Wireless Standards

802.11ax (Wi-Fi 6)

Branded as Wi-Fi 6, the 802.11ax standard went live in 2019 and will replace 802.11ac as the de facto wireless standard. Wi-Fi 6 maxes out at 10 Gbps, uses less power, is more reliable in congested environments, and supports better security.

Chart doesn't include newer 802.11ax

The following table describes the various wireless standards and their specifications:

Specification	Standard				
	802.11a	802.11b	802.11g	802.11n	802.11ac
Frequency	5 GHz (U-NII)	2.4 GHz (ISM)	2.4 GHz (ISM)	2.4 GHz (ISM) or 5 GHz (U-NII)	5 GHz (U-NII)
Maximum speed	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1.3 Gbps
Maximum distance	100 ft.	150 ft.	150 ft.	300 ft.	150 ft.
Channels (non-overlapped)	23 (12)	11 (3)	11 (3)	2.4 GHz: 11 (3 or 1) 5 GHz: 23 (12 or 6)	Depends on configuration
Modulation technique	OFDM	DSSS, CCK, DQPSK, DBPSK	DSSS (and others) at lower data rates OFDM, QPSK, BPSK at higher data rates	OFDM (and others, depending on implementation)	OFDM
Backwards compatibility	N/A	None	802.11b	802.11a/b/g, depending on implementation	802.11b/g/n

802.11a, b, g and n IEEE Wireless Standards

Each of these standards transmits and receives data using radio waves within a specified frequency range:

Frequency Ranges

- 802.11a uses the 5.75 gigahertz range

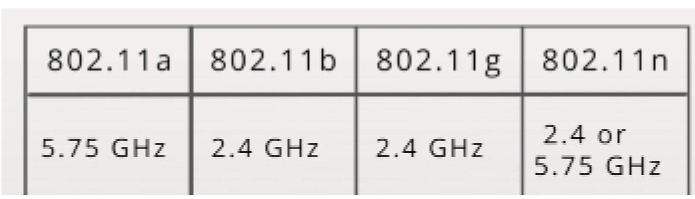
- 802.11b and G both use the 2.4 gigahertz range
- 802.11n is capable of using either 2.4 or 5.75, depending on how it's implemented and what kind of transmitters are in the device.
- **802.11ac offers 1.3 Gbps and uses 5 GHz frequency range**

Frequency Interference

Remember, the frequency a wireless network is using can cause interference. For example, in the 2.4 gigahertz range, there may be other wireless devices operating, like a cordless phone. Many cordless phones use the same frequency ranges as these 802.11 wireless standards.

Compatibility

802.11b and 802.11g - Because both B and G use the same frequency ranges, B and G compatible devices are compatible with each other.
802.11a - A and B use different frequency ranges. Therefore, A and B wireless devices aren't compatible.
802.11n - 802.11n is a special case. With 802.11n, you may have a single device that uses multiple radios, one that can operate at one frequency and another that can operate on a different frequency. **Because of this, 802.11n usually allows for compatibility between all 802.11 standards, depending upon the specific implementation.**



802.11a	802.11b	802.11g	802.11n
5.75 GHz	2.4 GHz	2.4 GHz	2.4 or 5.75 GHz

- 802.11a is only compatible with itself.
- 802.11b is not compatible with the A standard because it uses a different frequency range. However, it is compatible with the G standard.
- 802.11g was designed to be backwards compatible with B.
- 802.11n can be compatible with A, B and G, depending upon the radio transmitters and how the device is configured.
    - For example, if your N device only uses a 2.4 gigahertz radio, it will be compatible with B and G standards. If it only uses a 5 GHz radio, then it will be compatible with the A standard. If it has both radios enabled, it is compatible with all three. This means you can, take a device that uses an older 802.11b network card and connect it to an N network that has a 2.4 GHz radio enabled.

As you can see, if you want to ensure the broadest compatibility for your wireless networking equipment, you should consider purchasing 802.11n devices.

Speed

In addition to frequency, you should also be aware of the transmission speeds associated with each standard. Each standard lists a maximum data rate, but be aware that you can only achieve this if:

- The wireless devices are stationary. The faster a device is moving, the slower the data rate will be.
- The wireless devices are within range. Basically, the farther away you are, the slower the data rate will be. With each of these standards, you can only achieve the maximum speed if you're quite close.

Distance

- **802.11a** can transmit at about 54 megabits per second.
- **802.11b** can only transmit at 11 megabits per second.
- *802.11a is limited to a range of only about 150 feet, while 802.11b has a range of up to 300 feet. By sacrificing some speed, 802.11b was able to support longer ranges.*

- **802.11g** can transmit at 54 megabits per second and has a transmission range of about 300 feet. *As you can see, it incorporated the longer range provided by the B standard, while offering the faster data rates provided by the A standard.*

- **802.11n** has a limit of about 600 megabits per second, but that depends on how it's implemented. For range, you can get up to 1,200 feet.

	802.11a	802.11b	802.11g	802.11n
Frequency	5.75 GHz	2.4 GHz	2.4 GHz	2.4 or 5.75 GHz
Speed	54 Mbps	11 Mbps	54 Mbps	600 Mbps
Distance	150 ft.	300 ft.	300 ft.	1200 ft.
Compatibility		g	b	a/b/g

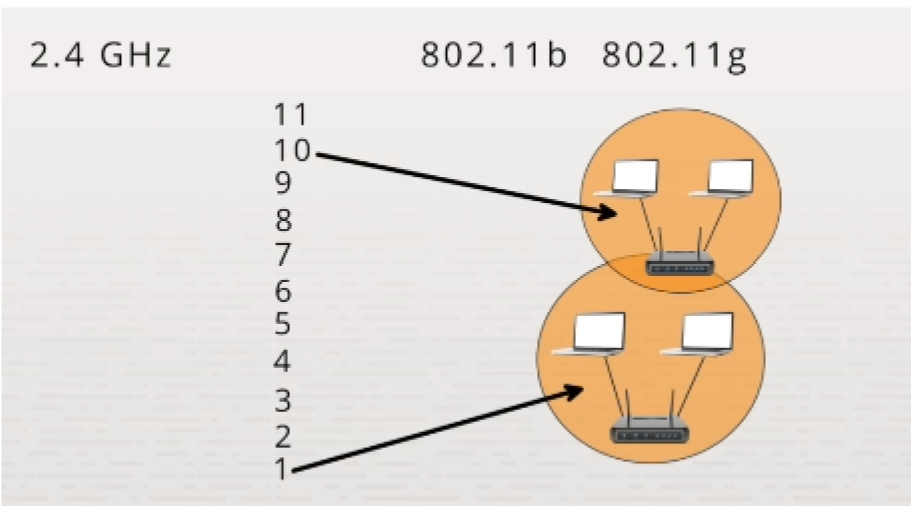
Note: The 802.11ac wireless standard offers speeds of 1.3 Gbps and uses the 5 GHz frequency range.

Supported Channels

A channel encompasses a defined portion of the wireless radio frequency range. By dividing a frequency range into channels, overlapping wireless networks can coexist in the same location, transferring data at the same time without interfering with each other.

For example, let's look at the 2.4 gigahertz frequency range used by 802.11b and 802.11g devices. The entire frequency range is divided into a limited number of channels. For the access point to communicate with multiple wireless devices, they need to all be set to use the same channel. Therefore, you could have a wireless network using channel 1, and another nearby wireless network using a different channel without the two networks interfering with each other.

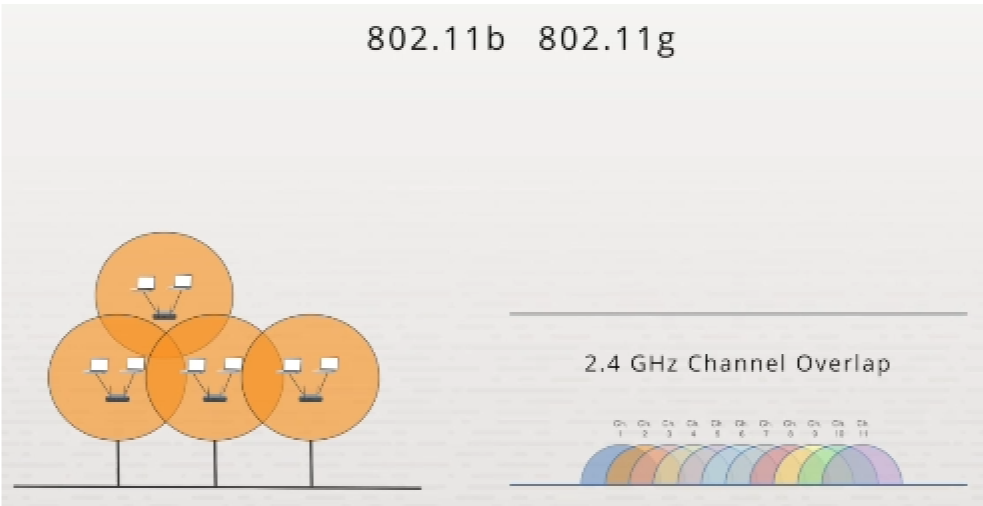
Because the channels are different, the devices can communicate within their own wireless networks without interfering with the other wireless network. If, on the other hand, you were using the same channel, the devices in both networks would be using the same radio frequency and their signals would interfere with each other. You would experience slow communications and dropped connections.



The number of channels available depends on which frequency range your wireless network is using. The 2.4 gigahertz frequency range is divided into 11 channels. Because there are 11 channels, you might assume that you can implement up to 11 different wireless networks in one location, but this is not the case. Wi-Fi channels are not defined like the channels like on a TV set, which are exclusive of each other. Instead, Wi-Fi channels encompass broad ranges within this frequency range. For example, channel one overlaps into the frequency range for channel two and three.

Channel Overlap Issues

This overlap issue has significant consequences when configuring a wireless network. For example, if you have multiple wireless networks in the same area, and if you don't want them to interfere with each other, you must use channels that do not overlap.

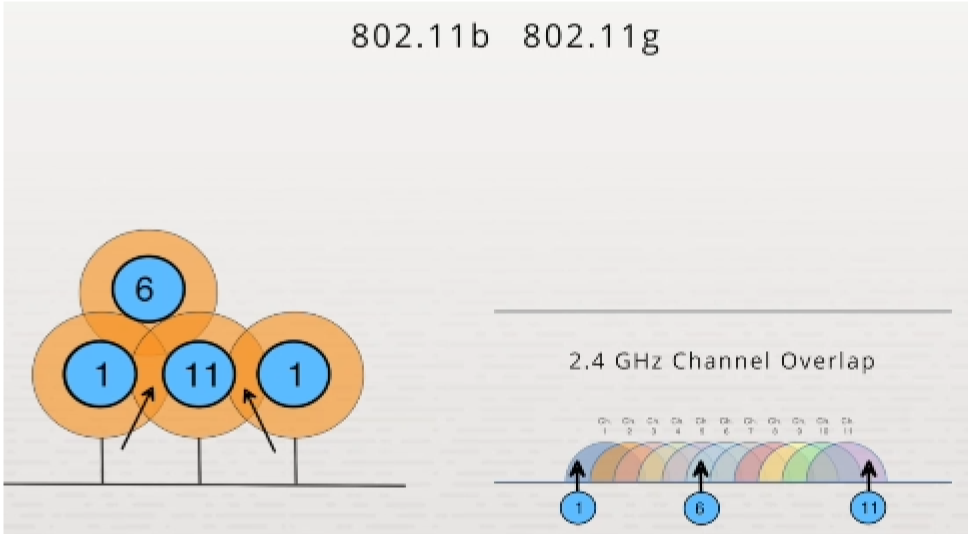


The same holds true if you have two access points that are members of the same wireless networks (that use the same SSID) and are connected to the same wired network. If they overlap, configure each access point to use a different channel so there's no interference where the coverage areas overlap.

Even though there are 11 channels within the 2.4 GHz frequency range, only three of them do not overlap, one, six and 11. Because the channels overlap so much, you must leave two channels on either side to prevent RF overlap and interference.

Example of Solving Overlap Issues

When implementing this network, suppose I had three wireless networks with some overlap. I would need to use non-overlapping channels for each one. I could set the first one to channel one, the middle one to channel 11, and the last one to channel one again because the network using channel one here does not overlap with the network work using channel one here. If I had a fourth access point in this area, I would probably choose channel six, because it will not overlap with either one or 11.



In the past, channel overlap was a big issue when everyone was using the 2.4 GHz frequency range for wireless networking, especially in situations like an office complex where each individual business had their own wireless network.

Many Issues with Overlap Solved With 5 GHz Frequency Range

- **5 Ghz -** 23 channels, with 12 non-overlapping channels.

Today, the 5 GHz frequency range has 23 channels instead of 11. The channels still overlap like they do in the 2.4 GHz range, but they don't overlap as much. Because of this and the number of channels available, there are 12 non-overlapping channels in the 5 GHz frequency range. This makes channel interference issues much easier to deal with.

The Technologies that give 802.11n higher data transfer speeds over a, b, g standards

MIMO - Multiple Input | Multiple Output

One of the technologies that increases both the distance and the speed for 802.11n networking is multiple input, multiple output, or MIMO. MIMO simply adds additional transmit and receive radios to your wireless access point.

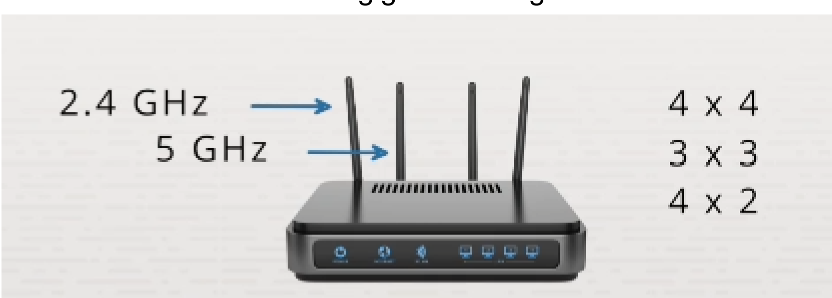
MIMO Allows Antennas to Simultaneously Send Same or Different Data

In the early days, if you bought a wireless access point, it probably came with a single radio. But later model access points have multiple antennas. With MIMO, these separate antennas can be used to simultaneously send the same data, or even different data.

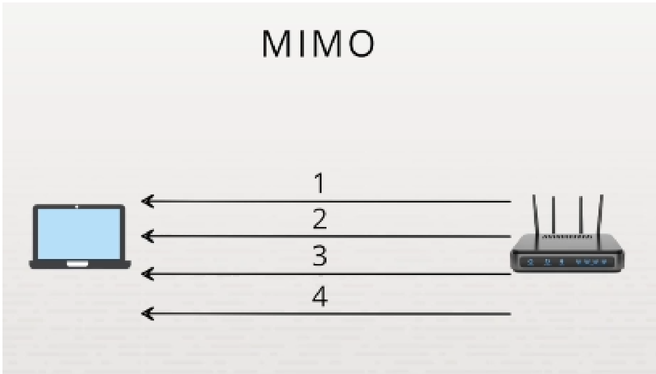
- **With 802.11n, you can have up to four transmit and four receive radios**, and it's often listed as a four by four, or a three by three, or maybe a four by two configuration, where one number indicates the number of send radios and the other number indicates the number of receive radios.

For the highest speeds, you configure all radios to transmit the same data. This also results in an increase in range.

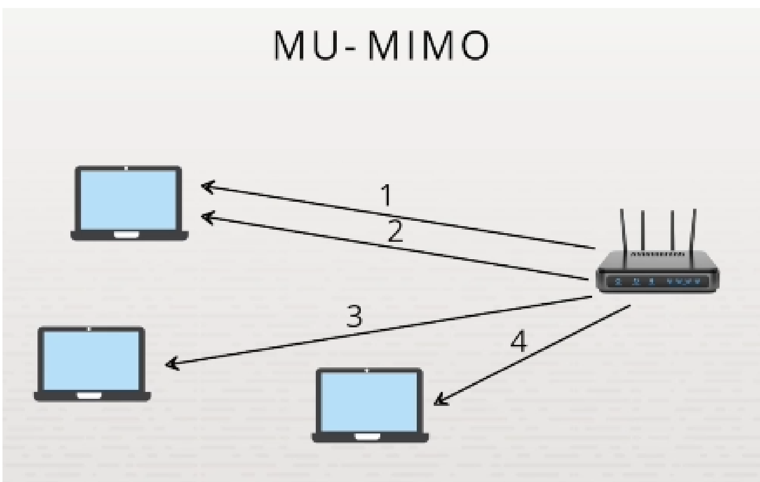
With multiple antennas on your access point, you can also configure some radios to transmit on different frequencies. For instance, you might have a radio that transmits in the 2.4 GHz frequency range, and another radio that transmits in the 5 GHz frequency range. In this case, 802.11n devices could connect to the radio that uses the 5 GHz range, and 802.11g devices could connect to the 2.4 GHz radio. This is why an 802.11n wireless access point can support both the 5 GHz and the 2.4 gigahertz ranges at the same time.



An advanced version of MIMO is also available in some higher-end access points called multi-user MIMO (MU-MIMO). Traditional MIMO involves a single transmitter with multiple antennae sending streams to a single receiver that also has multiple antennae. There is a one-to-one relationship between transmitters and receivers. All streams from the transmitter are sent to the same receiver.



MU-MIMO, on the other hand, allows the antennae on the access point to divide streams between multiple devices. In the example shown here, antennae 1 and 2 on the access point are communicating with the first notebook, while antenna 3 and antenna 4 are each communicating with a different notebook. To keep the three transmissions separate, the access point uses beamforming to focus each transmission toward the appropriate receiver. For this to work, each receiver must be physically separated by enough space so the transmissions don't interfere with each other.



Channel Bonding - To Increase Speed

Another improvement that increases the speed is channel bonding. With channel bonding, you combine two channels to more than double the transmission speed. Let's look at how channel bonding works in the 2.4 GHz range.

You have a total of eleven channels and your non-overlapping channels are 1, 6, and 11. With channel bonding, you combine two of those channels into one logical channel. In essence, you use both channels as if they were one very wide channel capable of transferring a lot of data.

Channel Bonding Rules

For instance, if your access point is capable of 54 Mbps data rates on one channel, you could get around 108 Mbps by using a bonded channel created from two 54 Mbps channels. One issue with channel bonding, at least in the 2.4 GHz range, is that of channel overlap. The bonded channels cannot overlap, so your choices are few (only 3 channels can be used). The rule is - any 2.4 GHz access points whose coverage areas overlap cannot use bonded channels. Because only three channels are available, there is no way for adjacent access points to use channel bonding.

5 GHz Range is Better for Channel Bonding
Therefore, if you want to take advantage of channel bonding, the 5 GHz frequency range is a much better choice. This range has a total of 23 channels, with 12 non-overlapping channels. Therefore, you can have up to 6 bonded non-overlapping channels. This allows adjacent access points with coverage overlap to still take advantage of channel bonding.

Channel Bonding and MIMO Used to Increase Wireless Network Throughput

Several newer 802.11 standards have been defined that leverage channel bonding and MIMO to dramatically increase wireless network throughput. For example, the 802.11ac standard is an improved version of the 802.11n standard. It increases channel bonding from 40 MHz with 802.11n to 160 MHz to dramatically increase network speeds. It also leverages MU-MIMO to increase the number of radio streams from 4 to 8, which also increases the speed of the network. Depending upon how the standard is implemented, 802.11ac can provide wireless network speeds from 433 Mbps all the way up to 1300 Mbps. To accomplish this, 802.11ac can only operate in the 5 GHz frequency range.

Other 802.11 standards seek to increase throughput and range by actually using frequency bands outside of the 2.4 GHz and 5 GHz bands that are exempt from regulation by the FCC. For example, the 802.11ah standard 'borrows' frequency bands below 1 GHz to dramatically extend the range of the wireless network, up to 1000 M.

When choosing a wireless networking standard, keep in mind the frequency, the speed, the distance, and compatibility. Also be aware of MIMO and channel bonding.

Infrared

Most notebook systems were equipped with infrared network adapters, but that is not the case anymore. Today, infrared is used mostly for connecting peripheral devices, such as printers, mice, and keyboards. However, even those types of devices are becoming more and more rare, Bluetooth has almost completely replaced infrared.

IrDA

The infrared networking standards are often referred to as IrDA. Infrared uses light waves that are beyond the visible red light spectrum. There are three different kinds of light that IrDA can use:

- Near IR is light that is really close to the red light frequency that you can actually see.
- Next is intermediate IR.
- Finally, there's far IR.

Infrared uses pulses of light to send data. In this way, it's somewhat similar to fiber optic bounded media. Fiber optic cabling also uses pulses of light for sending signals, but it does so through fiber optic cables. Infrared signaling also uses light, but it transmits the light pulses through the air instead of through a cable.

The first is Line of Sight, or LOS mode. In line of sight mode, devices must be lined up and aimed directly at each other. The device's transmit and receive points need to be aimed correctly so that they're pointing at each other. Line of sight infrared works much like the light beam that's installed across the bottom of a garage door used to stop the door from coming down if an obstruction is in the way. Both use a narrowly focused beam of light to send information between endpoints. If the devices aren't aimed correctly, then the signal won't reach the receiver on the other end.

Line of sight infrared has a range that is limited to about one meter in distance, so the sending and receiving devices need to be fairly close together. In addition, if there is an obstruction between the two devices, then the light will not be able to reach the receiver.

Infrared signals can also operate in defuse mode. In defuse mode, the light signal is fairly broad; it may even radiate in all directions. It's not the narrow beam that is used in LOS mode. With diffuse mode, the devices don't have to be precisely aimed at each other to work. They'll still be able to transmit and receive. However, if there are obstacles in the way, then the signal still may not be able to reach the receiver.

Diffuse mode offers increased range over LOS mode, a little more than one meter. However, the devices still need to be in the same room without anything between them. Frankly, this is the key reason why IR has fallen out of favor. Radio-based networking can transmit through walls and obstacles. In addition, radio-based networking doesn't require a direct line of sight between transmitter and sender.

To use infrared networking today, you will likely need to purchase a USB IR adapter, such as the one shown here. Be aware that IR networking is typically only used for point-to-point connections between devices. For example, you could connect two computers directly to each other using an IR connection and transfer data between them.

- **Early IR networking standards were limited to very low speeds (around 10 Kbps).**
- **GigaIR, however, can transfer data at speeds up to 1 Gbps.**

Bluetooth

The IEEE 802.11 committees for wireless technologies are in charge of radio wireless communications. However, there are two other common wireless networking technologies that you should be familiar with. The first is called Bluetooth.

Bluetooth Defined in the 802.15 Standard

Bluetooth is defined in the 802.15 standard and uses radio waves in the 2.4 to 2.45 gigahertz range.

Like infrared, Bluetooth devices are intended for short communications between devices. Depending on the implementation, you can have up to a maximum of 100 m between devices. Because it uses radio signals instead of light rays, Bluetooth is not as heavily affected by obstacles between the sender and receiver.

There are currently four specifications for Bluetooth:

- **Bluetooth 1.0** transmits data at up to one megabit per second

- **Bluetooth 2.0** transmits up to three megabits per second.
- **Bluetooth 3.0 and 4.0** both transmit data at up to 24 megabits per second.

The actual data rate you get will probably be much less. For example, Bluetooth 2.0 data rates usually end up being around two megabits per second. Keep this in mind when you're buying a Bluetooth device. Sometimes you'll see actual transmission speeds listed in a product's specification, while other times the theoretical maximum speed is listed instead (which you're unlikely to realize).

Bluetooth	
802.15	2.4 - 2.45 GHz
1.0	1 Mbps
2.0	3 Mbps
3.0 & 4.0	24 Mbps (Wi-Fi 802.11)

Personal Area Networks (PAN)

Be aware that Bluetooth 3 and 4 do not actually use the Bluetooth link to achieve the faster data rates. Instead, the Bluetooth link is used to negotiate and establish the connection, but then the actual data transfer is done using a WiFi (802.11) link. Bluetooth devices set up what's called a personal area network, or PAN. A personal area network is kind of like an 'ad hoc' wireless network. However, **in a PAN you have one device that's a master device while the rest of the devices are slave devices.** The devices broadcast the name of the personal area network and are able to join into the network and communicate. Much like infrared, Bluetooth is typically used for devices that are within close proximity.

Many different types of Bluetooth devices are available, including:

- Mobile devices (such as phones and tablets),
- printers,
- speakers,
- headsets,
- game controllers, and so on.

You can even connect two computers systems together using a Bluetooth link.

Near Field Communications (NFC)

NFC - Uses 13.56 megahertz frequency (same as RFID)

We need to look at Near Field Communications or NFC. NFC is a wireless communications technology that works like Radio Frequency Identification (RFID) technology which you might be familiar with. NFC allows for communication between two devices that are really close together.

In essence, NFC is designed to enable short range wireless communications between two NFC enabled devices. To do this, it uses the 13.56 megahertz frequency, which is the same frequency used by RFID. It's designed for devices that are very, very close together, around 4 cm or less.

NFC can be implemented in a variety of different wireless devices, including standard mobile phones, tablets, and full-size desktop PC systems. It can also be used in NFC readers and NFC passive tags which are similar to RFID tags. Basically, it allows you to implement a variety of different proximity-based applications and services.

For example, NFC can be used in an e-ticketing implementation at a movie theater or train station. With e-ticketing, you put your NFC enabled device close to a ticket reader. An NFC connection is automatically established, and then your device sends the e-ticket you purchased previously to get you into the theater or on a train.

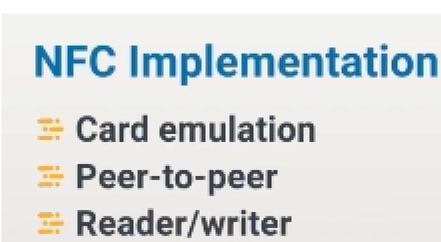
This is only one example. NFC can be used in a variety of different ways. In fact, there are three implementation modes for NFC:

NFC Implementation

The first one is called 'Card Emulation,' which allows an NFC device to work as a contactless smart card (like the e-ticketing application we just looked at).

The next mode is called peer-to-peer. This allows two different NFC devices to establish an NFC link and exchange data by directionally using half-duplex communications.

The final NFC mode is reader/writer. This mode allows an active NFC device, like your mobile phone or tablet, to read information from a passive NFC device like a tag.



Wireless Standards Facts

The original 802.11 specification operated in the 2.4 GHz range and provided up to 2 Mbps transfer speeds. Since then, additional IEEE subcommittees have further refined wireless networking.

Specification	Standard				
	802.11a	802.11b	802.11g	802.11n	802.11ac
Frequency	5 GHz (U-NII)	2.4 GHz (ISM)	2.4 GHz (ISM)	2.4 GHz (ISM) or 5 GHz (U-NII)	5 GHz (U-NII)
Maximum speed	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1.3 Gbps
Maximum distance	100 ft.	150 ft.	150 ft.	300 ft.	150 ft.
Channels (non-overlapped)	23 (12)	11 (3)	11 (3)	2.4 GHz: 11 (3 or 1) 5 GHz: 23 (12 or 6)	Depends on configuration
Modulation technique	OFDM	DSSS, CCK, DQPSK, DBPSK	DSSS (and others) at lower data rates OFDM, QPSK, BPSK at higher data rates	OFDM (and others, depending on implementation)	OFDM

Backwards compatibility	N/A	None	802.11b	802.11a/b/g, depending on implementation	802.11b/g/n

802.11n

802.11n modified the previous 802.11a (5 GHz) and 802.11g (2.4GHz) standards to increase their potential bandwidth and transmission distance. The following table describes the technologies implemented as part of this modification:

Technology	Details
Multiple-Input, Multiple-Output (MIMO)	MIMO increases bandwidth by using multiple antennas for both the transmitter and receiver. A system is described by the number of sending and receiving antennas. The 802.11n specifications allow up to four sending and four receiving antennas. The benefit of adding additional antennas declines as the number increases; going above 3x3 provides a negligible performance increase.
Channel bonding	Channel bonding combines two non-overlapping 20 MHz channels into a single 40 MHz channel, resulting in slightly more than double the bandwidth. • The 5 GHz range has a total of 23 channels, 12 of which are non-overlapping. This allows for a maximum of 6 non-overlapping bonded (combined) channels. • The 2.4 GHz range has a total of 11 channels, three of which are non-overlapping. This allows for a maximum of 1 non-overlapping channel. For this reason, channel bonding isn't usually practical for the 2.4 GHz range.
Frame composition	802.11n changes the frame composition, resulting in increased efficiency of data transmissions due to less overhead.

When running at 802.11n speeds, 802.11a and 802.11g are considered high throughput (HT) and sometimes referred to as 802.11a-ht and 802.11g-ht.

802.11ac

802.11ac increased bandwidth and communication speeds by using the following technologies:

Technology	Details
Multi-user MIMO (MU-MIMO)	MU-MIMO is an enhancement to MIMO that allows multiple users to use the same channel. In addition to adding MU-MIMO, 802.11ac doubled the number of MIMO radio streams from four to eight.
Channel bonding	Channel bonding is used to combine even more channels in the 5 GHz band, allowing for up to 160 MHz wide channels. Even though 160 MHz wide channels are supported, most 802.11ac networks use 80 MHz wide channels.
Frame composition	802.11ac added four fields to the wireless frame, which identify the frame as very high throughput (VHT).

Wireless Network Implementation

The following table describes wireless network implementation considerations:

Consideration	Description
Speed and signal distance	When implementing the wireless network, keep in mind the following concerning signal distance and speed: • Transmission speeds are affected by distance, obstructions (such as walls), and interference. • Maximum signal distance depends on several factors, including obstructions, antenna strength, and interference. For example, for communications in a typical environment (with one or two walls), the actual distance would be roughly half of the maximum. • Because transmission speeds decrease with distance, you can either achieve the maximum distance or the maximum speed, but not both.

Mixing newer and older devices	Newer devices' ability to communicate with older devices depends on the capabilities of the transmit radios in the access point. • Some 802.11n devices are capable of transmitting at either 2.4 GHz or 5 GHz. However, a single radio cannot transmit at both frequencies at the same time. • Most 802.11g devices can transmit using DSSS, CCK, DQPSK, and DBPSK for backwards compatibility with 802.11b devices. However, the radio cannot transmit using both DSSS and OFDM at the same time. When you connect a legacy device to the wireless network, all devices on the network operate at the legacy speed. For example, connecting an 802.11b device to an 802.11n or 802.11g access point slows down the network to 802.11b speeds.
Dual band access points	A dual band access point can use one radio to transmit at one frequency and a different radio to transmit at a different frequency. For example, you can configure many 802.11n devices to use one radio to communicate at 5 GHz with 802.11a devices, and the remaining radios to use 2.4 GHz to communicate with 802.11n devices. Dual band 802.11a and 802.11g devices are also available.
Mixed mode	Be aware of the following when combining clients that use different 802.x standards. • When you configure an access point, some configuration utilities use the term mixed mode to designate a network with both 802.11n and non-802.11n clients. In this configuration, one radio transmitter is used for legacy clients, and the remaining radio transmitters are used for 802.11n clients. • Many 802.11n access points can support clients running other wireless standards (802.11a/b/g). When a mix of clients using different standards are connected, the access point must disable some 802.11n features to be compatible with non-802.11n devices. This decreases the effective speed. • Some newer 802.11a and 802.11g devices provide up to 108 Mbps using 802.11n pre-draft technologies (MIMO and channel bonding).

The following IEEE 802.11 standards exist or are in development to support the creation of technologies for wireless local area networking:

802.11a: 54 Mbps standard, 5 GHz signaling (ratified 1999)
802.11b: 11 Mbps standard, 2.4 GHz signaling (1999)
802.11c: Operation of bridge connections (moved to 802.1D)
802.11d: Worldwide compliance with regulations for use of wireless signal spectrum (2001)
802.11e: Quality of Service support (2005) to improve the delivery of delay-sensitive applications, such as Voice Wireless LAN and streaming multimedia
802.11F: Inter-Access Point Protocol recommendation for communication between access points to support roaming clients (2003)
802.11g: 54 Mbps standard, 2.4 GHz signaling (2003)
802.11h: Enhanced version of 802.11a to support European regulatory requirements (2003)
802.11i: Security improvements for the 802.11 family (2004)
802.11j: Enhancements to 5 GHz signaling to support Japan regulatory requirements (2004)
802.11k: WLAN system management
802.11m: Maintenance of 802.11 family documentation
802.11n: 100+ Mbps standard improvements over 802.11g (2009)
802.11p: Wireless Access for the Vehicular Environment
802.11r: Fast roaming support using Basic Service Set transitions
802.11s: ESS mesh networking for access points
802.11T: Wireless Performance Prediction — recommendation for testing standards and metrics
802.11u: Internetworking with cellular and other forms of external networks
802.11v: Wireless network management and device configuration
802.11w: Protected Management Frames security enhancement
802.11y: Contention-Based Protocol for interference avoidance
802.11ac: 3.46Gbps standard, supports 2.4 and 5GHz frequencies through 802.11n
802.11ad: 6.7 Gbps standard, 60 GHz signaling (2012)

802.11ah: Creates extended-range Wi-Fi networks that go beyond the reach of a typical 2.4 GHz or 5 GHz networks
802.11aj: Approved in 2017; primarily for use in China
802.11ax: Approval expected 2018
802.11ay: Approval expected 2019
802.11az: Approval expected 2019