# Wi-Fi

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May 9, 2025

## Contents

# 1 How Wifi works

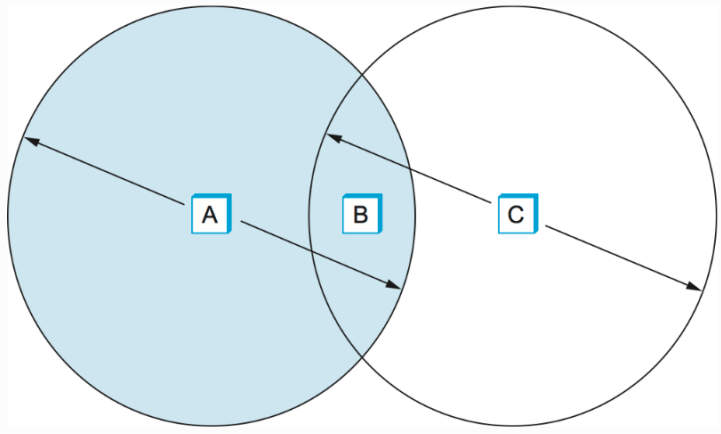
- Access points connect to the wired network
- APs transmit radio signals at a specific frequency range
- Client devices assosiate with the AP and receive these signals
- SSID is used to identify the network

# 2 Improving Performance of Wifi

- **MIMO (Multiple Input Multiple Output)**: Uses multiple antennas at both the transmitter and receiver to improve communication performance. This increases the capacity and reliability of the wireless link by allowing multiple data streams to be transmitted simultaneously.
- **Beamforming**: Focuses the wireless signal towards a specific receiving device, rather than having the signal spread in all directions. This improves signal strength and reduces interference, leading to better performance and range.
- **Channel Bonding**: Combines two or more adjacent channels to create a wider channel, which increases the data rate. This allows for faster data transmission and improved overall network throughput.
- **Quality of Service (QoS)**: Prioritizes certain types of traffic, such as video or voice, to ensure they receive the necessary bandwidth and low latency. This improves the performance of time-sensitive applications and provides a better user experience.

# 3 Hidden Nodes

Consider a situation where A and C (devices) are both within range of B (access point) but not each other. Suppose both A and C want to communicate with B and so they each send it a frame. A and C are unaware of each other since their signals do not carry that far. These two frames collide with each other at B, but unlike an Ethernet, neither A nor C is aware of this collision. A and C are said to be hidden nodes with respect to each other.

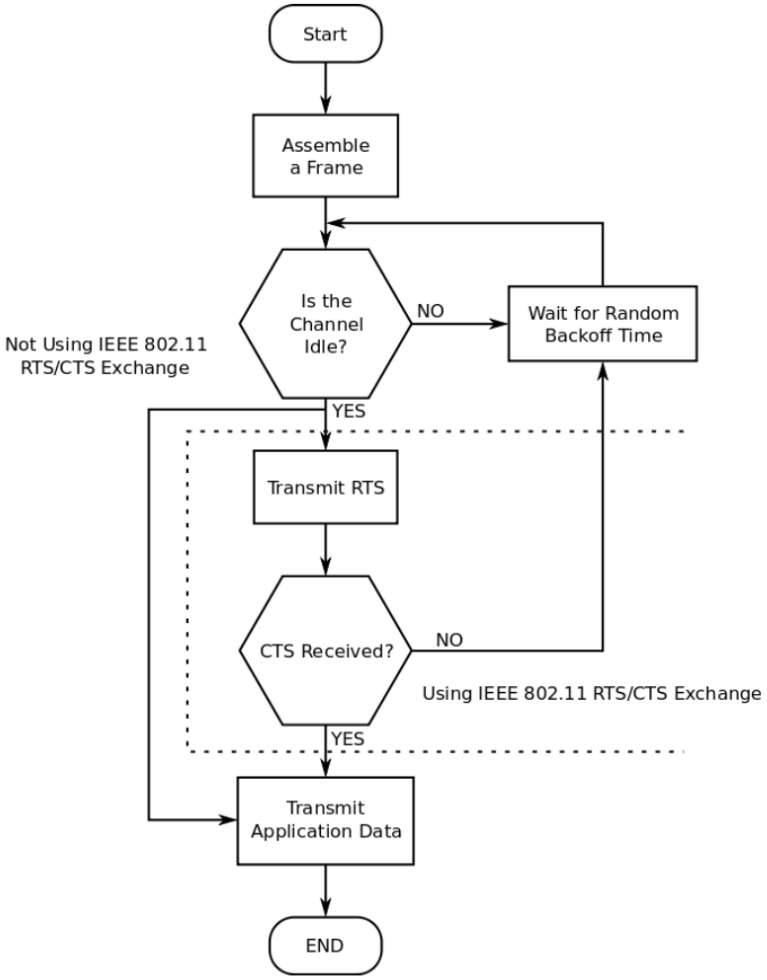



## 3.1 Hidden Node solution

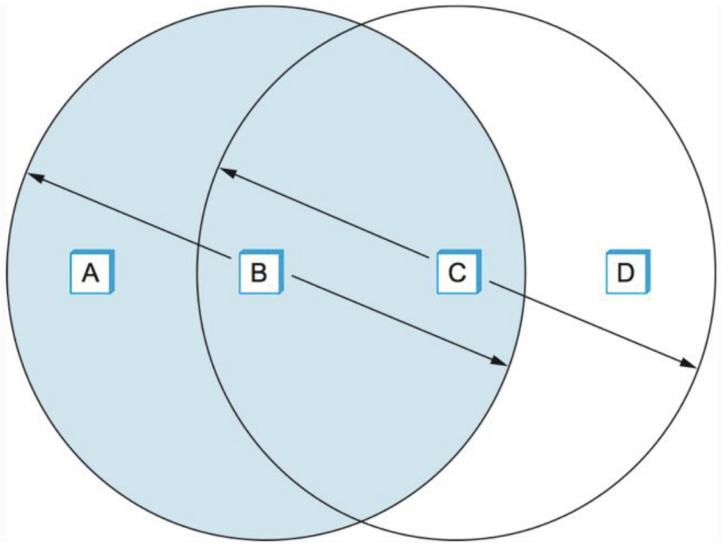
- **Request to Send**
  - Device sends an RTS to the access point
  - If the channel is free, the AP replies with a CTS (clear to send) if the channel is free
  - Device transmits data, while other devices wait

## 3.2 CSMA/CA

- A method of **collision detection**
- Listens to the channel and **waits for it to be idle** before transmitting
- Uses ACKs to confirm reciept



# 4 Exposed Node




Each of the four nodes is able to send and receive signals that reach just the nodes to its immediate left and right. For example, B can exchange frames with A and C but it cannot reach D, while C can reach B and D but not A. Suppose B is sending to A. Node C is aware of this communication because it hears B's transmission. It would be a mistake, however, for C to conclude that it cannot transmit to anyone just because it can hear B's transmission. For example, suppose C wants to transmit to node D. This is not a problem since C's transmission to D will not interfere with A's ability to receive from B

## 4.1 Exposed Node Management

The exposed node problem can reduce network efficiency as nodes that could safely transmit are unnecessarily prevented from doing so. Wi-Fi networks implement several techniques to manage this issue:

- **Virtual Carrier Sensing**: Wi-Fi uses the Network Allocation Vector (NAV) that allows nodes to reserve the medium for a specific duration. This helps distinguish between transmissions that would cause interference and those that would not.
- **RTS/CTS with NAV**: The RTS/CTS mechanism includes duration information in both messages. Exposed nodes can use this information to determine if their intended transmission would interfere:
  - When a node hears an RTS but not the corresponding CTS, it may be an exposed node
  - It can transmit to nodes outside the sender's transmission range
- **Directional Antennas**: Advanced Wi-Fi systems can use directional transmission to reduce the exposed node problem by focusing signals only where needed rather than broadcasting omnidirectionally.
- **Spatial Reuse**: Modern Wi-Fi standards (802.11ax/Wi-Fi 6) implement spatial reuse techniques like BSS Coloring, which allows simultaneous transmissions from different basic service sets when interference is minimal.
- **Dynamic Sensitivity Control (DSC)**: Adjusts the clear channel assessment threshold based on network conditions to avoid unnecessarily preventing transmissions from exposed nodes.

These mechanisms allow Wi-Fi networks to maximize channel utilization by enabling more simultaneous transmissions while still avoiding harmful interference.