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The Inner Workings of QoS for Modern Wireless Networks

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Agenda

- The Wireless QoS Problem
- The Age of QoS Emerges
- The Modern Era
- Looking to the Future of Wireless QoS
- Questions for Discussion

The Age Before QoS

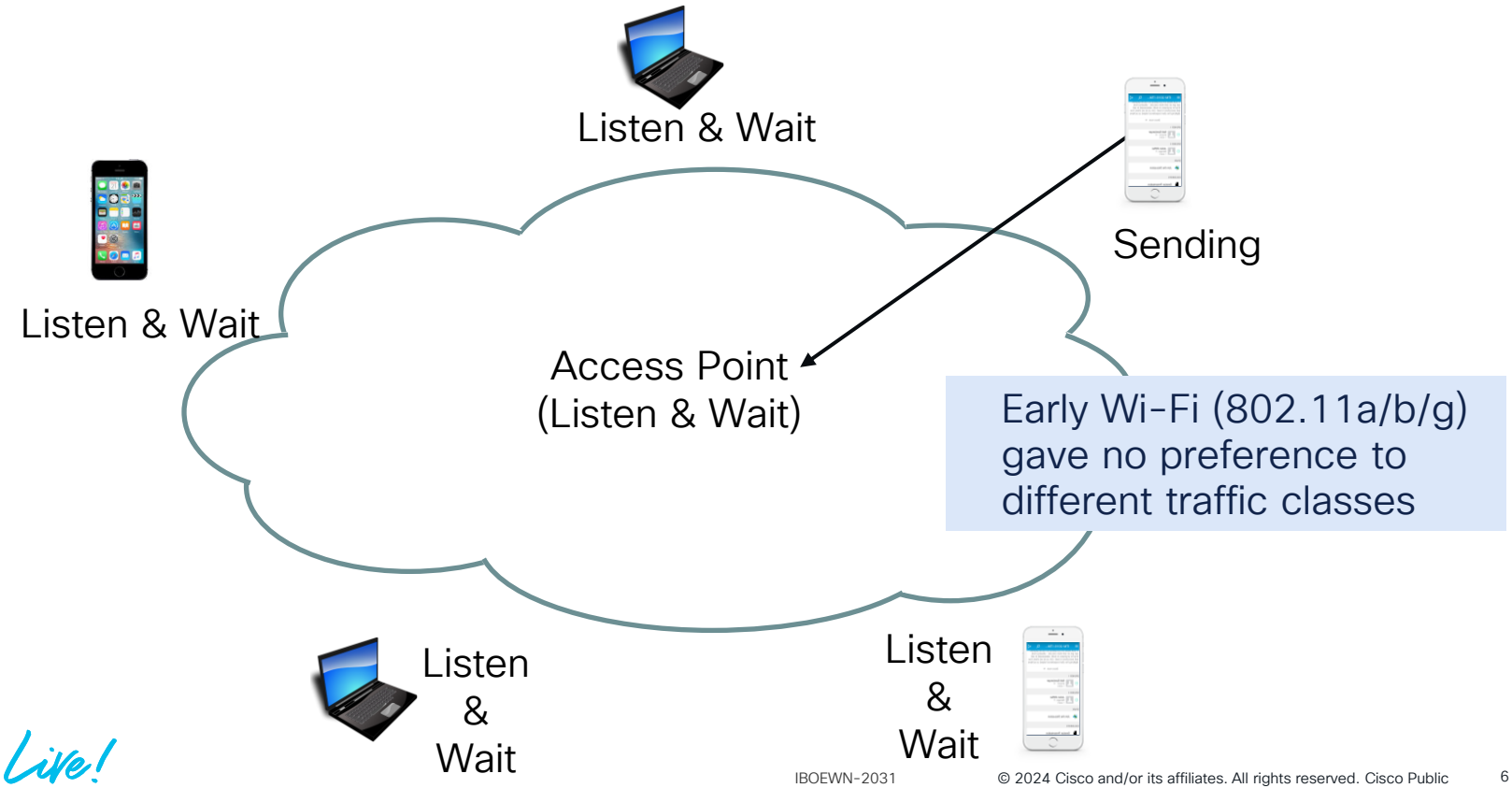
In the Beginning, there was no QoS in Wi-Fi

- Wired environments are Full Duplex, Wireless is Half Duplex (for now)
  - Half duplex environments are very susceptible to collisions
- 802.11a/g/n had no capability for QoS whatsoever!

Classic Wireless QoS is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA)

- Wireless networks have no way to detect that a collision occurred!
- Uses a system of fixed and random wait timers to ensure everyone gets a chance to send
- Thus, every frame must be acknowledged

Classic Wi-Fi Media Access was Contention-Based



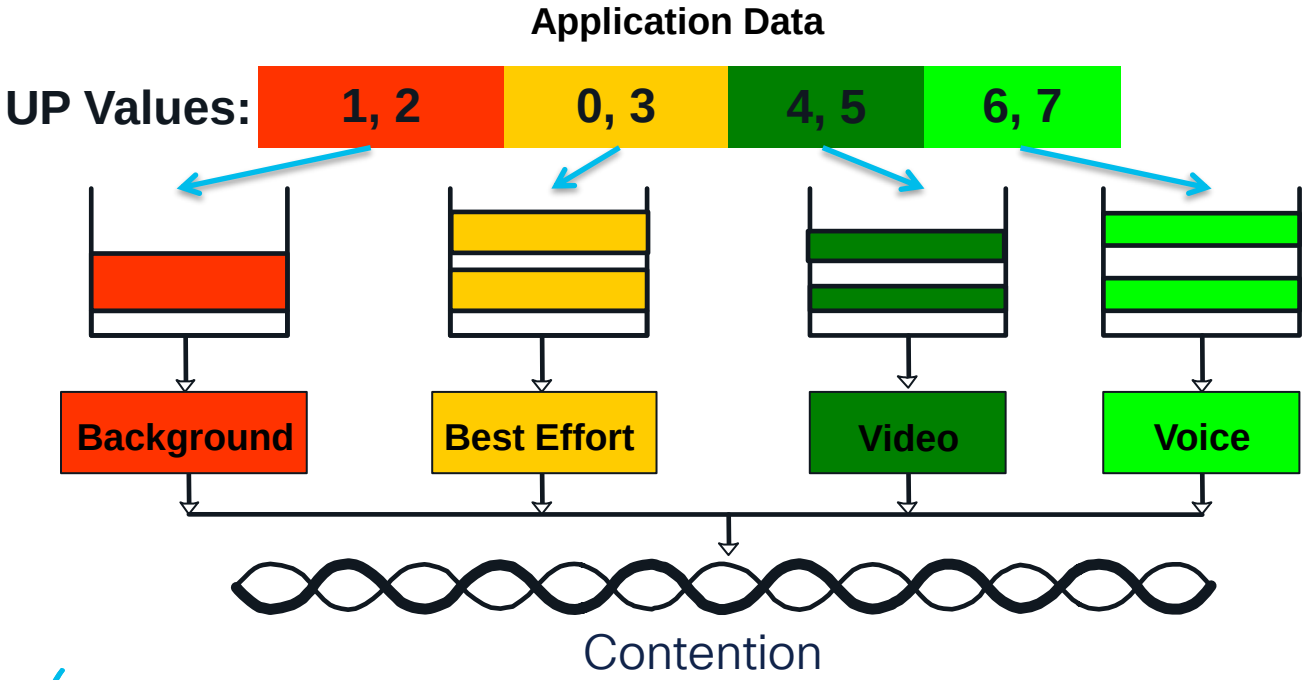
The Age of QoS Emerges:
The Enhanced Distributed Channel Access (EDCA) Model

802.11e Introduced the Enhanced Distributed Channel Access (EDCA) Model in 2005

- 802.11e was tasked with bringing QoS to Wi-Fi
- EDCA was introduced by IEEE 802.11e in 2005, and has been adopted by the Wi-Fi Alliance as Wireless Multimedia (WMM)
- WMM is now a mandatory part of modern Wi-Fi
  - 802.11a/b/g are based on DCF (no QoS)
  - 802.11n/ac are based on EDCA (QoS is supported)

EDCA Introduced Wireless Access Categories

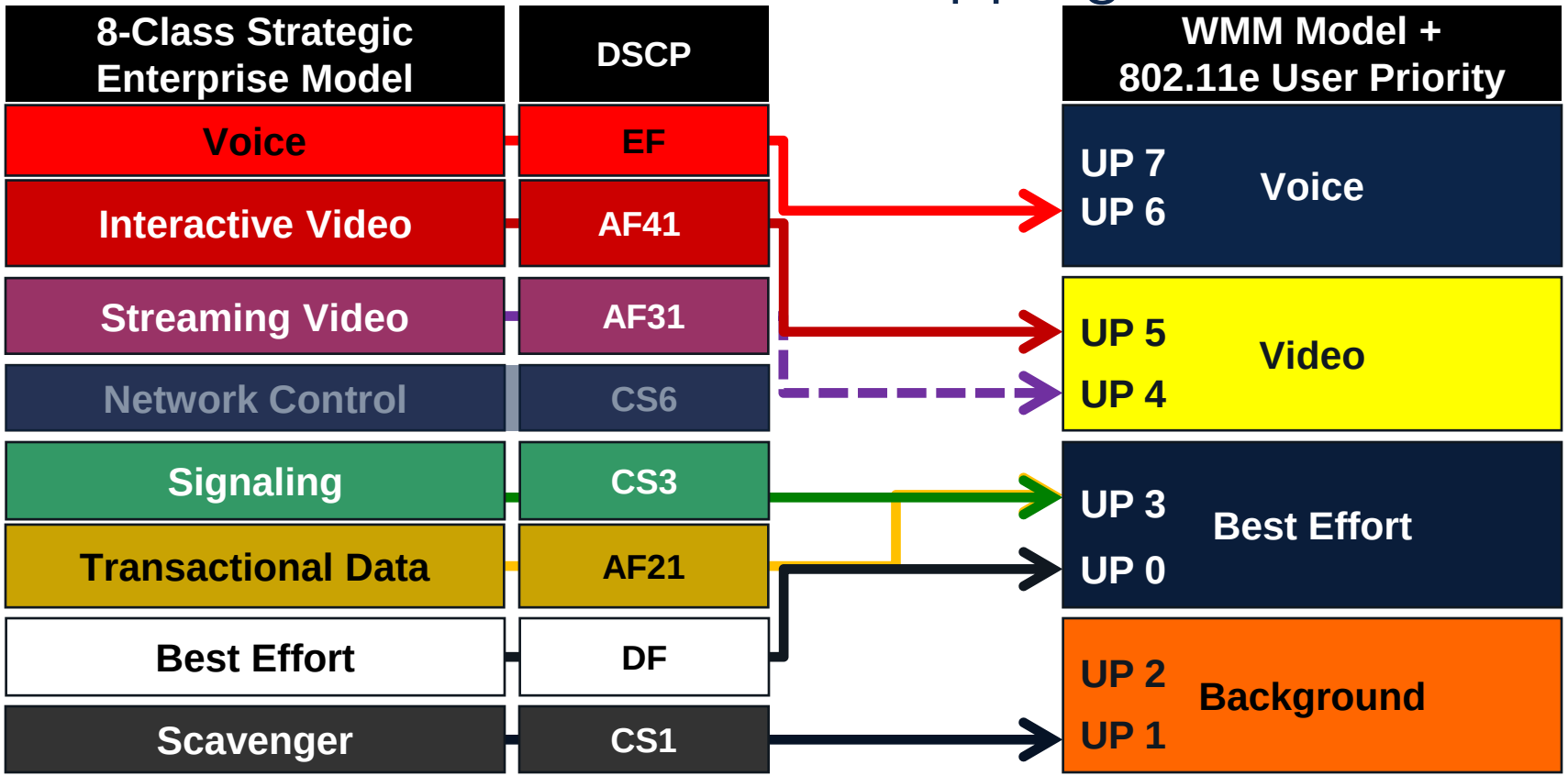
- When wireless frames are transmitted, a 3-bit QoS value known as the **User Priority** (UP) is written into the 802.11 header
- Each AC gets different priority to transmit onto the medium



Default DSCP ←→ UP Mapping Table

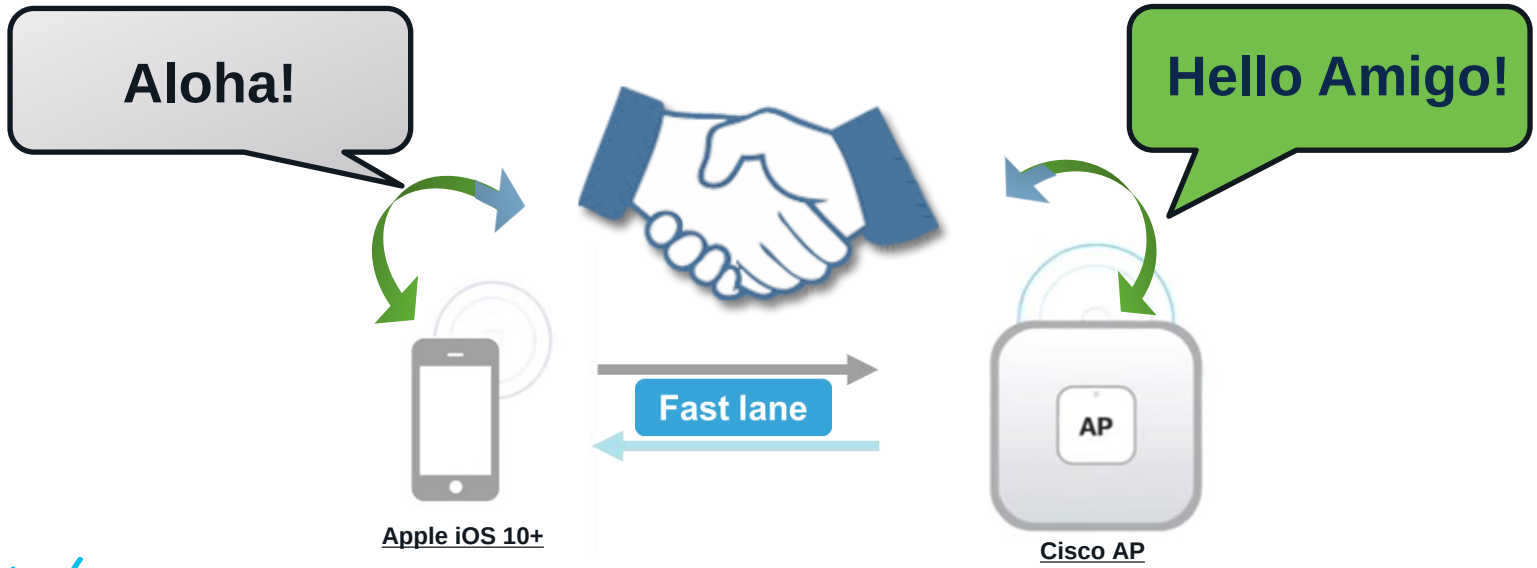
Traffic Type	DSCP	802.11e UP / WMM	Access Category
Voice	46 (EF)	6	Voice
Interactive Video	34 (AF41)	5	Video
Call Signaling	24 (CS3)	3	Best Effort
Transactional / Interactive Data	18 (AF21)	3	Best Effort
Bulk Data	10 (AF11)	2	Background
Best Effort	0 (BE)	0	Best Effort

Downstream Traffic QoS Mappings



Enhanced QoS Capabilities for Apple Devices (Fastlane+)

iOS 10+ devices and Cisco APs perform a “handshake” that allow them to recognize each other



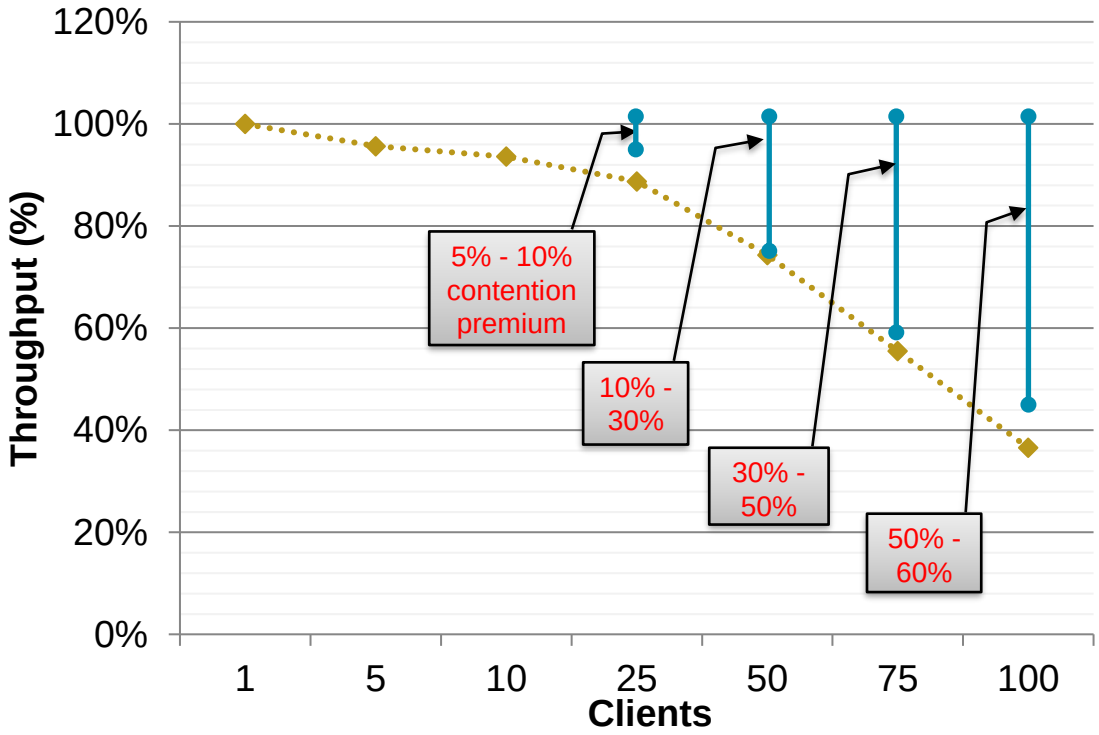
Questions for Discussion

1. What are some of the biggest challenges you face with Wireless QoS?
   - Working with a 4-class system?
   - QoS alignment on end devices?
2. What has been your experience deploying wireless QoS on the IOS-XE controller (Catalyst 9800)?

The Modern Era:
Wi-Fi6 / 6E (802.11ax)

The Contention Breaking Point (802.11n-ac)

(source: IEEE 802.11-15/0351r2)

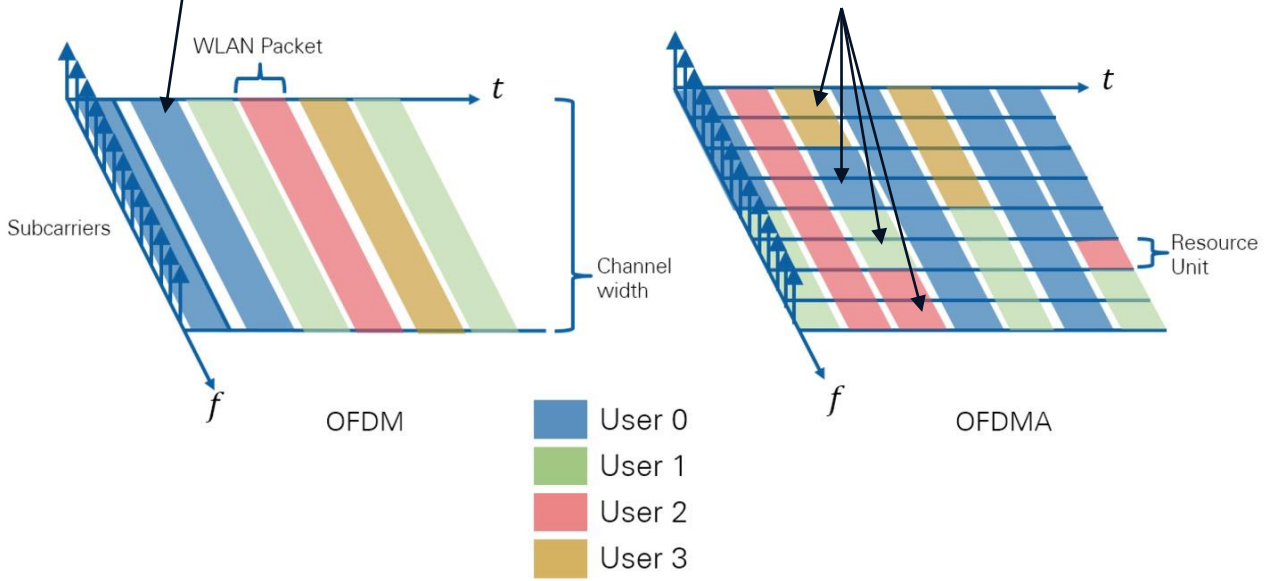


As more clients associate and transmit, WLAN contention increases for all clients, degrading performance for all

OFDMA (Orthogonal Frequency Division Multiple Access)

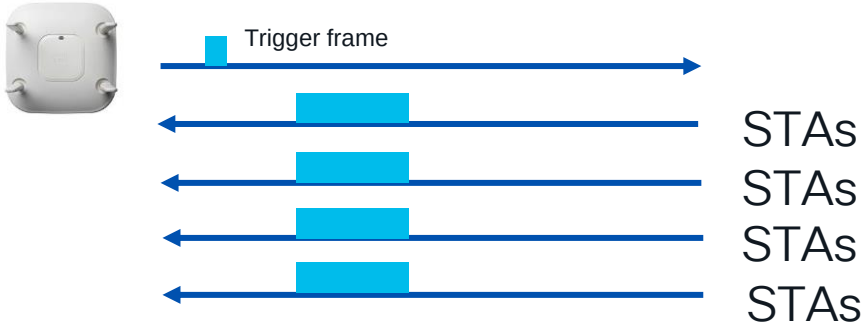
A Single Station Transmits in a Timeslot won by the contention algorithm (EDCA)

Multiple Stations Transmit in a scheduled Timeslot



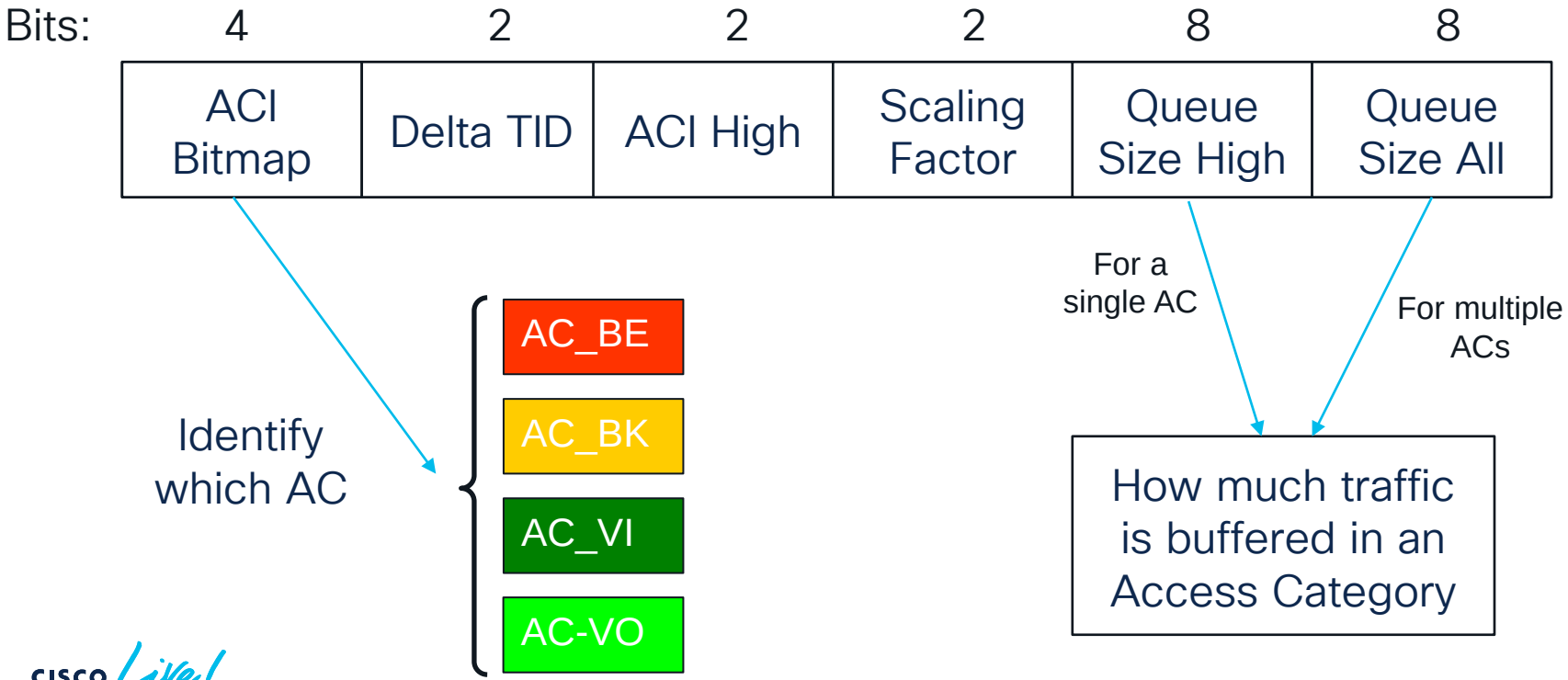
802.11ax Uplink (UL) MU-MIMO

- 802.11ac allows for downlink MU-MIMO
- 802.11ax adds uplink MU-MIMO
  - AP checks which STAs can send together
  - AP sends trigger frame and STAs respond all at the same time

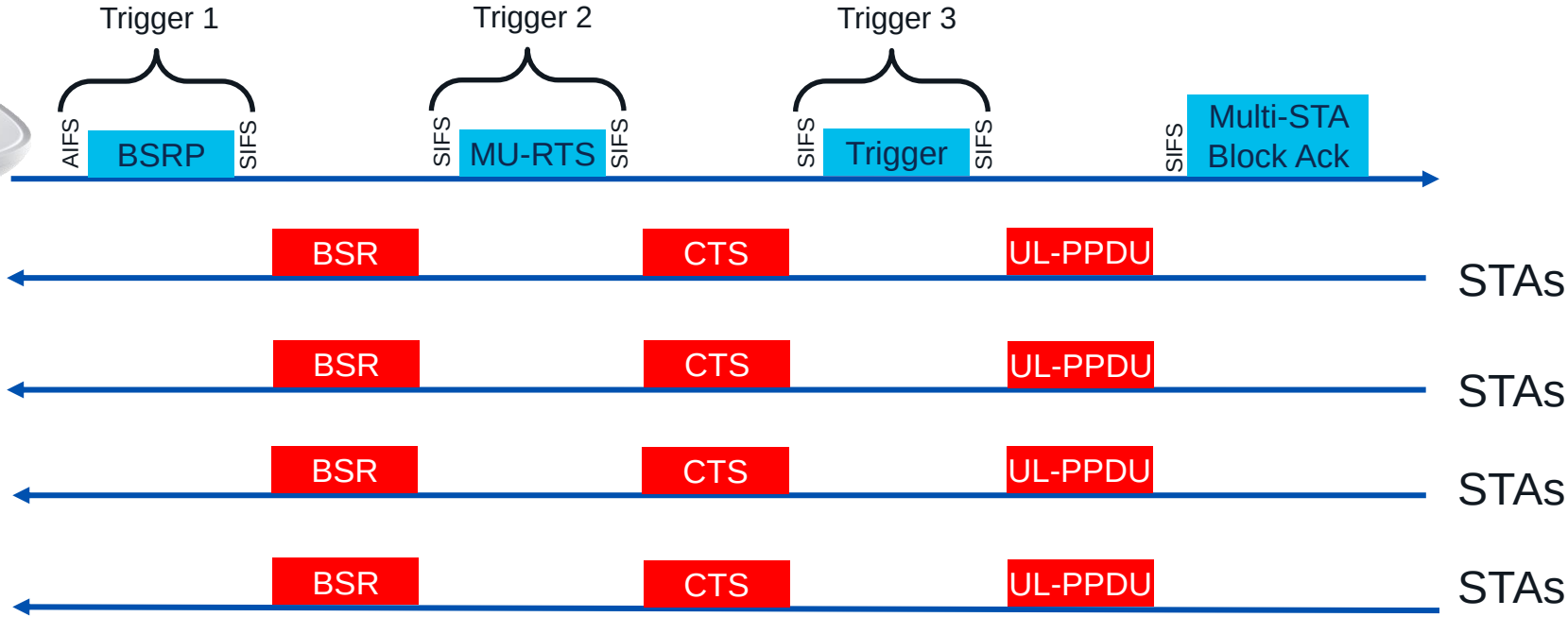


Buffer Status Reports (BSRs)

STAs may send QoS information in the **BSR Control subfield** of any frame



Buffer Status Report Polling (BSRP)
(Figuring out how many RUs to Assign)



Questions for Discussion

1. Are you seeing benefits from 802.11ax (Wi-Fi6)?

Looking to the Future:
IEEE 802.11be and Beyond

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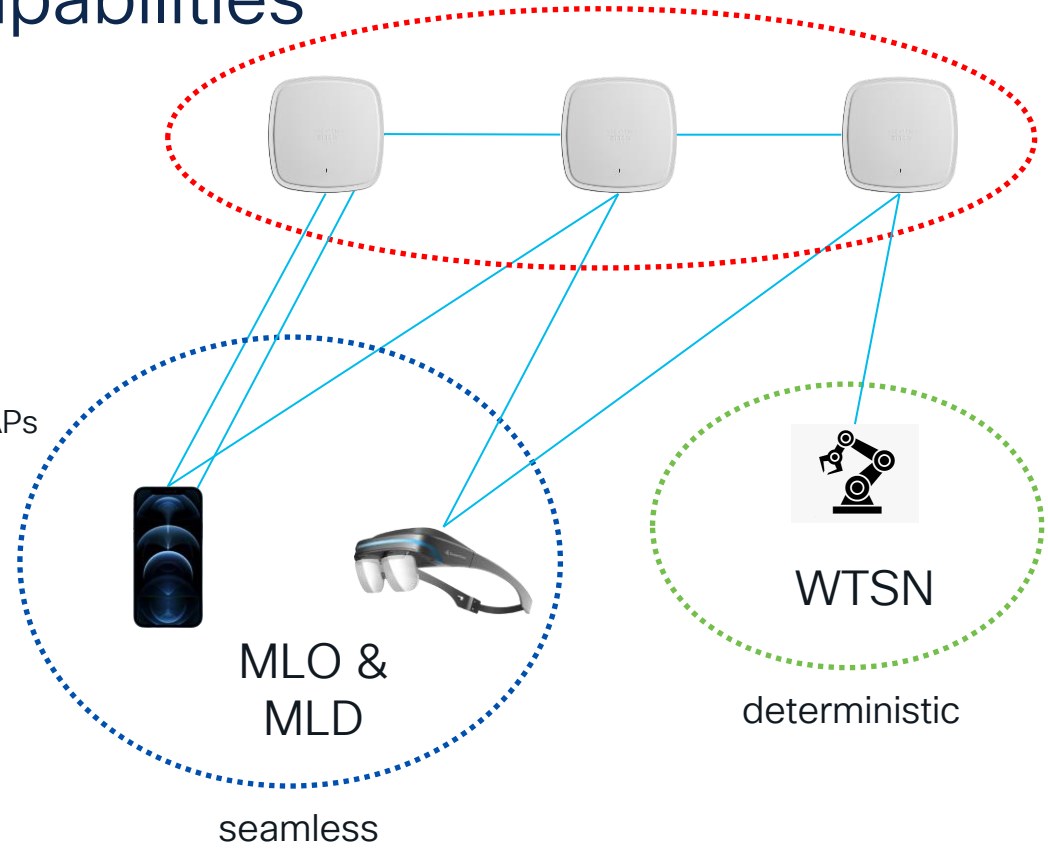
Ultra Reliable and Deterministic Wireless

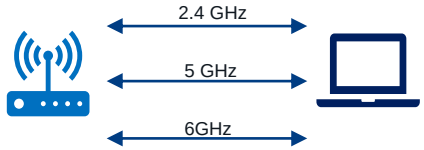
- 5G Release 16 introduced Ultra-Reliable Low Latency Communication (URLLC) for fast moving vehicles and seamless roaming
- Cisco CURWB (formerly Fluidmesh) supports this today
- Wi-Fi will follow soon with 802.11be (Wi-Fi7)

IEEE 802.11be key capabilities

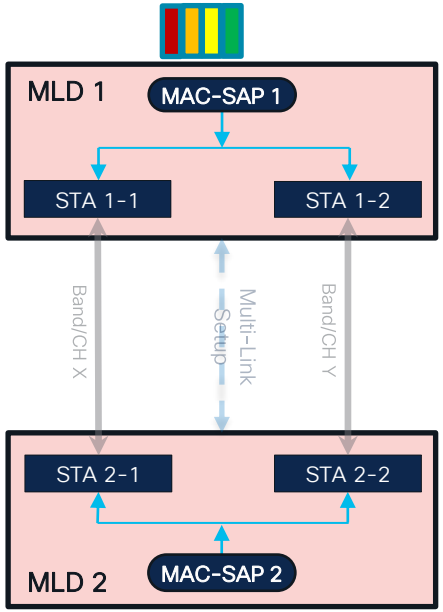
- Multi-Link Operations (MLO)
  - **Ability to Tx and Rx on multiple channels**
  - **QoS-based** link selection/steering
- MAPC
  - Time and space scheduling across multiple APs
- Wireless Time Sensitive Networking (TSN)
- Enhanced QoS Capabilities
  - **Stream Classification Service** (SCS)
  - **SLA-based** KPI support (latency, jitter, etc.)



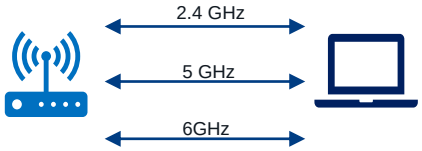
Multi-Link Operation (MLO)

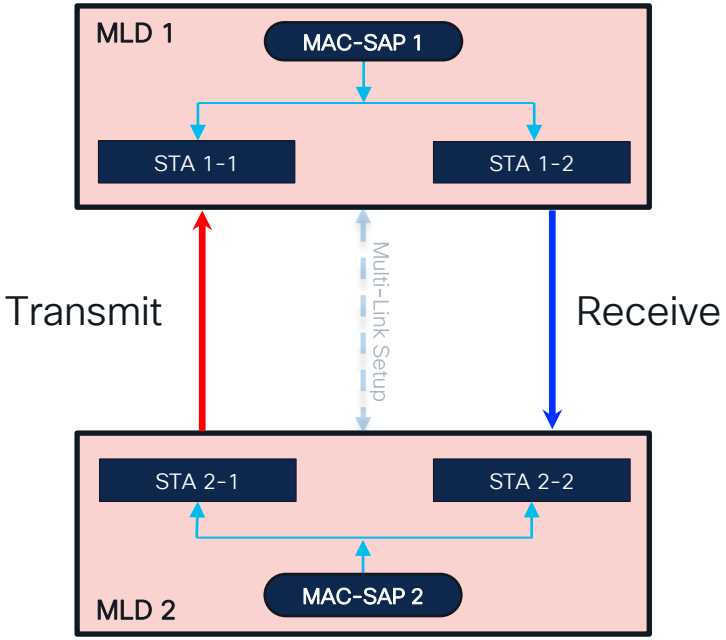


- A **MLO-capable** device is called a Multi-Link Device (**MLD**)
- The MLD can be associated to both/all radios of an AP using both or all of its radios
- MLDs have more than one affiliated Stations (STAs), but generally **ONE** MAC Service Access Point (SAP) connected to the LLC
- The SAP is tasked with aggregating data from multiple links

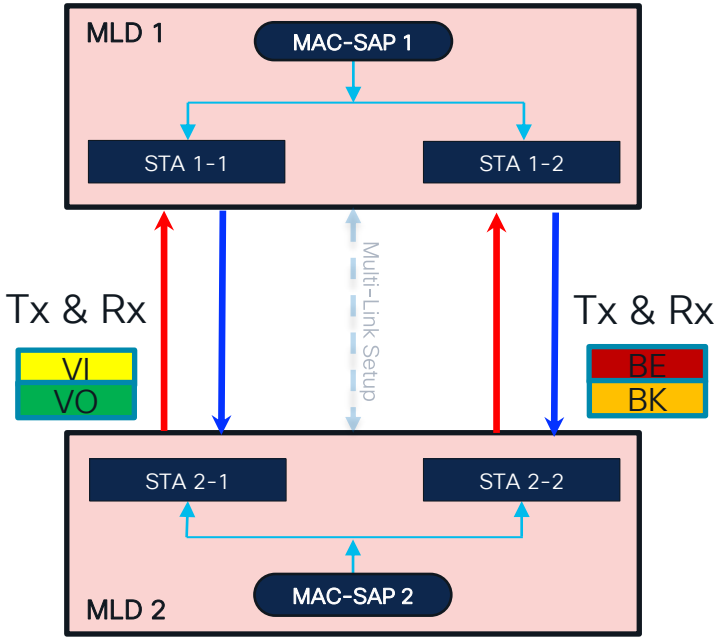


Multi-Link Operation (MLO) Enables new Capabilities





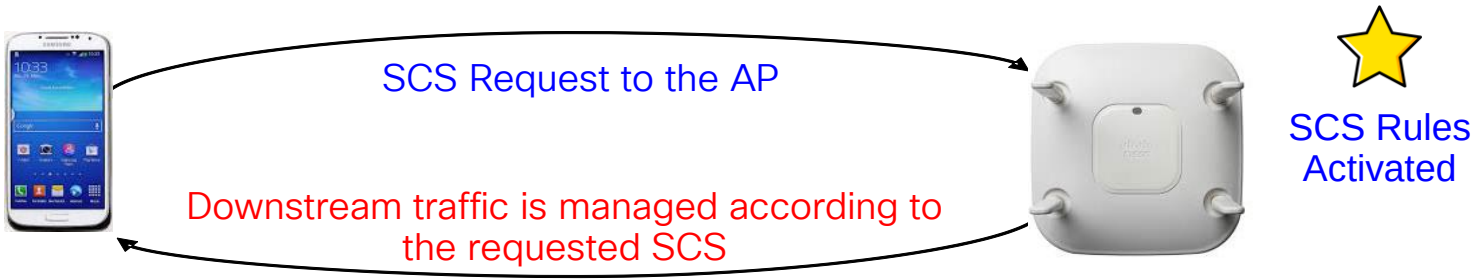
STR Mode (Simultaneous Tx and Rx)
Essentially Full-Duplex



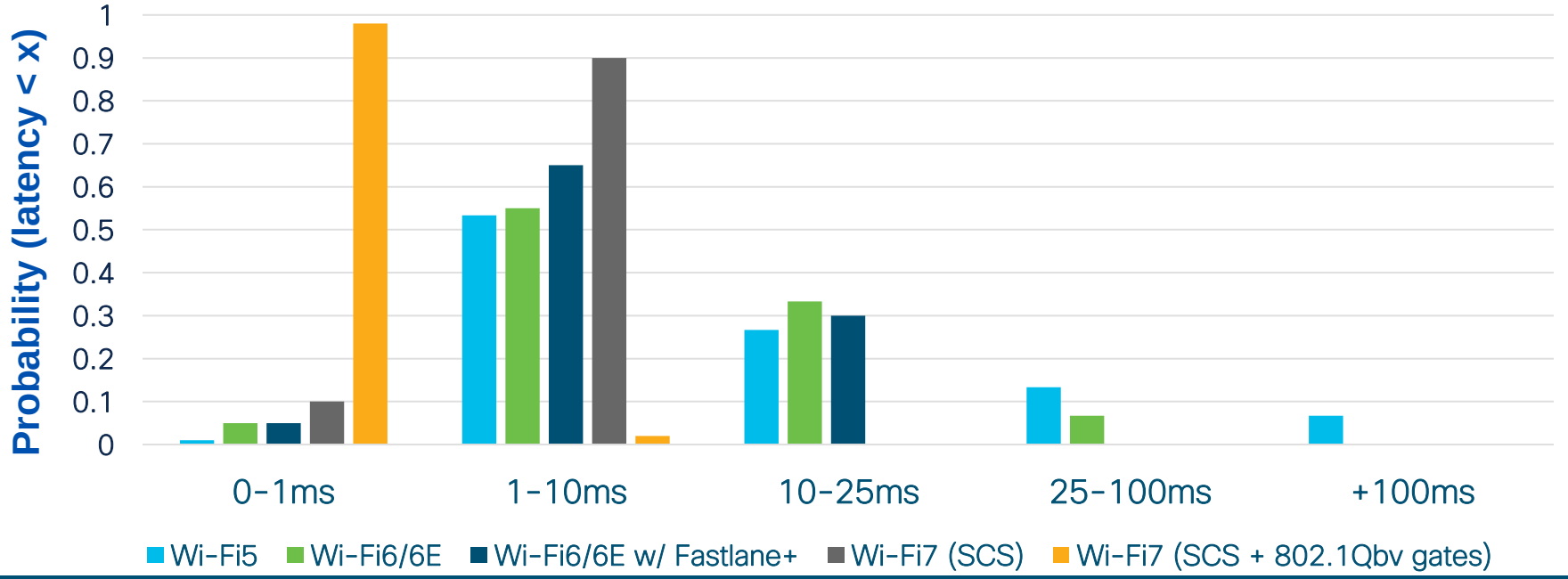
NSTR Mode (Non-Simultaneous Tx and Rx)
Load balanced traffic across multiple links

A New QoS Paradigm: Stream Classification Service (SCS)

- SCS (Stream Classification Service) specifies traffic flows using an SCS request frame (a QoS **Information Element / IE**)
- The AP derives QoS rules by monitoring the corresponding uplink flows
- Allows the STA to explicitly provide traffic classifiers and priority for each downlink flow using Traffic Identifiers (TIDs) - a 4-bit field based on the UP value, that can be used to select a variety of link characteristics (burst interval, which link to use, delay, reliability, etc.



Enhanced QoS: 802.11be SCS Enables Determinism



Latency performance improvements in high-traffic scenarios

Source: https://mentor.ieee.org/802.11/dcn/22/11-22-0634-00-00be-802-11be-enhancements-for-tsn-time-aware-scheduling-and-network-management-considerations.pptx

Questions for Discussion

1. How would you take advantage of Wi-Fi7 MLO and it's QoS capabilities?
2. What do you think IEEE 802.11 should do next?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