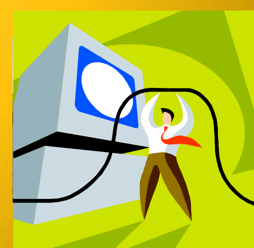
Mobile Networks

Connections and structures



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Outline (continuation from last class)

- 802.11 standard
- Physical layer
- MAC
  - ➢DCF
  - PCF
- Advanced MAC functions

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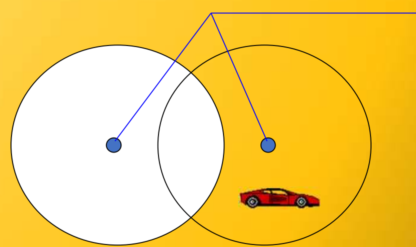
Recap: Public cellular network

- Access network with radio link
  - Space is divided in cells with a base station
  - Mobile Node (MN) can work when changing between cells



Cell coverage size is
- Highly variable
- Depends on the technology
- Depends on the number of users

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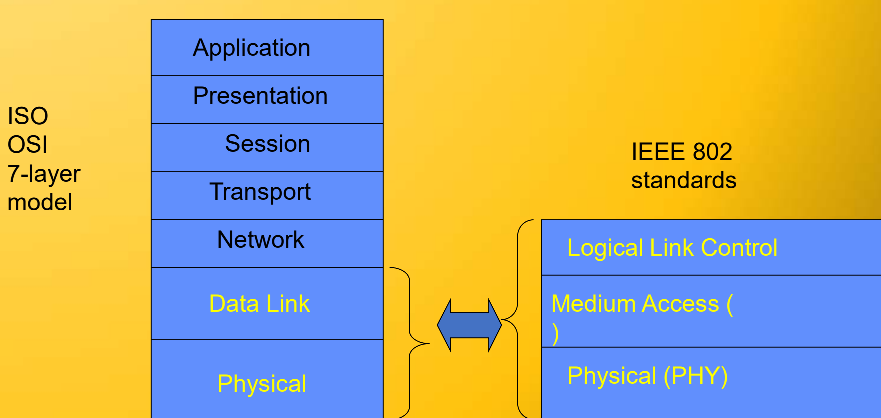
Recap: Standardization of Wireless Networks

- Wireless networks are standardized by IEEE.
- Under 802 LAN MAN standards committee.

LAN – Local Area Netework
MAN – Metro Area Network



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Recap: Historic IEEE 802.11 Family

Protocol	Release Data	Freq.	Rate (typical)	Rate (max)	Range (indoor)
Legacy	1997	2.4 GHz	1 Mbps	2Mbps	?
802.11a	1999	5 GHz	25 Mbps	54 Mbps	~30 m
802.11b	1999	2.4 GHz	6.5 Mbps	11 Mbps	~30 m
802.11g	2003	2.4 GHz	25 Mbps	54 Mbps	~30 m
802.11n	2008	2.4/5 GHz	200 Mbps	600 Mbps	~50 m
802.11ac	2014	5 GHz	600Mbps	3.5 Gbps	~35m
802.11ax (Wi-Fi 6)	2021	2.4/5 GHz	130 (2.4 GHz) 400-800Mbps (5GHz)	10 Gbps	~30m
802.11be (Wi-Fi 7)	TBD	2.4/5/6 GHz	?	40 Gbps	?
802.11ay	2021	60 GHz	20 Gbps	20-40 Gbps	300-500m

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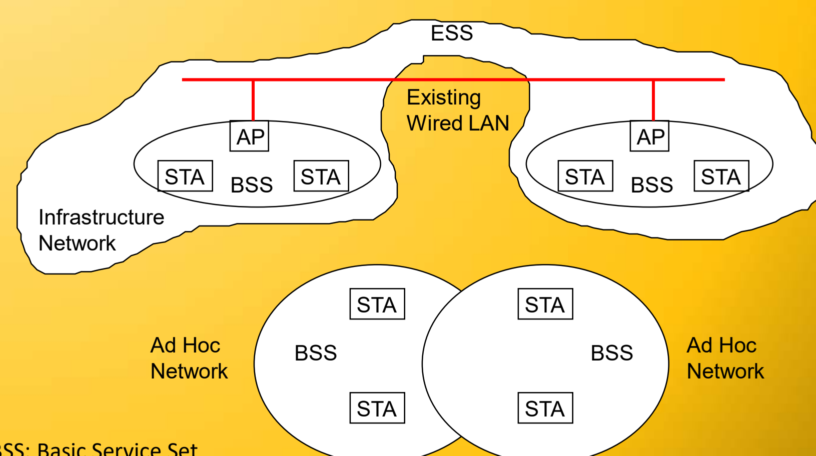
Recap: 802.11 Architecture



BSS: Basic Service Set
ESS: Extended Service Set
DS: Distribution System

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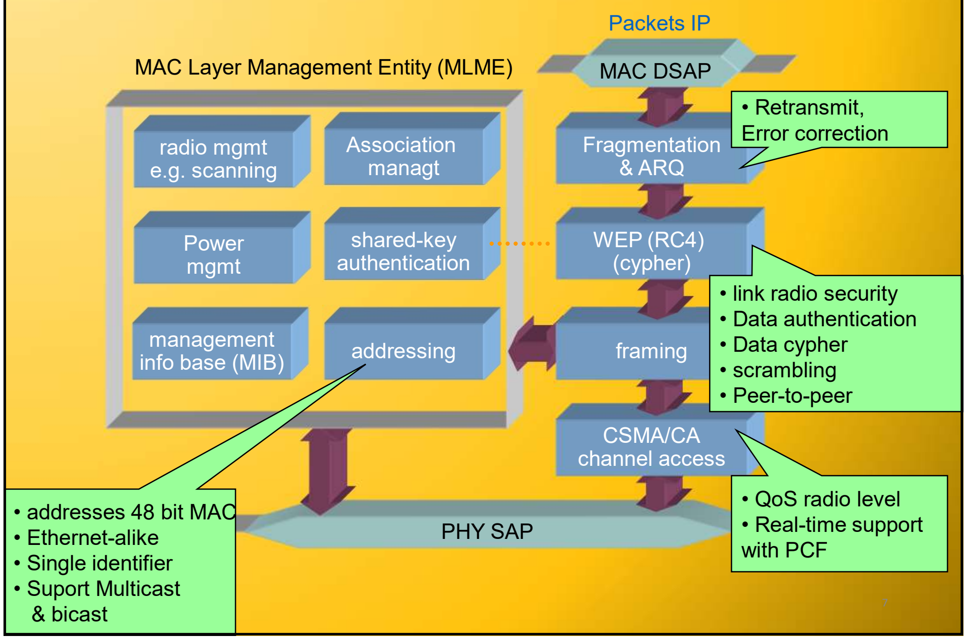
Recap: MAC IEEE802.11



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Outline (continuation from last class)

- 802.11 standard
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  - ➢ DCF
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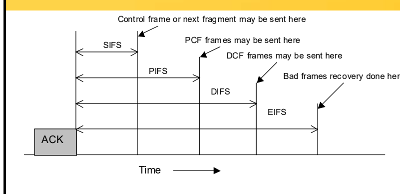
MAC Layer

- Asynchronous Data Service (DCF)
  - CSMA/CA
  - RTS/CTS
- Timing-controlled service (PCF)
  - Polling
- Inter-frame spacing (IFS)
  - DIFS (distributed), for the node to start transmitting
  - PIFS (point), used by PCF for network access
  - SIFS (short), between packets of the same flow



DCF: Distribution Coordination Function
PCF: Point Coordination Function
DIFS: DCF Inter Frame Spacing
PIFS: PCF Inter Frame Spacing
SIFS: Short Interframe Spacing

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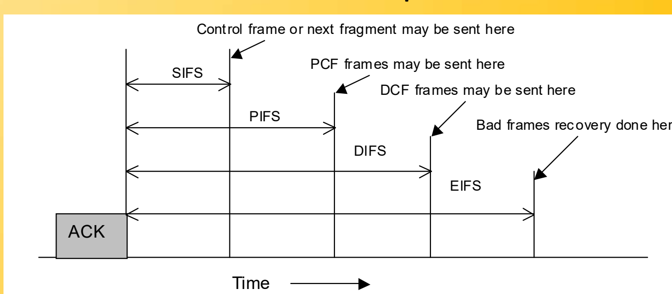
Carrier Sense Multiple Access



- Before transmitting a packet, sense carrier
- If it is idle, send
  - After waiting for one DCF inter frame spacing (DIFS)
- If it is busy, then
  - Wait for medium to be idle for a DIFS (DCF IFS) period
  - Go through exponential backoff, then send
    - Want to avoid that several stations waiting to transmit automatically collide
- Wait for ACK
  - If there is one, you are done
  - If there isn't one, assume there was a collision, retransmit using exponential backoff

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Exponential Backoff

- Force stations to wait for random amount of time to reduce the chance of collision
  - Backoff period increases exponentially after each collision
  - Similar to Ethernet
- If the medium is sensed busy:
  - Wait for medium to be idle for a DIFS (DCF IFS) period
  - Pick random number in contention window (CW) = backoff counter
  - Decrement backoff timer until it reaches 0
    - But freeze counter whenever medium becomes busy
  - When counter reaches 0, transmit frame
  - If two stations have their timers reach 0; collision will occur;
- After every failed retransmission attempt:
  - increase the contention window exponentially
  - $2^i - 1$ starting with CW_{min} up to CW_{max} e.g., 7, 15, 31, …

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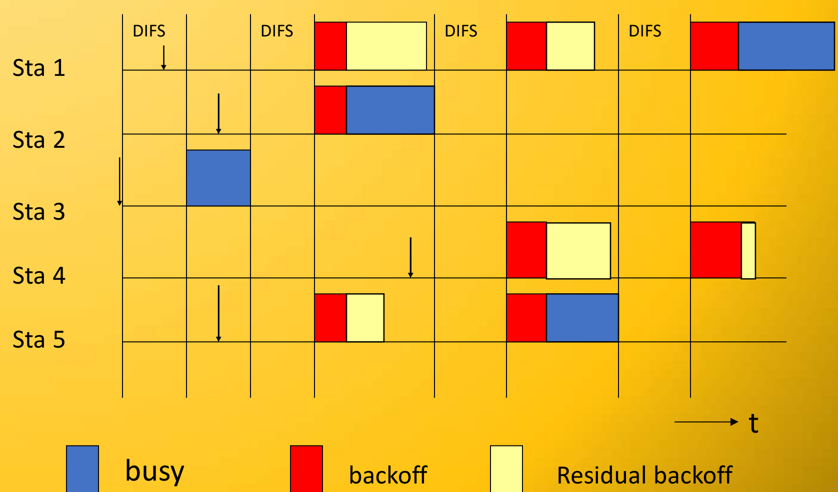
CSMA/CA



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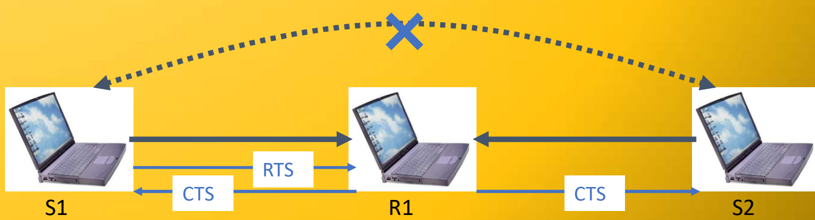
Collision Avoidance

- Difficult to detect collisions in a radio environment
  - While transmitting, a station cannot distinguish incoming weak signals from noise – its own signal is too strong
- Why do collisions happen?
  - Near simultaneous transmissions
    - Period of vulnerability: propagation delay
  - Hidden node situation: two transmitters cannot hear each other and their transmission overlap at a receiver



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Request-to-Send and Clear-to-Send

- Before sending a packet, a station first sends a RTS.
- The receiving station responds with a CTS.
  - RTS and CTS are smaller than data packets
  - RTS and CTS use shorter IFS to guarantee access
- Stations that hear either the RTS or the CTS “remember” that the medium will be busy for the duration of the transmission
  - Based on a Duration ID in the RTS and CTS
- Virtual Carrier Sensing: stations maintain Network Allocation Vector (NAV)
  - Time that must elapse before a station can sample channel for idle status

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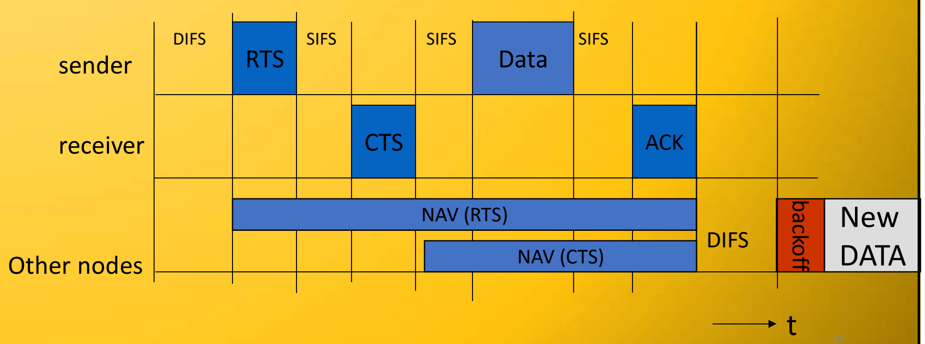
RTS/CTS: NAV

- NAV: Network Allocation Vector
- NAV acts as a distributed (in each node) resource allocation register
- RTS/CTS
  - Not a “major” concern



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Synchronization

- Timing synchronization function (TSF)
  - Beacons of the AP are sent in well-defined instants.
  - Content of packet is the exact instant when it goes to the network.
- Used also for power management
  - All clocks of all stations in the BSS are synchronized
    - This allows STA to wake-up to check if packets exist.

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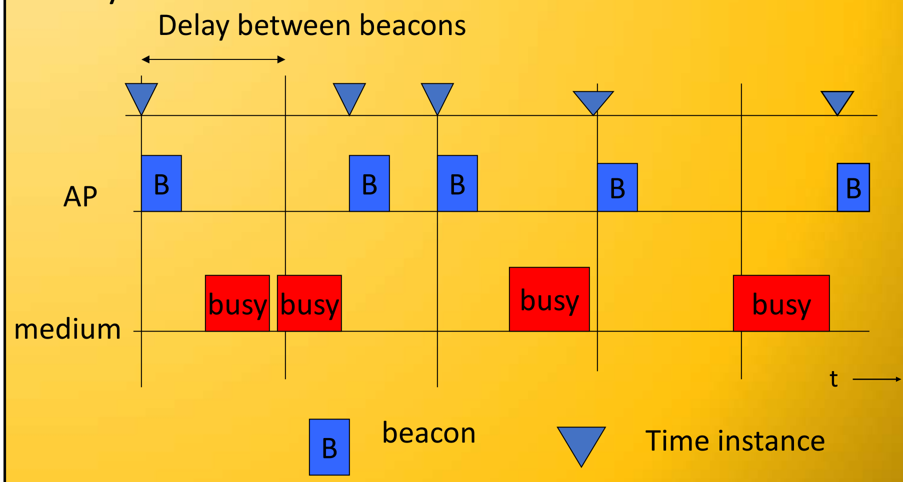
Synchronization



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Outline

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Some More MAC Features

- Use of RTS/CTS is controlled by an RTS threshold
  - RTS/CTS is only used for data packets longer than the RTS threshold
  - Pointless to use RTS/CTS for short data packets – high overhead!
- Number of retries is limited by a Retry Counter
  - Short retry counter: for packets shorter than RTS threshold
  - Long retry counter: for packets longer than RTS threshold
- Packets can be fragmented.
  - Each fragment is acknowledged
  - But all fragments are sent in one sequence
  - Sending shorter frames can reduce impact of bit errors
  - Lifetime timer: maximum time for all fragments of frame

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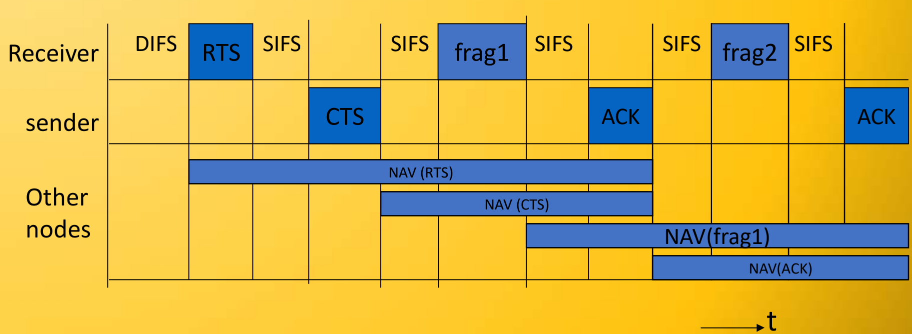
Fragmentation



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Power management (infrastructure)

- APs buffer packets to stations in power saving mode
  - APs announce in beacons which packets are waiting with the TIM (traffic indication Map)
  - Broadcast/multicast frames are also buffered at AP
    - Sent after beacons, same common timing period.
    - Uses Delivery Traffic Indication Map (DTIM)
    - AP controls DTIM interval
- STA in power save wake periodically to listen for beacons
  - If it has data pending, send a PS-Poll
  - AP sends buffered data to this PS-poll
- TSF (Timing Synchronization Function) assures AP and stations are synchronized
  - Synchronizes clocks of the nodes in the BSS

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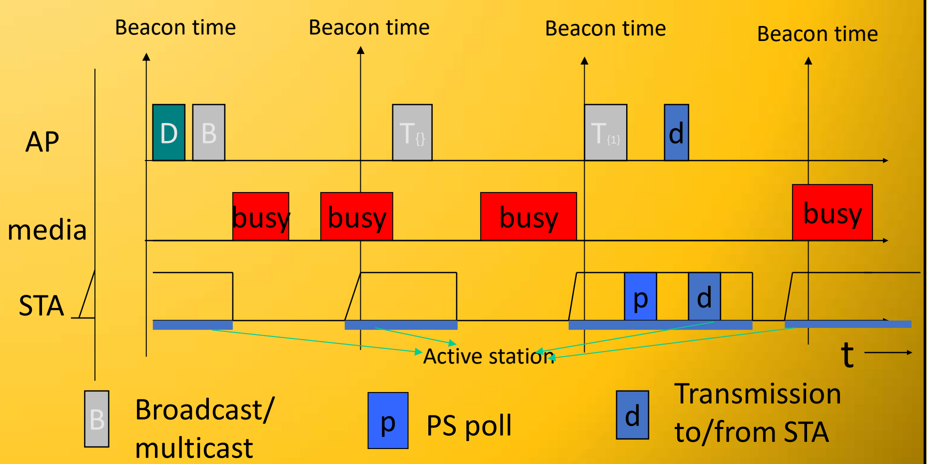
Power management



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How does a station connect to an Access Point?

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Control services at MAC

- Synchronization, Roaming and Association
  - Functions to find a network
  - Change APs
  - Search APs.
- Power Management
  - sleep mode without losing packets
  - Power management functions
- MIB: Management information base
- Security: authentication and cypher

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SSID

- Mechanism used to segment wireless networks
  - Multiple independent wireless networks can coexist in the same location
- Each AP is programmed with a SSID that corresponds to its network
- Client computer presents correct SSID to access AP
- Security Compromises
  - AP can be configured to "broadcast" its SSID
  - Broadcasting can be disabled to improve security
  - SSID may be shared among users of the wireless segment

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Association Management: Scanning

- Scanning is needed to:
  - Find and connect to a networks
  - Find a new AP during roaming
- Passive Scanning:
  - Station simply listens for Beacon and get info of the BSS. Power is saved.
- Active Scanning:
  - Station transmits Probe Request; elicits Probe Response from AP. Saves time.

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Association Management: Scanning, and Joining

- Station must associate with an AP before they can use the network
  - AP must know about them so it can forward packets
- Re-association (roaming): association is transferred
  - Supports mobility in the same ESS
- Disassociation: station or AP can terminate association
- Stations can detect AP based on scanning
- Joining a BSS
  - Synchronization in Timestamp Field and frequency (i.e., channel) :
  - Adopt PHY parameters
  - Other parameters: BSSID, WEP, Beacon Period, etc.

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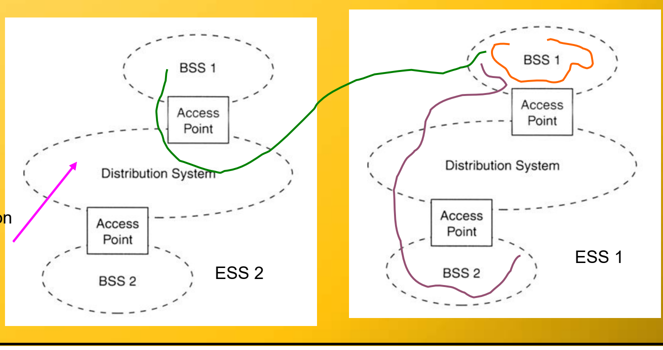
IEEE 802.11 Mobility

- Standard defines the following mobility types:
  - No-transition: no movement or moving within a local BSS
  - BSS-transition: station moves from one BSS in one ESS to another BSS within the same ESS
  - ESS-transition: station moves from a BSS in one ESS to a BSS in a different ESS (continuos roaming not supported)

- Address to destination mapping
- seamless integration of multiple BSS



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Roaming

- Roaming: station changes network (BSS)
- STA may go:
  - Outside the coverage area of their AP
  - But still under the coverage area of another AP
- Reassociate the STA with the new AP allows the communication to continue

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Roaming

- STA decides that the signal with the current AP is bad.
- STA does scanning (act/pas) to find new AP
- STA reassociates with the New AP (NAP)
  - Includes authorization.
- Without positive answer
  - STA does new scan
- With positive answer:
  - STA changed network to the new NAP
  - AP informs the ESS of the new association
  - Information in the distributed system is always updated.

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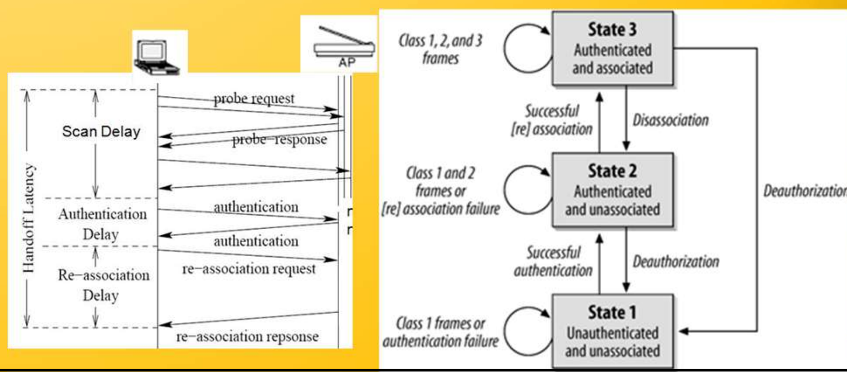
Attachment to a BSS

- The STA finds a BSS/AP through **Scanning/Probing**
- Both **Authentication** as well as **Association** are necessary to enter a BSS



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Phase 1: Scanning

- The STA searches for APs
  - **Passive Scanning**
    - STA analizes channels looking for ***Beacon*** packets, which are periodically sent by the AP, announcing its presence and SSID
  - **Active Scanning**
    - STA sends ***Probe Request*** packets to all channels in sequence
    - AP's listening in these diferente channels respond with a ***Probe Response***

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Phase 2: Authentication

- After finding and selecting an AP, the STA has to authenticate with it. Two main methods:
- Method 1: **Open System Authentication**
  - Default procedure, executed in 2 steps:
    - 1 - STA sends an authentication frame including its identity
    - 2 - AP responds with a frame as a Ack/NAck
- Method 2: **Shared Key Authentication**
  - STA and AP have a shared secret, obtained in some other way
  - 1 – STA sends an initial authentication request
  - 2 – AP replies to the STA with a challenge
  - 3 – STA decyphers the challenge with its own key and sends it to the AP
  - 4 – AP uses its own key to decifer the challenge and compares results

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Phase 3: Association

- After authenticated, the STA begins the **association** process, i.e., Exchange roaming and capacity information between STA and AP
- Procedure:
  - 1 – STA sends a **Associate Request** to AP, indicating supported transmission rates and intended association SSID
  - 2 – AP allocates resources and decides if it accepts or rejects the STA
  - 3 – AP sends an **Association Response**, indicating the association identifying and supportted transmission rates, in case the association is accepted
  - 4 (optional) – In case of a handover (transition of the STA between two different APs), the new AP informs the old AP
- Only after associating to the AP, can the STA start to send and receive data

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How to extend range in Wi-Fi?

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Wi-Fi “extenders”.

- Inexpensive
- They set up a new SSID, and forward all traffic to the original SSID
- Multi-hop configurations are possible
  - Require manual configuration
- Because the original access point and the extender have different SSIDs
  - Many devices will not automatically connect to whichever is closer
  - They prefer to maintain connection with the original SSID until that signal disappears
  - This is, for many mobile users, reason enough to give up on this strategy.

http://intronetworks.cs.luc.edu/current2/mobile/wireless.html

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Mesh

- Different standards
  - IEEE 802.11s standard
    - Focuses on the setup of the mesh networks
    - Uses a mandatory routing protocol – Hybrid Wireless Mesh Protocol
    - Mesh Stations can collocate 802.11 AP's and provide access to the mesh network for 802.11 devices
    - A Mesh Gateway interconnects the mesh to other non-802 networks
  - Wi-Fi Alliance standard (a.k.a., "EasyMesh")
    - Focuses on more "easy" setup of mesh WiFi networks
      - incorporates parts of the IEEE 1905.1 standard for home networks, which simplifies initial configuration.
    - Specifies that one access point – the one connected to the Internet – will be a "Multi-AP" Controller
    - the other access points are called Agents.
    - The EasyMesh standard also

http://intronetworks.cs.luc.edu/current2/mobile/wireless.html

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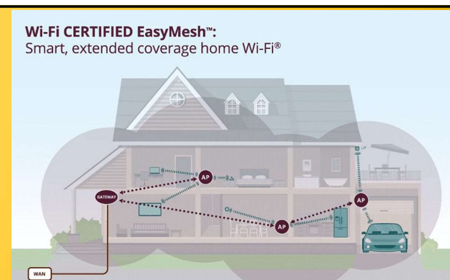
Wi-Fi EasyMesh



- WiFi Alliance Certification program that defines multiple access point home and small office Wi-Fi networks that are easy to install and use, self-adapting, and add multi-vendor interoperability.
- This technology brings both consumers and service providers additional flexibility in choosing Wi-Fi EasyMesh devices for home deployment.
- Wi-Fi EasyMesh uses a controller to manage the network, which consists of the controller, plus additional APs, called agents.
- Establishing controllers to manage and coordinate activity among the agents ensures that each AP does not interfere with the other, bringing both expanded, uniform coverage and more efficient service.

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EasyMesh: reusage of technologies

EasyMesh specification relies on other standards / specification, either by extending them or simply referencing them.

This includes, most notably:

- Building on and extending IEEE Standard 1905.1 to configure Wi-Fi access point interfaces
  - **Discovery**: how nodes are finding each other and identifying the controller
  - **Push-Button Configuration**: to initialize "onboarding" of access points-the process commonly referred to as "meshing"
  - **Backhaul communication**: Communication between the nodes / access points in the mesh network

IEEE 1905.1 standard, Convergent Digital Home Network for Heterogeneous Technologies.

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IEEE 1905.1 Convergent Digital Home Network for Heterogeneous Technologies.

- Networked devices connected by different network media operate as if they were connected across a single network
  - E.g. Gigabit Ethernet 2.4Ghz, and 5Ghz Wi-Fi,.
  - In EasyMesh, the controllers use data from it to configure each agent's AP radios.
  - It includes mechanisms to configure control-related policies on agents, such as metrics and steering. Additionally, the controller determines the topology of the network of agents, so it can adapt to changing network conditions.
- Uses mechanisms from the new Wi-Fi Alliance Agile Multiband standard.
  - New Agile Multiband certified devices will work better as they're moved from spot to spot with intelligent steering and faster network transitions.

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Architecture and components

- **Controller** - every EasyMesh network must have one. The controller can be a unique device or embedded in a device that also has other functionality
- **Agent** - in order for a mesh network to exist, at least two agents must be connected to the controller
- **Device** - any component of a mesh network, whether it contains a controller, an agent, or both

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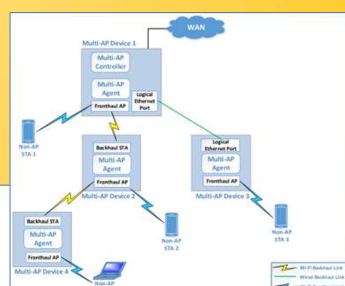
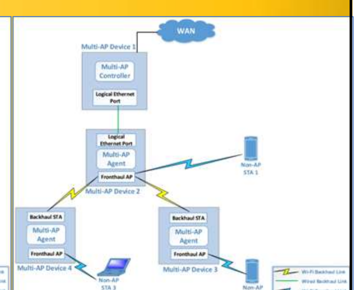
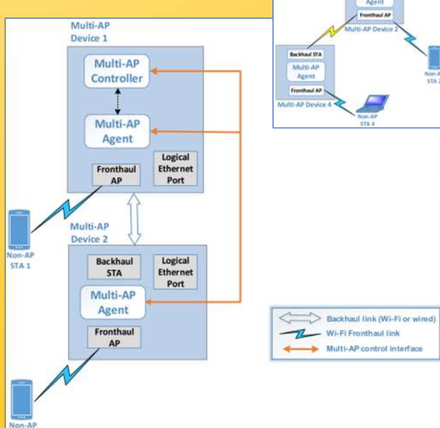
Example deployments







Wi-Fi EasyMesh™ Specification v4.0
Wi-Fi Alliance

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Proprietary limitations

- the specification does *not* standardize algorithms or decision-making
- How to do client steering makes up a significant part of the specification, telling manufacturers how to direct a client from one access point to another.
- When a client should be steered is not covered. Therefore, algorithms will still vary (and client roaming mechanisms may of course still interfere).

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Wireless Mesh network operations mechanisms

OAM (operations, administration and management) required for efficient network operations. Major aspects:

- Link Metric Collection – sets protocol for info collection in the network
- Capability reporting –Master can keep optimizing the network with controls to the nodes.
- Channel selection – Master node picks info on channels from different nodes, and configures the network.
- Client steering –Master Node can suggest clients to move (Network initiated handovers)
- Optimizing connection between agents – manage the connections, selecting the best path between nodes (including wireless and wired)

https://www.slideshare.net/kanquillano/iecep-agm-2018-wireless-mesh-technology-by-kristian-anquillano

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