2.jpeg)

![](_page_21_Picture_3.jpeg)

![](_page_21_Figure_5.jpeg)

## Wi-Fi vs. LTE-LAA (Licensed Assisted Access)

- □ Competitive or complementary?
- □ Competition with LTE-LAA
  - Carrier aggregation of LTE-A aggregating licensed spectrum and unlicensed spectrum @5 GHz
- □ Interworking between Wi-Fi and LTE to use Wi-Fi and LTE-A simultaneously
  - KT GiGA LTE
  - Samsung's download booster
  - AirPlug's ABC

![](_page_22_Figure_8.jpeg)

![](_page_22_Picture_9.jpeg)

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![](_page_22_Picture_12.jpeg)

#### Conclusion

- □ Wi-Fi is a major connectivity solution in IoT era
- □ Three main directions of evolution
  - Throughput enhancements
  - Long-range extensions
  - Greater ease of use
- □ Future vision and issues
  - More diversified services with spectrum heterogeneity and greater ease of use
  - Performance enhancement in dense environment will be a key challenge
  - Close interworking with cellular and coexistence/interworking with other unlicensed band-based connectivity technologies

![](_page_23_Picture_10.jpeg)

![](_page_23_Picture_12.jpeg)