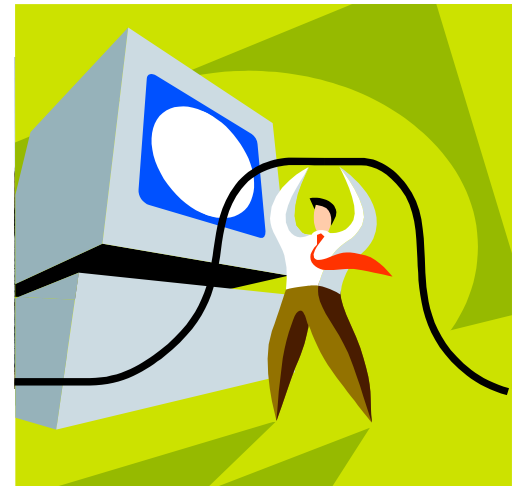


Mobile Networks

Connections and structures



Outline (continuation from last class)

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

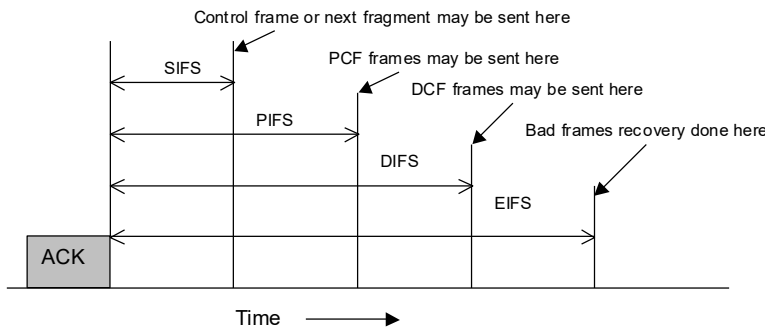
MAC Layer

• Access Mechanisms

- Asynchronous Data Service (DCF)
 - CSMA/CA
 - RTS/CTS
- Timing-controlled service (PCF)
 - Polling

• Durations of Periods between frames

- 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

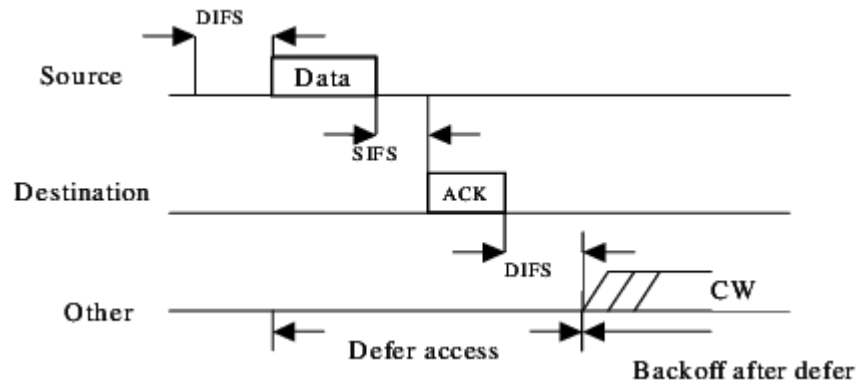
PIFS: PCF Inter Frame Spacing

SIFS: Short Interframe Spacing

Note

- DCF – Distributed Coordinated Function
 - Mandatory CSMA/CD method
 - Contention-based access
- PCF – Point Coordination Function
 - Optional Centralized polling method
 - Also contention-based access
 - Rarely implemented in modern devices

Carrier Sense Multiple Access

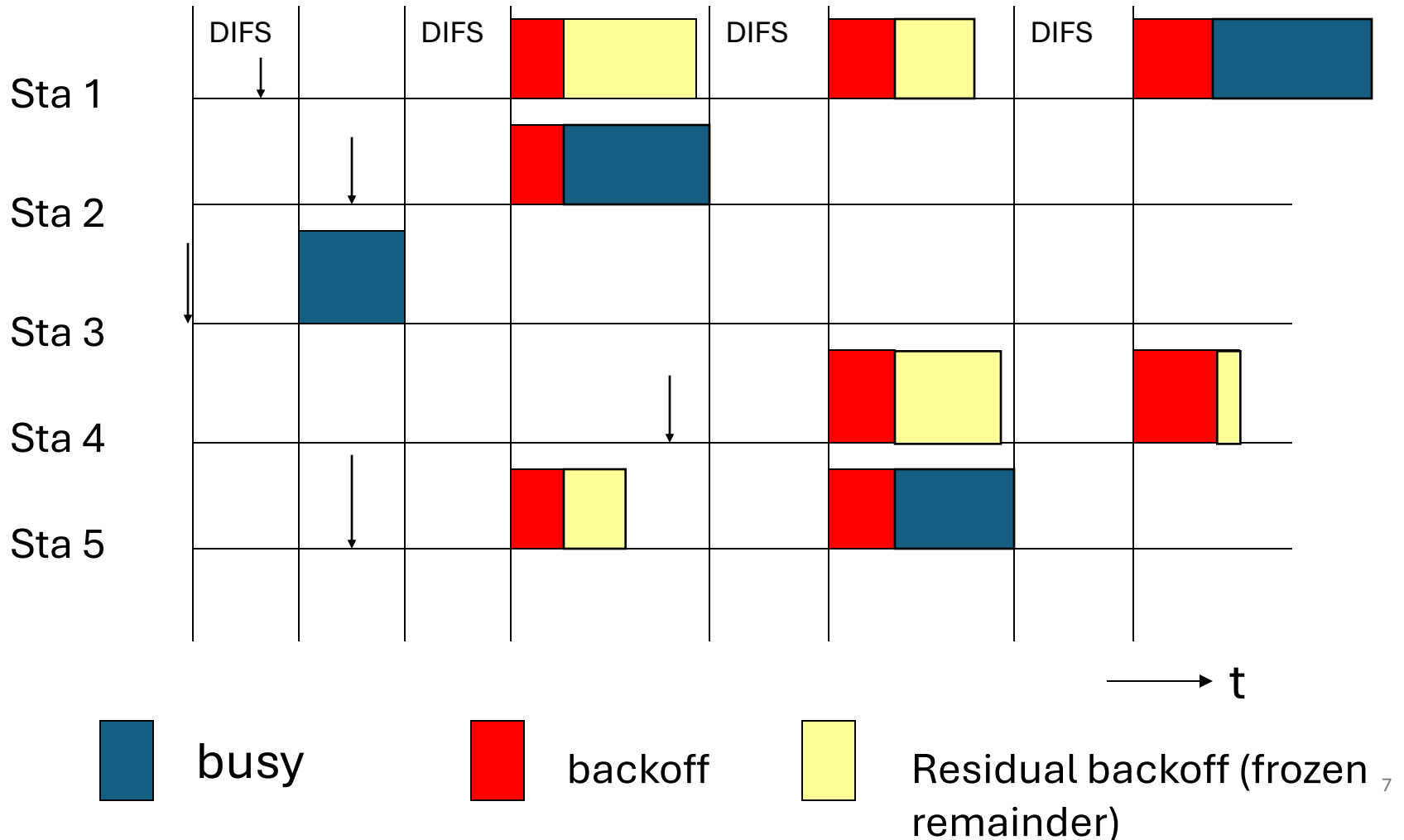


- Before transmitting a packet, sense carrier
- If it is idle, send
 - After waiting for one DCF inter frame spacing (DIFS)
- If it is busy, then
 - Wait for medium to be idle for a DIFS (DCF IFS) period
 - Go through exponential backoff, then send
 - Want to avoid that several stations waiting to transmit 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

Exponential Backoff

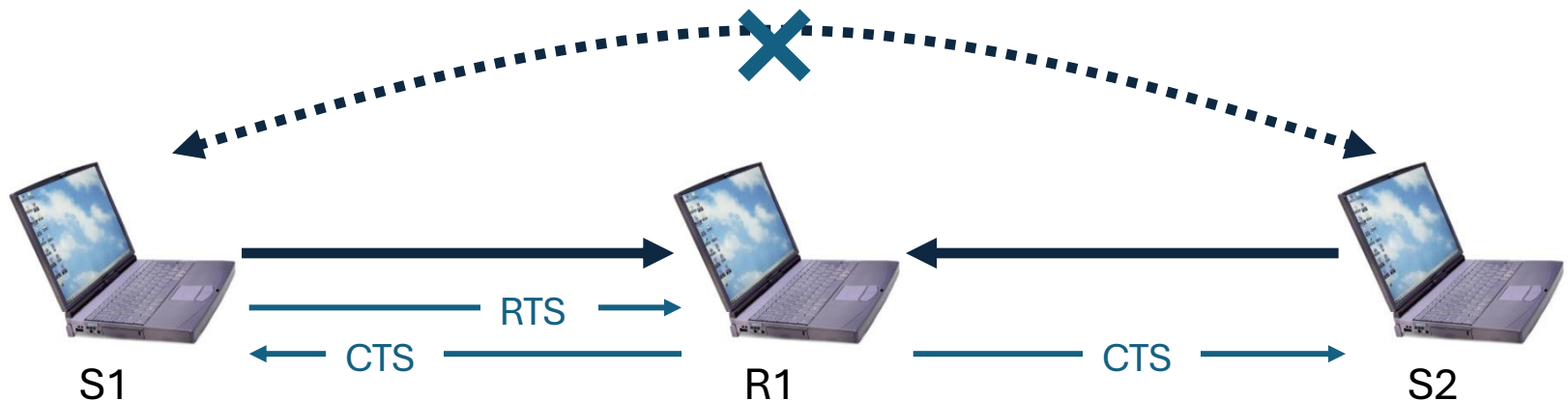
- Force stations to wait for random amount of time to reduce the chance of collision
 - Backoff period increases exponentially after each collision
 - Similar to Ethernet
- If the medium is sensed busy:
 - Wait for medium to be idle for a DIFS (DCF IFS) period
 - Pick random number in contention window (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, ...

CSMA



Collision Avoidance → CSMA/CD

- 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

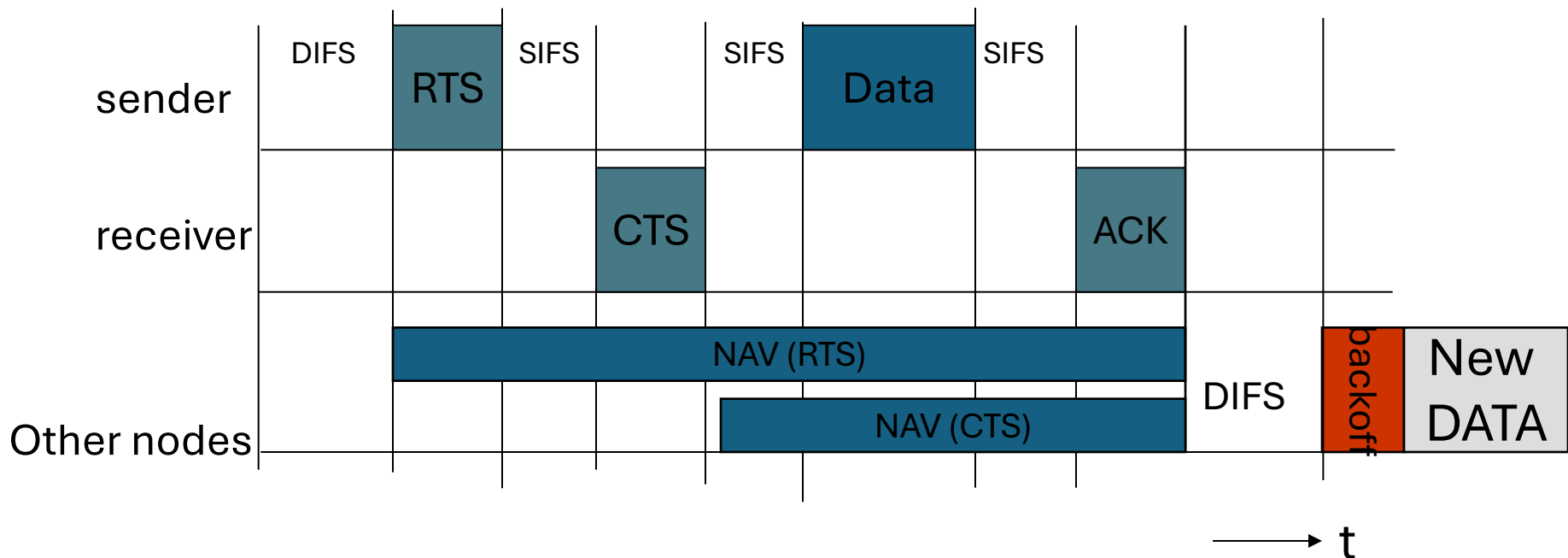


Request-to-Send and Clear-to-Send

- 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

RTS/CTS: NAV

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

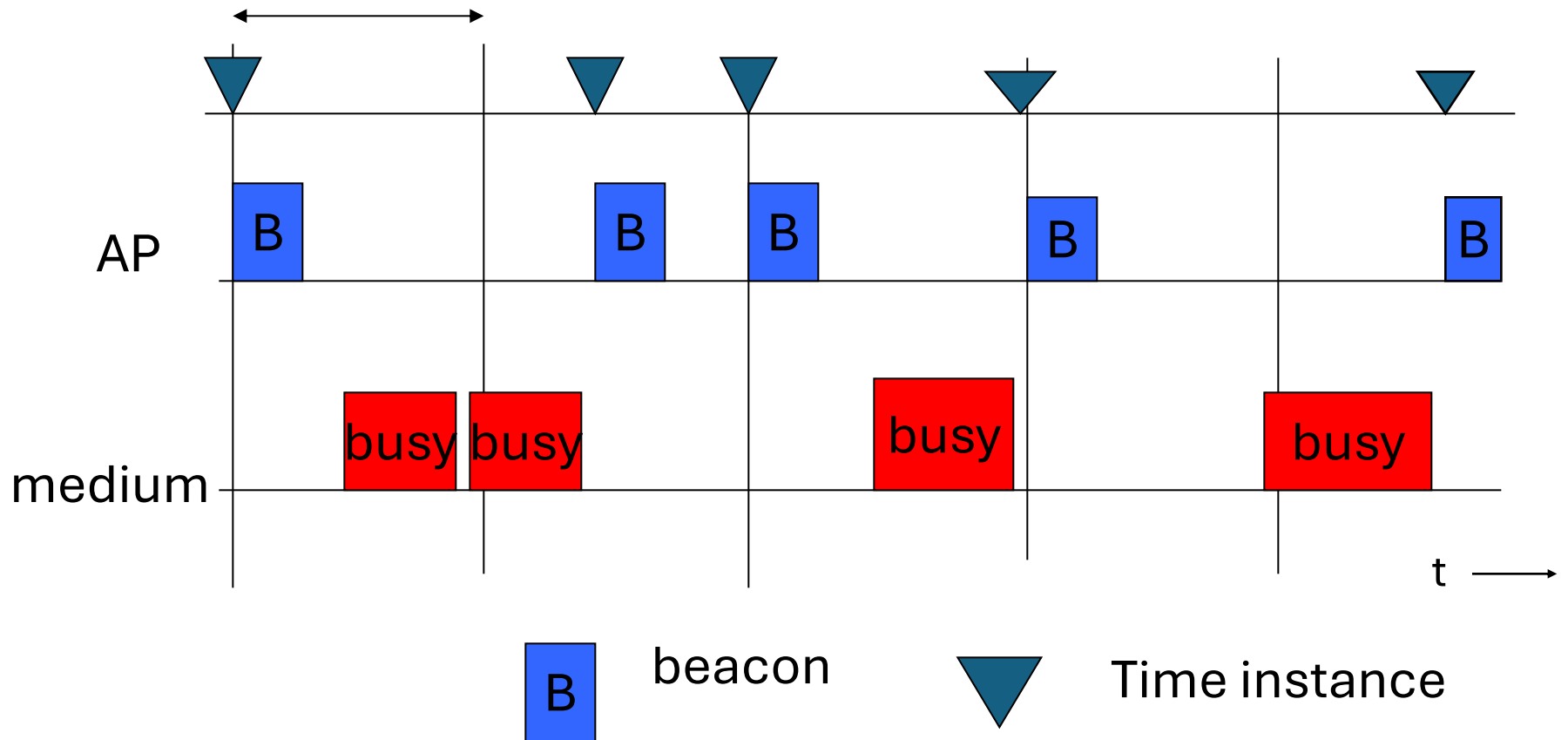


Synchronization

- Timing synchronization function (TSF)
 - Beacons of the AP are sent in well-defined instants.
 - Typically 100ms, but configurable
 - 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.

Synchronization

Delay between beacons



THE NEXT BEACON IS NOT PUSHED IN TIME: they are sent at the designated time

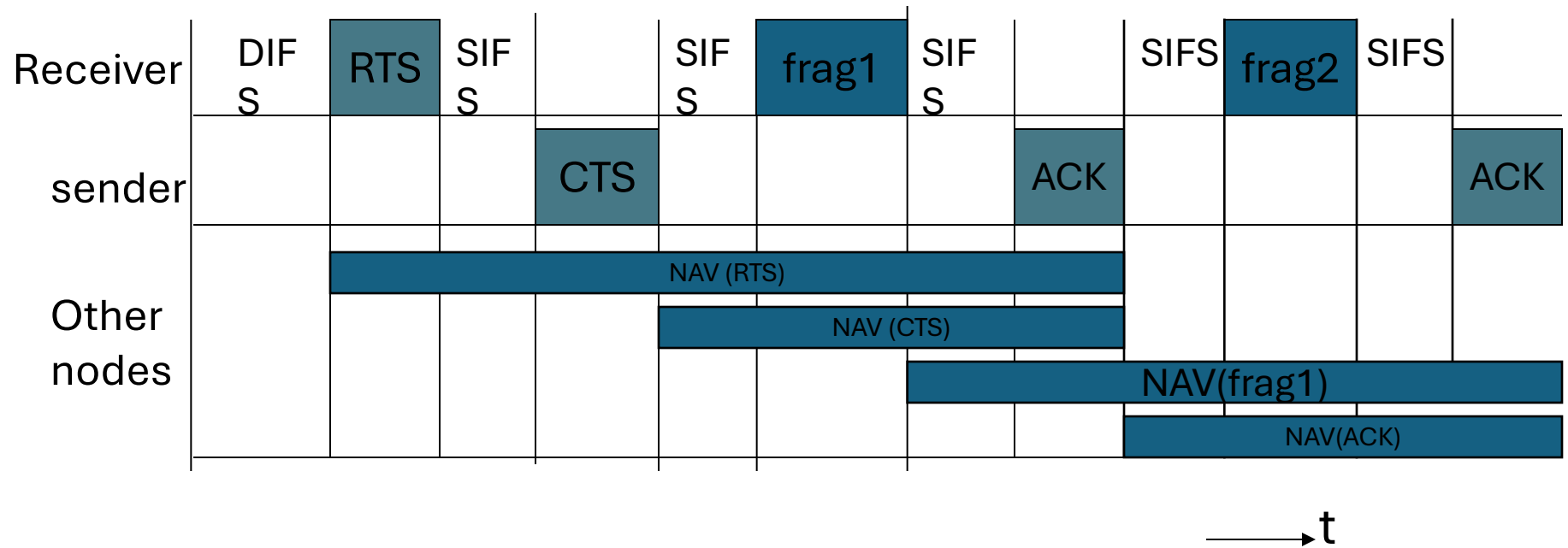
Outline

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

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

Fragmentation



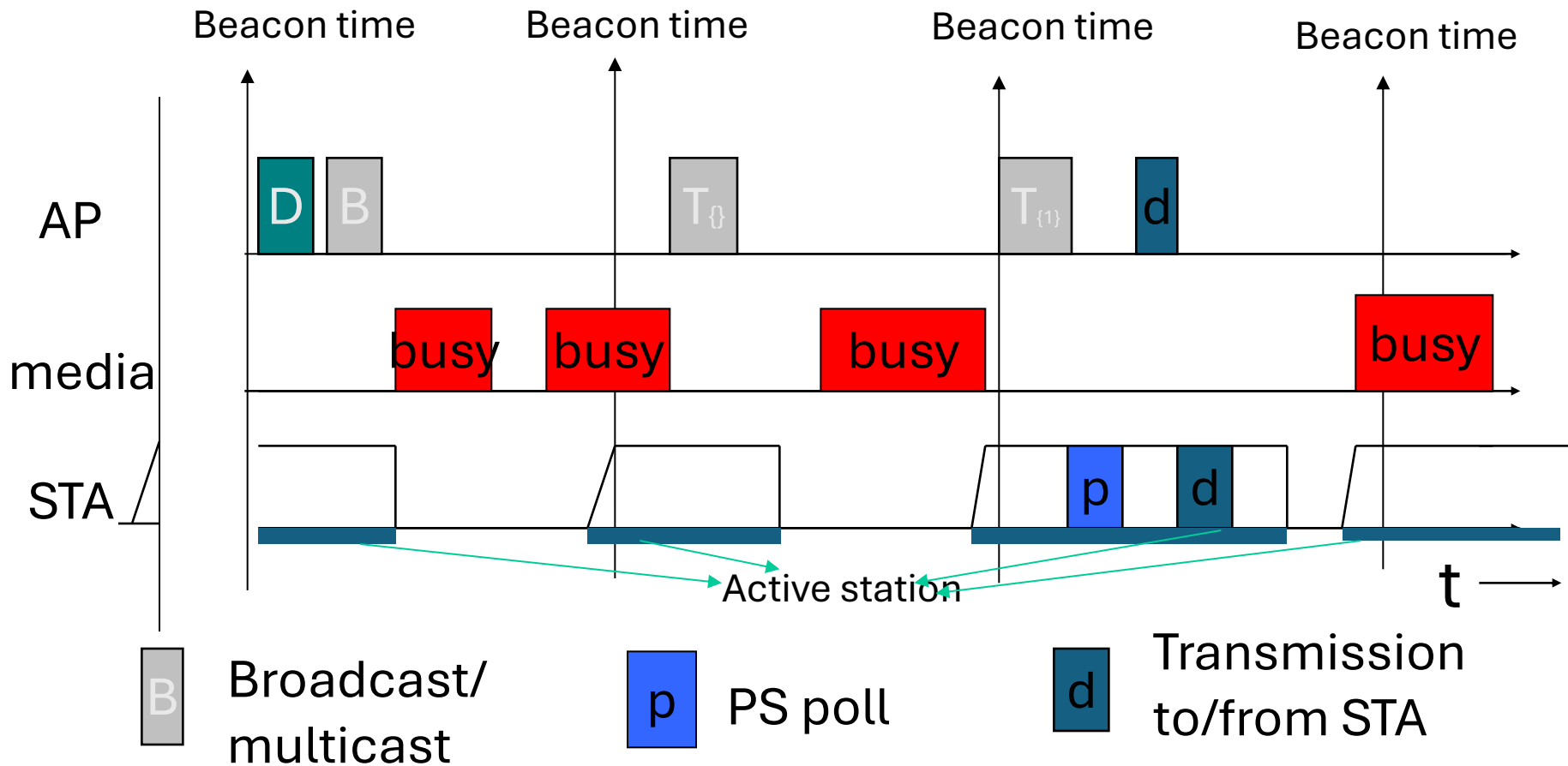
Power management

- Stations (STAs) can enter doze/sleep mode to save battery.
- In sleep, they turn off their radio most of the time.
- The AP buffers unicast frames destined for sleeping STAs.
- The AP signals in each Beacon frame (in the Traffic Indication Map, TIM) which STAs have buffered data waiting.

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 (when it sees its Association ID in the TIM of a Beacon) send a PS-Poll
 - AP sends buffered data (one buffered frame) to this PS-poll
- TSF (Timing Synchronization Function) assures AP and stations are synchronized
 - Synchronizes clocks of the nodes in the BSS

Power management



How does a station connect to an
Access Point?

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

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

Association Management: Scanning

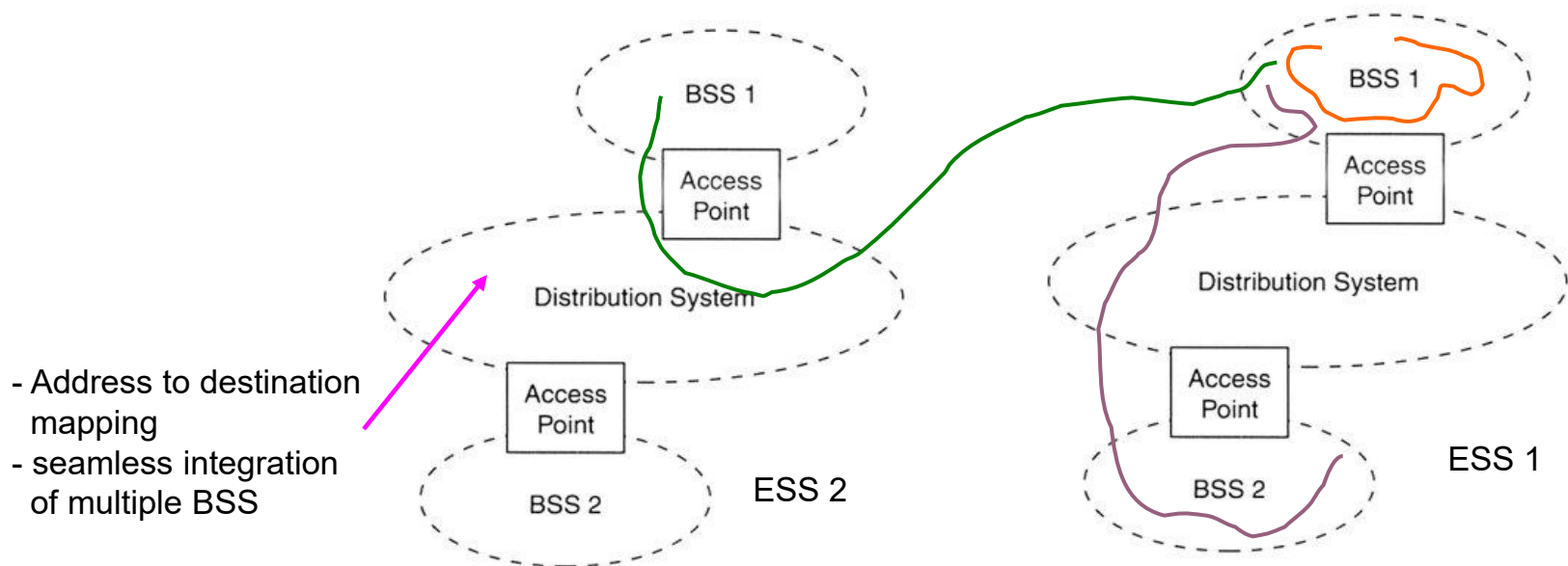
- Scanning is needed to:
 - Find and connect to a networks
 - Find a new AP during roaming
- Passive Scanning:
 - Station simply listens for Beacon and get info of the BSS. Power is saved.
- Active Scanning:
 - Station transmits Probe Request; elicits Probe Response from AP. Saves time.

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.

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 (continuous roaming not supported)**



Roaming

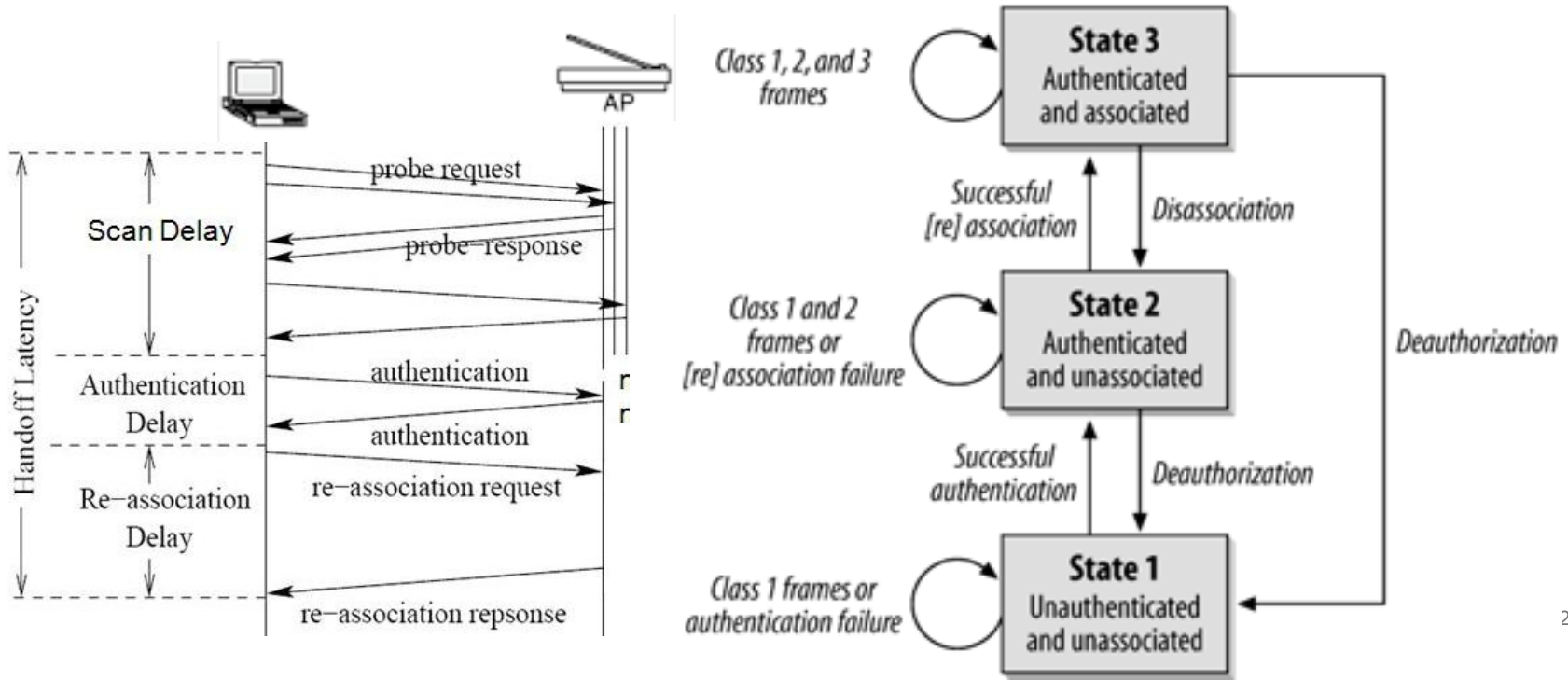
- Roaming: station changes network (BSS)
- STA may go:
 - Outside the coverage area of their AP
 - But still under the coverage area of another AP
- Reassociate the STA with the new AP allows the communication to continue

Roaming

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

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



Phase 1: Scanning

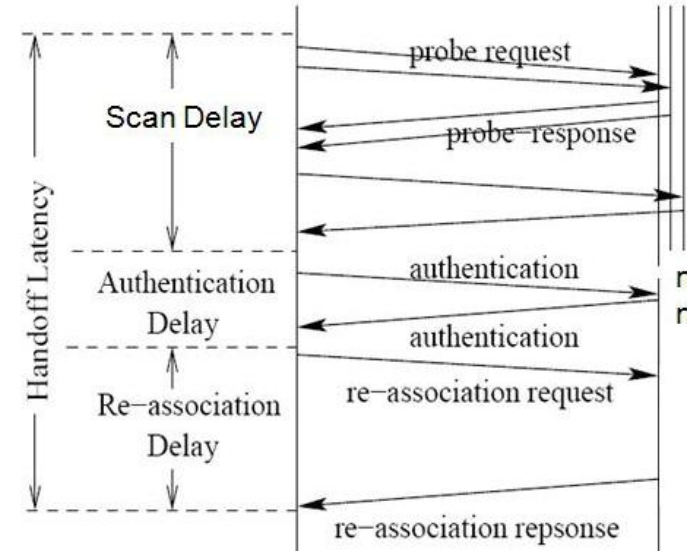
- The STA searches for APs

- **Passive Scanning**

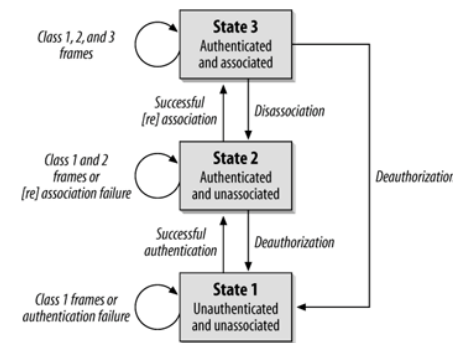
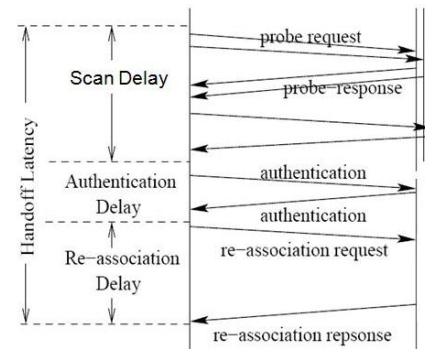
- STA analyzes channels looking for **Beacon** packets, which are periodically sent by the AP, announcing its presence and SSID

- **Active Scanning**

- STA sends **Probe Request** packets to all channels in sequence
 - AP's listening in these different channels respond with a **Probe Response**

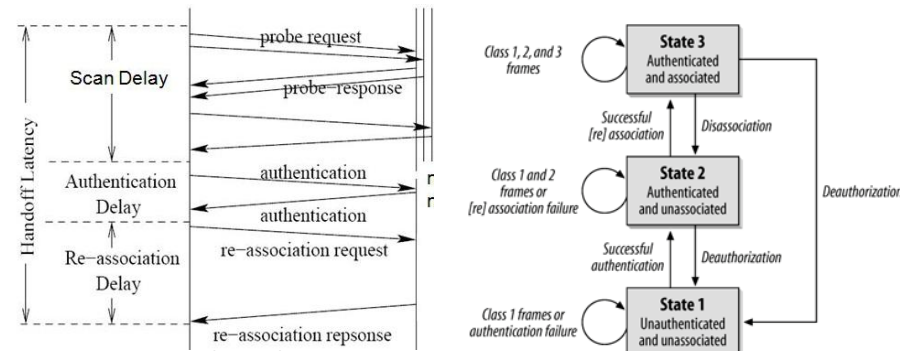


Phase 2: Authentication



- 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 decipher the challenge and compares results

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 supported 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

How to extend range in Wi-Fi?

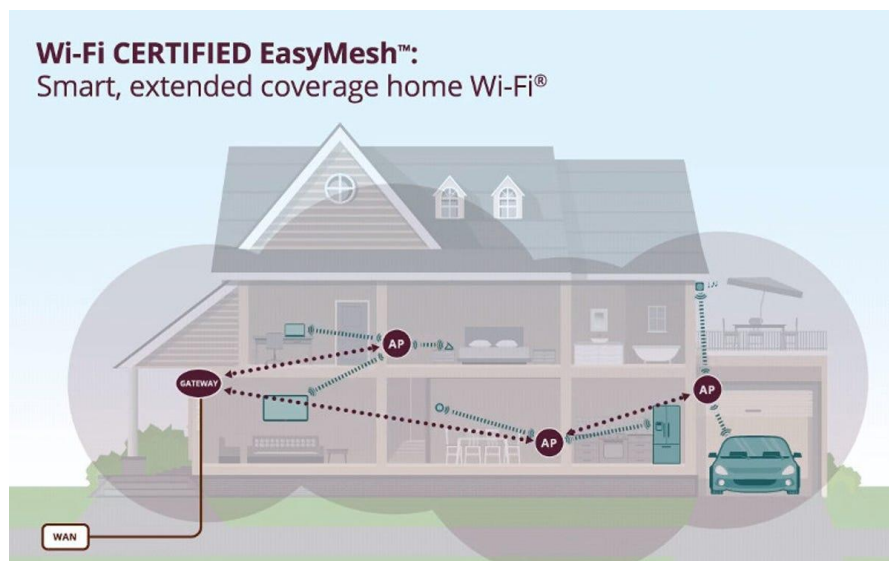
Wi-Fi “extenders”.

- 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.

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](http://www.ieee.org/publications_standards/publications_standards_info/standards/index.html) 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

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.

EasyMesh: reuse 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.](#)

IEEE 1905.1

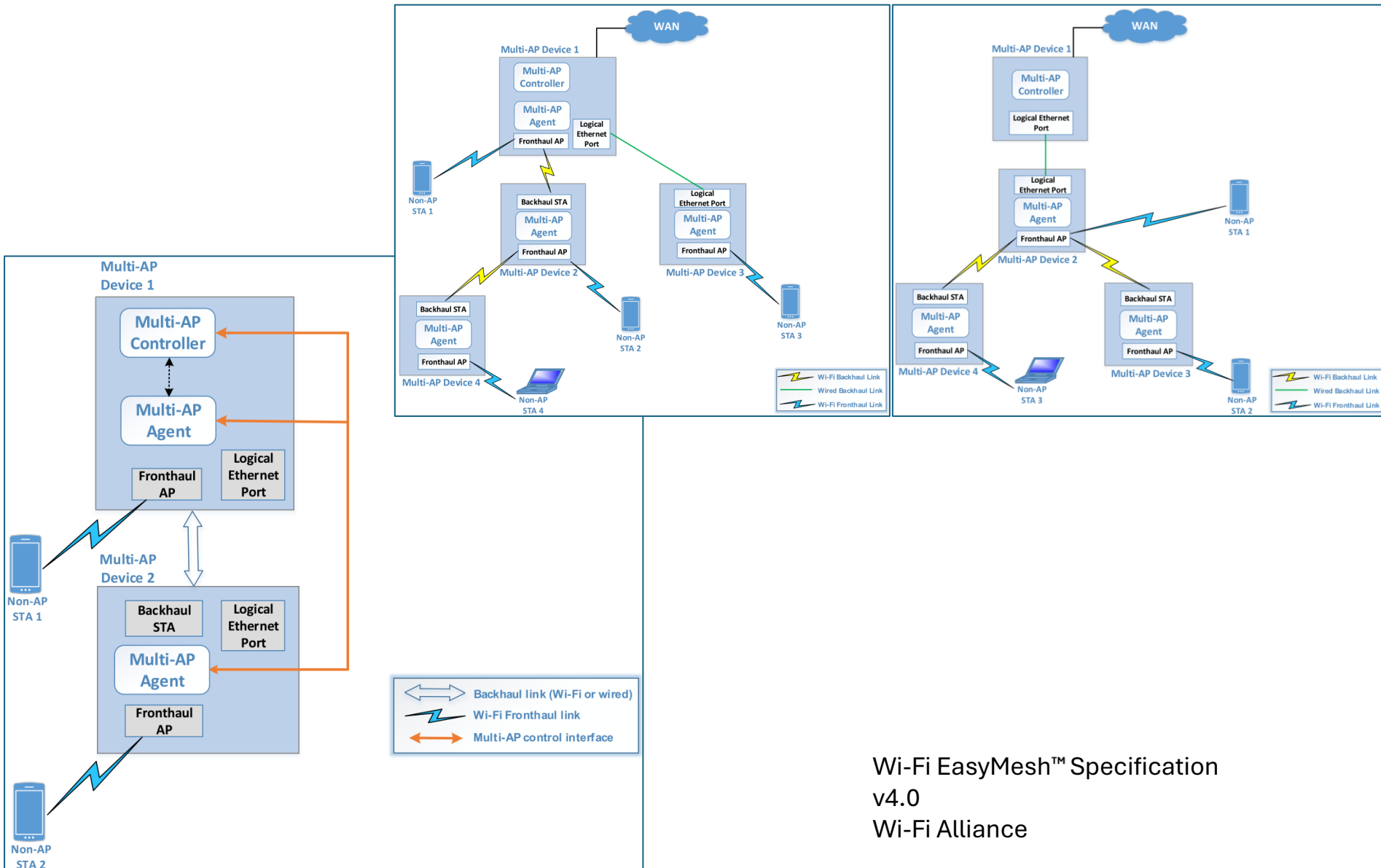
Convergent Digital Home Network for Heterogeneous Technologies.

- 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.

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

Example deployments



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

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).

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)