Newer Wi-fi Standards

Chelsea Chen
Samuel Kim

Overview

- 802.11ah
- 802.11af
- 802.11ax
802.11ah

say ‘HaLow’ to the IoT era

802.11ah (HaLow, “HEY-Low”)

- **Operating band**
  - 900 MHz, licensed
- **Primary application**
  - ‘Internet of Things’ devices
- **Advantages**
  - Supports very large number of clients
  - Low power consumption
  - Extended range
802.11ah - two PHY layer bandwidth modes

- Mandatory channel standardizations
  - 1MHz
  - 2MHz
  - Minimum channel bandwidth for all countries
- Optional channel bandwidths
  - 4MHz, 8MHz, 16MHz

802.11ah - PHY layer 1MHz mode

- OFDM - 24 subcarriers
- Introduced a new Modulation and Coding Scheme Index (MCS Index): MCS-10
  - Same as MCS-0 except 2x data repetition for higher resiliency in data transmission
802.11ah - PHY layer 2MHz mode

- Design based on IEEE 802.11ac’s PHY layer but with enhanced long range transmission resiliency
  - Supports Downlink Multi-user MIMO
  - 10 times down-clocking - 1/10th data rate compared to 802.11ac
  - Ie. 10 times longer symbol time - each symbol has 10x increased chance of getting received
- Supports bandwidths of 2MHz and more - 2MHz, 4MHz, 8MHz, and 16MHz
  - In 802.11ac, these are 20MHz, 40MHz, 80MHz, 160MHz
- OFDM - 52 subcarriers

802.11ah - MAC

- Supports a large number of stations - scalability
  - Uses Hierarchical Association ID (AID) structure
  - AID: an ID that the access point associates each station with
  - 4 hierarchical levels
  - $2^{13} - 1 = 8191$ stations
  - Other standards: only 2007 stations
- Lowers energy consumption
  - Sets a wake-up interval and only communicates when woken up
  - “Bursty packets”
- Improves throughput
  - Shortens MAC headers
  - Eliminates channel access delay, ACK transmission delay
802.11ah Evaluation result

- 802.11ah(900MHz) vs 802.11n(2.4GHz) vs 802.11ac(5GHz)
- Evaluated based on path-loss
- Indoor and outdoor evaluations: 802.11ah has longer transmission range

802.11af

‘Super Wi-Fi’ saves the day in rural areas
802.11af (White-Fi or Super Wi-Fi)

- **Primary application**
  - Long-Range wireless to rural areas
- **Operating band**
  - 54 - 790 MHz
- **PHY layer**
  - Based on 802.11ac's PHY layer
- **Advantages**
  - Utilizes unused spectrum left by broadcast television channels

802.11af - Efficient Spectrum Utilization

- TV white space spectrum advantages over higher band spectrums
  - Less path loss in Non Line Of Sight propagation
  - Lower capacity over longer range, as opposed to higher capacity over shorter range
  - Underutilization -> have to deal with less interference
802.11af - Challenges

- Interferes with TV transmissions. Solutions:
  - Cognitive radio
    - Senses frequencies in the surroundings
    - Avoid busy channels
    - Could still suffer from hidden terminal problem
  - Geographic sensing
    - Uses a geolocation database (GDB) to check channel availabilities
    - Has to immediately stop transmission if GDB tells it to
    - Updates and queries to GDB might not be timely enough

802.11ax

802.11a/b/g/n/ac… and now ax
802.11ax (Wi-Fi 6)

- Successor to 802.11ac
- Operating on 2.4 GHz and 5 GHz
- Primary need: Dense environments
  - e.g. stadiums, airports, outdoor hotspots
- Main advantages
  - Focus on user experience:
    - Nominal increase to max data rate compared to 11ac
    - But higher user throughput with efficient spectrum utilization
      - 4-10x more capacity than 11ac
  - Massive parallelism
  - Power saving technologies

802.11ax - OFDMA (Orthogonal Frequency Division Multiple Access)

- Spread multiple users across different subcarriers (frequency diversity)
- Problem: High MAC contention
  - 11n combines short packets in time
  - 11ac combines different users spatially
  - OFDMA combines different users in frequency
- 11ac introduced wide bands (80/160 MHz from 20/40 MHz) to increase speed
  - Problem: Susceptible to frequency selective interference
  - Solution: OFDMA can now choose a subcarrier based on best frequency
- Additionally, longer symbols than 11ac
802.11ax - Uplink MU-MIMO

- Problem: Multi-user collision in UL direction
- Uplink MU-MIMO uses a ‘Trigger’ frame
  - 1. AP has to discover which users are ready to transmit
  - 2. AP must calculate best allocation of MU-MIMO groups and OFDMA subcarriers
  - 3. AP then sends necessary information (e.g. RU allocation, modulation scheme) to users for transmission
- Some issues
  - UL requires grouped users to have similar conditions
  - Backward compatibility

802.11ax - Increased QAM

- 11ax adds 1024-QAM
- Spectral efficiency increased by 25%
- Requires high SNR
802.11ax - Challenge: Power consumption

- **BSS Coloring**
  - Motivation: Overlapping BSS in dense environments
  - Station can set different ‘defer’ thresholds for different BSS ‘colors’
    - i.e. don’t care about transmissions from BSS far from mine

- **Target Wake Time**
  - Introduced in 802.11ah
  - 11ax introduces a Broadcast TWT mode that groups devices together

- **And more…**
  - Extends life of IoT sensors and other clients
  - 20 MHz-only mode, Receive/Transmit operating mode, optimize client settings

### Summary of 802.11ah/af/ax

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Thank you - Any questions?

- Additional resources
  - 802.11ah
    - [https://pdfs.semanticscholar.org/dbe4/3f9e28e125203439c8b554f19f0b6ce79443.pdf](https://pdfs.semanticscholar.org/dbe4/3f9e28e125203439c8b554f19f0b6ce79443.pdf)
  - 802.11af
  - 802.11ax
    - IEEE Research Paper on 802.11ax
    - 802.11ax White Paper from Aruba
    - See current IEEE 802.11ax progress/reports!
      - TGax - UL MIMO (May 2014)
      - TGax - Longer symbol times (Jan 2015)