Supplement to Wireless LANs Part II: 802.11a/b/g/n/ac

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Audio/Video recordings of this class lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-20/

Student Questions

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Overview

1. Wi-Fi Generations
2. Wi-Fi 6
3. White-Fi or Super Wi-Fi
4. Wi-Fi HaLow
5. Other upcoming standards

Note: This is a supplement to Modules 5 and 6 on Wi-Fi. All modules are available on the course URL below.

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Wi-Fi Generations

- 802.11n vs 802.11ac
- General public has no idea of which one of these is superior
- Wi-Fi Alliance: Wi-Fi Interoperability and Marketing organization solved it by assigning generations
  1=2 Mbps, 2=11 Mbps, 3=56 Mbps, …
- Wi-Fi Alliance renamed 802.11n and 802.11ac retroactively as Wi-Fi 4, Wi-Fi 5
- Similar to 4G/5G, Bluetooth 4.0/Bluetooth 5.0, …
- **Wi-Fi 4**: IEEE 802.11n **Wi-Fi 5**: IEEE 802.11ac
- Easier for public to remember when comparing products with different versions of Wi-Fi
- Most products were developed before the name Wi-Fi 5 was announced. So all products still say 802.11n and 802.11ac

Ref: https://www.duckware.com/tech/wifi-in-the-us.html

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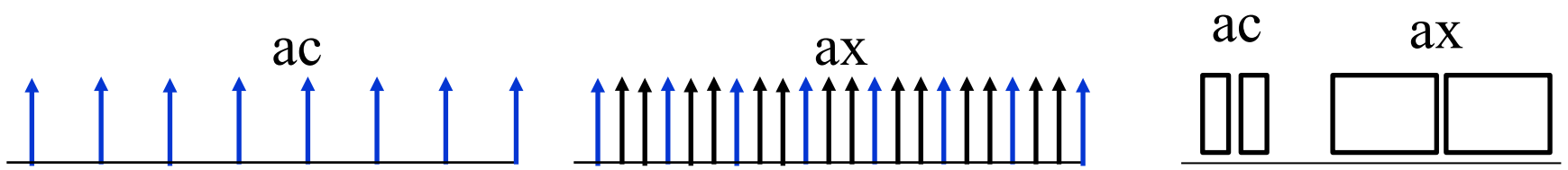
Wi-Fi 6

- IEEE P802.11ax: Named Wi-Fi 6 by Wi-Fi Alliance
- To be fully approved by IEEE in September 2020
- More efficient 802.11ac ⇒ 4× Throughput
- 1/4th subcarrier spacing ⇒ 4 × subcarriers
  - 20 MHz = 4 × 64 = 256 subcarriers
  - 40 MHz = 4 × 128 = 512 subcarriers
  - 80 MHz = 4 × 256 = 1024 subcarriers
  - 160 MHz = 4 × 512 = 2048 subcarriers
- 1/4th subcarrier spacing ⇒ 4 × symbol size (in time)
  - 4 × 32. μs = 12.8 μs ⇒ More inter-symbol interference



Ref: E. Khorov, A. Kiryanov, A. Lyakhov and G. Bianchi, "A Tutorial on IEEE 802.11ax High Efficiency WLANs," in *IEEE Communications Surveys & Tutorials*, vol. 21, no. 1, pp. 197-216, Firstquarter 2019, https://ieeexplore.ieee.org/document/8468986

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Wi-Fi 6E

- Wi-Fi 6 extended to 6 GHz band
- More contiguous Spectrum: FCC approved all 1200 MHz spectrum at 6 GHz for unlicensed use
  ⇒ 14 additional 80 MHz channels
  or 7 160 MHz channels
- Wider Channels ⇒ Less queueing ⇒ Low latency
- Shorter range ⇒ Less Interference

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Ref: https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-6

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White-Fi or Super Wi-Fi

- IEEE 802.11af-2014
- Operates in TV white spaces in 54 and 790 MHz.
- Uses cognitive radio technology
- Stations determine their position using GPS to determine what bands are available in that location and use it while the TV station is not transmitting
- Lower frequency ⇒ Longer range than 11-11ax
- 26.7 Mbps to 568.9 Mbps
- Significant market confusion with popular 802.3af power over Ethernet capability
- Spectrum in USA but not globally ⇒ No products so far

Ref: https://www.mwrf.com/technologies/active-components/article/21846205/whats-the-difference-between-ieee-80211af-and-80211ah

https://en.wikipedia.org/wiki/IEEE_802.11af

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Wi-Fi HaLow

- IEEE 802.11ah-2016
- Wi-Fi for Internet of Things (IoT)
- Designed for 900 MHz spectrum
- Can reach 3 times longer than 2.6 Ghz
- 900 MHz is available in USA but not globally
  - No global standard
  - US and proprietary products

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Ref: https://en.wikipedia.org/wiki/IEEE_802.11ah

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Wi-Fi 7

- Extremely High Throughput
- Bands between 1 and 7.125 GHz
- **Study group** approved in July 2018
- Not a Task Group yet

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Ref: E. Khorov, I. Levitsky and I. F. Akyildiz, "Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7," in *IEEE Access*, vol. 8, pp. 88664-88688, 2020, https://ieeexplore.ieee.org/document/9090146

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IEEE 802.11 Activities

- **P802.11ay**: Increase the data rate in 60 GHz band Enhancement of 802.11ad
- **P802.11az**: Next generation positioning with improved accuracy, scalability, and directionality
- **P802.11ba**: Low power control stations
- **P802.11bb**: Light Communications
- **P802.11bc**: Enhanced broadcase service
- **P802.11bd**: Next Generation Vehicle-to-X
- **Real time applications**: Latency and stability issues with mobile and multiplayer games, robotics and industrial automation

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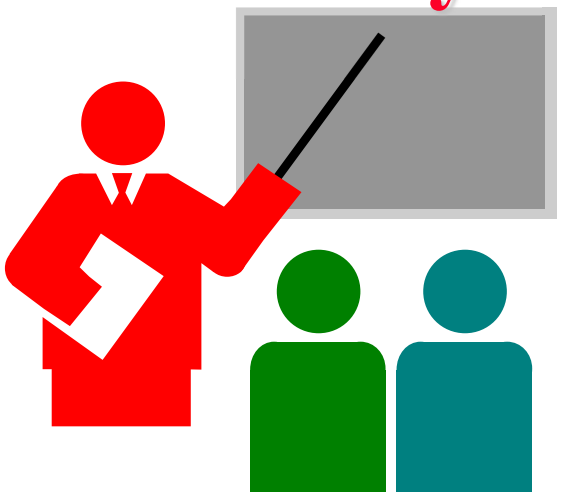
Summary



1. Wi-Fi Generations: 1=802.11, 2=11b, 3=11a/11g, 4=11n, 5=11ac, 6=11ax
2. Wi-Fi 6 is here. 6E is coming.
3. Wi-Fi 7 is in works.
4. White-Fi or Super Wi-Fi uses TV spectrum, but may not come.
5. Wi-Fi HaLow is designed for IoT but may not come.

Student Questions

Wikipedia Links

- https://en.wikipedia.org/wiki/IEEE_802.11
- https://en.wikipedia.org/wiki/IEEE_802.11ax
- https://en.wikipedia.org/wiki/Super_Wi-Fi
- https://en.wikipedia.org/wiki/IEEE_802.11ah

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Optional Reading

- E. Khorov, A. Kiryanov, A. Lyakhov and G. Bianchi, "A Tutorial on IEEE 802.11ax High Efficiency WLANs," in *IEEE Communications Surveys & Tutorials*, vol. 21, no. 1, pp. 197-216, Firstquarter 2019, https://ieeexplore.ieee.org/document/8468986
- E. Khorov, I. Levitsky and I. F. Akyildiz, "Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7," in *IEEE Access*, vol. 8, pp. 88664-88688, 2020, https://ieeexplore.ieee.org/document/9090146

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rajjain.com/cse574-18

http://www.cse.wustl.edu/~jain/cse574-20/j_06lan.htm

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Related Modules

CSE567M: Computer Systems Analysis (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),
https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcgy5e_10TiDw

Recent Advances in Networking (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypLHyBN8mOgwJLHD2FFIMGq5

CSE571S: Network Security (Fall 2011),
https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u

Video Podcasts of Prof. Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw

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