

# ELG4179: Wireless Communication Fundamentals

## Wi-Fi: History & Overview

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# WiFi: the most popular wireless system

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- wireless → no cable, mobile
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  - tablets
  - cell phones
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  - IoT devices, etc.

# WiFi: the most popular wireless system

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- various devices
  - computers, printers, etc.
  - tablets
  - cell phones
  - TV
  - IoT devices, etc.
- various services
  - Internet access (Google, YouTube, social networks, etc...)
  - video/audio streaming/download
  - video/audio calls/conferences/lectures etc.
  - data storage/sharing
  - TV broadcast

Bonus Q: do you know someone without a WiFi device?

# WiFi: History & Overview

- WiFi = wireless local area network (WLAN)
- IEEE 802.11: the main industrial standard<sup>1 2</sup>
- various versions: 802.11/b/a/g/n/ac/ax/be
- 1997 to present day, still under development<sup>3 4 5</sup>

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<sup>1</sup>IEEE 802.11: Wikipedia, [https://en.wikipedia.org/wiki/IEEE\\_802.11](https://en.wikipedia.org/wiki/IEEE_802.11)

<sup>2</sup>E. Perahia and R. Stacey, Next Generation Wireless LANs: 802.11n and 802.11ac, Cambridge Univ. Press, 2013.

<sup>3</sup>D. Lopez-Perez et al., IEEE 802.11be Extremely High Throughput: The Next Generation of Wi-Fi Technology Beyond 802.11ax, IEEE Commun. Mag., vol. 57, no. 9, Sep. 2019, pp. 113-119.

<sup>4</sup>E. Khorov et al., Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7, IEEE Access, vol. 8, May 2020, pp. 88664–88688.

<sup>5</sup>A. Garcia-Rodriguez et al, IEEE 802.11be: Wi-Fi 7 Strikes Back, IEEE Comm. Mag., vol. 59, no. 4, pp. 102–108, May 2021.

# Generations of Wi-Fi

Generation	Year	Max. Rate	Frequency	Bandwidth
WiFi 0 = 802.11	1997	2 Mb/s	2.4 GHz	22 MHz
WiFi 1 = 802.11b	1999	11 Mb/s	2.4 GHz	22 MHz
WiFi 2 = 802.11a <sup>6</sup>	1999	54 Mb/s	5 GHz	20 MHz
WiFi 3 = 802.11g	2003	54 Mb/s	2.4 GHz	20 MHz
WiFi 4 = 802.11n <sup>7</sup>	2009	600 Mb/s	2.4/5 GHz	20-40 MHz
WiFi 5 = 802.11ac <sup>8</sup>	2013	7 Gb/s	5 GHz	20-160 MHz
WiFi 6 = 802.11ax	2021	10 Gb/s	2.4/5/6 GHz	20-160 MHz
WiFi 7 = 802.11be <sup>9</sup>	2024	50 Gb/s	2.4/5/6 GHz	20-320 MHz

<sup>6</sup>major upgrade: OFDM + BPSK/QPSK/16-QAM/64-QAM

<sup>7</sup>major upgrade: MIMO (4 streams)

<sup>8</sup>MIMO-OFDM (8 streams), up to 256 QAM

<sup>9</sup>MIMO-OFDM (16 streams), up to 4096 QAM

## IEEE 802.11 legacy (Wi-Fi 0)

- released in June 1997, now obsolete
- rates: up to 2 Mb/s
- carrier: 2.4 GHz (ISM) band
- bandwidth: 22 MHz
- range: 20m - 100m (indoor-outdoor)<sup>10</sup>
- modulation: DSSS, FHSS

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<sup>10</sup>depends on propagation conditions, interference, etc.

# IEEE 802.11b (Wi-Fi 1)

- released in Sep. 1999
- rates: up to 11 Mb/s
- carrier: 2.4 GHz (ISM) band
- bandwidth: 22 MHz
- range: 35m - 140m (indoor-outdoor)<sup>11</sup>
- modulation: DSSS

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<sup>11</sup>depends on propagation conditions, interference, etc.



## IEEE 802.11a (Wi-Fi 2)

- released in Sep. 1999
- rates: up to 54 Mb/s
- carrier: 5 GHz band
- bandwidth: 20 MHz
- range: 35m - 120m (indoor-outdoor)<sup>12</sup>
- modulation: OFDM, BPSK/QPSK/16-QAM/64-QAM

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<sup>12</sup>depends on propagation conditions, interference, etc.

## IEEE 802.11g (Wi-Fi 3)

- released in June 2003
- rates: up to 54 Mb/s
- carrier: 2.4 GHz (ISM) band
- bandwidth: 20 MHz
- range: 38m - 140m (indoor-outdoor)<sup>13</sup>
- modulation: OFDM, BPSK/QPSK/16-QAM/64-QAM

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<sup>13</sup>depends on propagation conditions, interference, etc.

## IEEE 802.11n (Wi-Fi 4): major upgrade (MIMO)

- released in Oct. 2009
- rates: up to 600 Mb/s<sup>14</sup>
- carrier: 2.4/5 GHz bands
- bandwidth: 20/40 MHz
- range: 70m - 250m (indoor-outdoor)<sup>15</sup>
- modulation: MIMO-OFDM (4 streams), 64-QAM

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<sup>14</sup>depends on distance, propagation, interference

<sup>15</sup>depends on propagation, interference, etc.

# IEEE 802.11ac (Wi-Fi 5)

- released in Dec. 2013
- rates: up to 7 Gb/s<sup>16</sup>
- carrier: 5 GHz band
- bandwidth: 20/40/80/160 MHz
- range: 35m (indoor)<sup>17</sup>
- modulation: MIMO-OFDM (8 streams), 256-QAM

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<sup>16</sup>depends on distance, propagation, interference

<sup>17</sup>depends on propagation, interference, etc.

# IEEE 802.11ax (Wi-Fi 6)<sup>20</sup>

- released in Feb. 2021
- rates: up to 10 Gb/s<sup>18</sup>
- carrier: 2.4/5/6 GHz bands
- bandwidth: 20/40/80/160 MHz
- range: 30m - 120m (indoor-outdoor)<sup>19</sup>
- modulation: MIMO-OFDM (8 streams), 1024-QAM

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<sup>18</sup>depends on distance, propagation, interference

<sup>19</sup>depends on propagation, interference, etc.

<sup>20</sup>E. Khorov et al., A tutorial on IEEE 802.11ax high efficiency WLANs, IEEE Comm. Surveys & Tutorials, vol. 21, no. 1, Feb. 2019.

## IEEE 802.11be (Wi-Fi 7)

- to be released in May 2024<sup>21 22 23</sup>
- rates: up to 50 Gb/s<sup>24</sup>
- carrier: 2.4/5/6 GHz bands
- bandwidth: 20/40/80/160/320 MHz
- range:
- modulation: MIMO-OFDM (16 streams), 4096-QAM

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<sup>21</sup>D. Lopez-Perez et al., IEEE 802.11be Extremely High Throughput: The Next Generation of Wi-Fi Technology Beyond 802.11ax, IEEE Commun. Mag., vol. 57, no. 9, Sep. 2019, pp. 113-119.

<sup>22</sup>E. Khorov et al., Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7, IEEE Access, vol. 8, May 2020.

<sup>23</sup>A. Garcia-Rodriguez et al, IEEE 802.11be: Wi-Fi 7 Strikes Back, IEEE Comm. Mag., vol. 59, no. 4, pp. 102-108, May 2021.

<sup>24</sup>depends on distance, propagation, interference

# Summary

- IEEE 802.11 = Wi-Fi
- Generations of WiFi (0 to 7)
- typical parameters
  - rates & range
  - frequencies
  - modulation/transmission formats

## References (all available online)

1. IEEE 802.11: Wikipedia, [https://en.wikipedia.org/wiki/IEEE\\_802.11](https://en.wikipedia.org/wiki/IEEE_802.11); see also <https://en.wikipedia.org/wiki/Wi-Fi>
2. E. Perahia and R. Stacey, Next Generation Wireless LANs: 802.11n and 802.11ac, Cambridge Univ. Press, 2013.
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