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THE WI-FI PERFORMANCE COMPANY

The Leader in Wireless Experience Monitoring

BASICS OF 802.11 ARBITRATION

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About Jim Vajda

- Chief Wireless Officer at 7SIGNAL
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- CCNP Enterprise (Core, Wireless Design, Wireless Implementation)
- Experience in healthcare, K12, higher ed, non-profit, MSP, more
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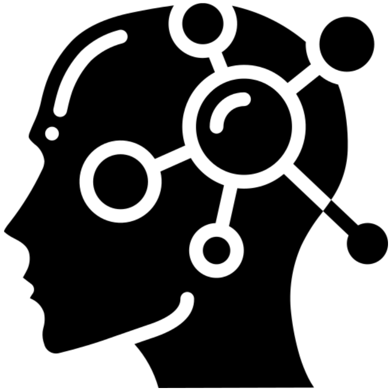
- Amateur radio callsign KE8OKV

What is 802.11 Arbitration?

- Standardized protocol used to politely share usage of the channel that AP’s and clients are operating on.
- **The heart and soul of Wi-Fi**



Why is it Needed?

- 802.11 uses noisy unlicensed spectrum
- 802.11 is has no centralized scheduling like cellular
- Channel access decisions are distributed to each individual station
- The RF channel is a **half-duplex** medium
  - Only one station can transmit at a time
  - A transmitting station cannot receive at the same time it Tx's
  - Same principle that walkie talkies use

Wi-Fi Compared to Ethernet

- 802.3 Ethernet
  - Full duplex
  - CSMA/CD: Transmitting NIC knows if there was a collision because it heard it
  - Switching breaks up collision domains
- 802.11 Wi-Fi
  - Half duplex (but keep an eye on 802.11be)
  - CSMA/CA: Transmitting station doesn’t know if there was collision because it can’t Rx while it Tx’s
  - AP’s on separate channels breaks up the collision domains (the channel is the collision domain, not the AP)

5 GHz Spectrum

5 GHz Channel Allocations

Frequency					DFS Channels																					
														TDWR												
Radio Band	U-NII-1				U-NII-2a				U-NII-2c (Extended)												U-NII-3					
Frequency	5.180	5.200	5.220	5.240	5.260	5.280	5.300	5.320	5.500	5.520	5.540	5.560	5.580	5.600	5.620	5.640	5.660	5.680	5.700	5.720	5.745	5.765	5.785	5.805	5.825	Qty
20 MHz	36	40	44	48	52	56	60	64	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	25
40 MHz	38		46		54		62		102		110		118		126		134		142		151		159			12
80 MHz	42				58				106				122				138				155					6
160 MHz	50								114												*165 was ISM, now U-NII-3*					2

- 20 MHz – 25 available channels
- 40 MHz – 12
- 80 MHz – 6
- 160 MHz - 2

Enhanced Distributed Coordination Access (EDCA)

- **All 802.11 stations (AP's and clients) must make sure the channel is free before transmitting**
- Protocol that defines the modern 802.11 arbitration process
- Defined in 802.11e-2005 which added QoS queues to DCF

EDCA Arbitration

CCA → **NAV** → **IFS** → **CW** → **Tx**

CCA
- Clear Channel Assessment (Layer 1)
- Signal Detect (CCA-SD)
- Energy Detect (CCA-ED)

NAV
- NAV Timer (Layer 2)

IFS
- Inter-frame spacing

CW
- Random backoff timer (contention window)

Tx
- Transmit if clear
- Start over if not

CCA Signal Detect

- Sometimes called Signal Detect (SD) or Preamble Detect (PD)
- Station listens to the channel for any 802.11 frame it can demodulate
  - Real-world RSSI threshold for CCA-SD is 4 dB above the noise floor
  - 802.11 stations do not sense the noise floor uniformly
- PHY layer timer set by the Length field of preamble
  - Length of current frame only
- **There is no consideration of RSSI of received frames**

CCA Energy Detect

- Station listens to the channel for any RF energy
  - Standard puts the RSSI threshold for CCA-ED at 20 dB above CCA-SD threshold
  - 802.11 radios are unreliable at detecting noise, and employ very different methods with mixed results. Don’t trust wireless adapter noise measurements.

MAC NAV Timer

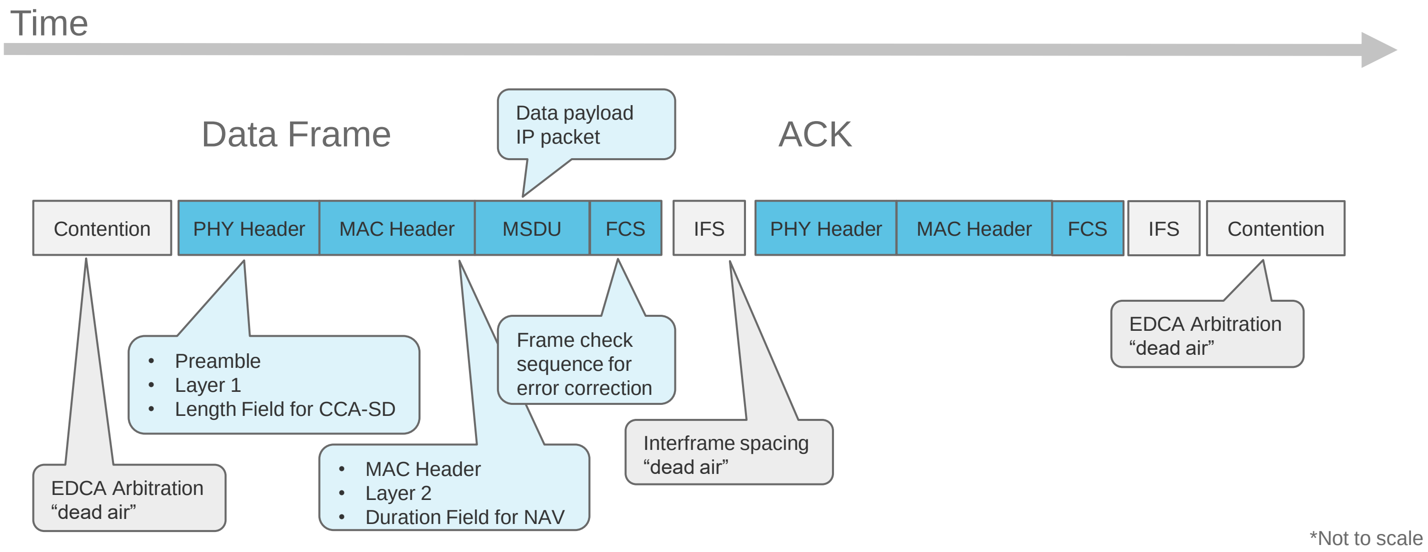
- MAC layer timer set by a frame's Duration field
- Also set by separate RTS/CTS control frames
- Informs listening stations of duration of remaining IFS, and ACK

```
▶ Frame 31: 774 bytes on wire (6192 bits), 774 bytes captured (6192 bits)
▶ Radiotap Header v0, Length 58
▶ 802.11 radio information
▼ IEEE 802.11 QoS Data, Flags: ......F.C
    Type/Subtype: QoS Data (0x0028)
  ▶ Frame Control Field: 0x8802
    .000 0000 0011 0000 = Duration: 48 microseconds
    Receiver address: OnePlusT_6c:9f:05 (94:65:2d:6c:9f:05)
    Transmitter address: Cisco_b2:a5:d9 (00:62:ec:b2:a5:d9)
    Destination address: OnePlusT_6c:9f:05 (94:65:2d:6c:9f:05)
    Source address: Cisco_44:a7:88 (ec:bd:1d:44:a7:88)
    BSS Id: Cisco_b2:a5:d9 (00:62:ec:b2:a5:d9)
    STA address: OnePlusT_6c:9f:05 (94:65:2d:6c:9f:05)
    .... .... .... 0000 = Fragment number: 0
    1100 0101 1000 .... = Sequence number: 3160
    Frame check sequence: 0x1937efab [unverified]
    [FCS Status: Unverified]
```

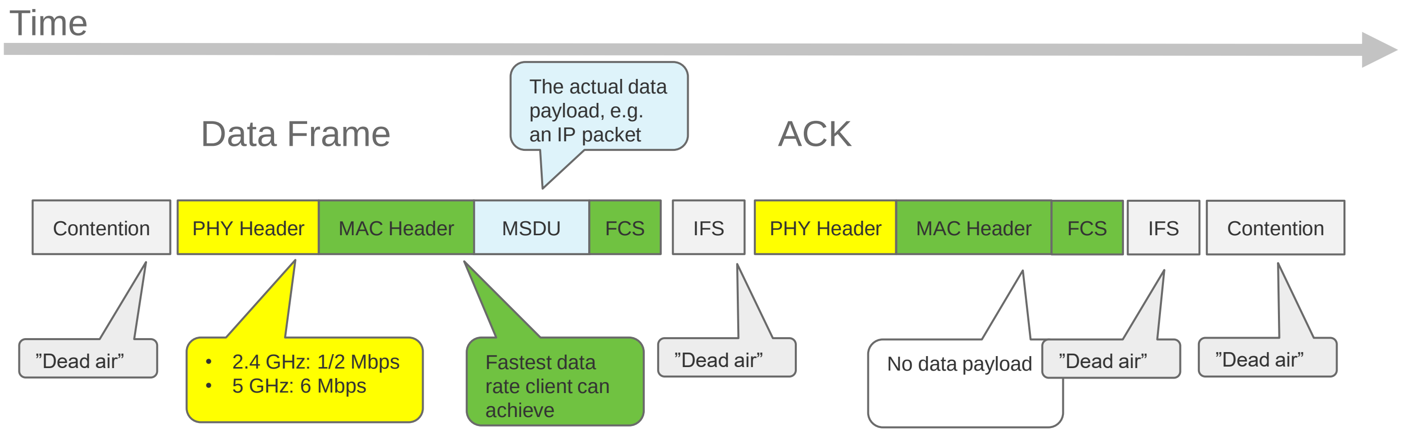
Contention Window

- Random backoff timer, with starting values of 0-15 slot times
- 1 slot time value is 9µs
- Doubles in possible values for each retry!
  - 32, 64, 128, 256, 512, 1024, then drop the frame
- QoS alters the possible slot time values
  - e.g. Voice queue never uses a CW greater than 7

802.11 Frame Fields and Timing

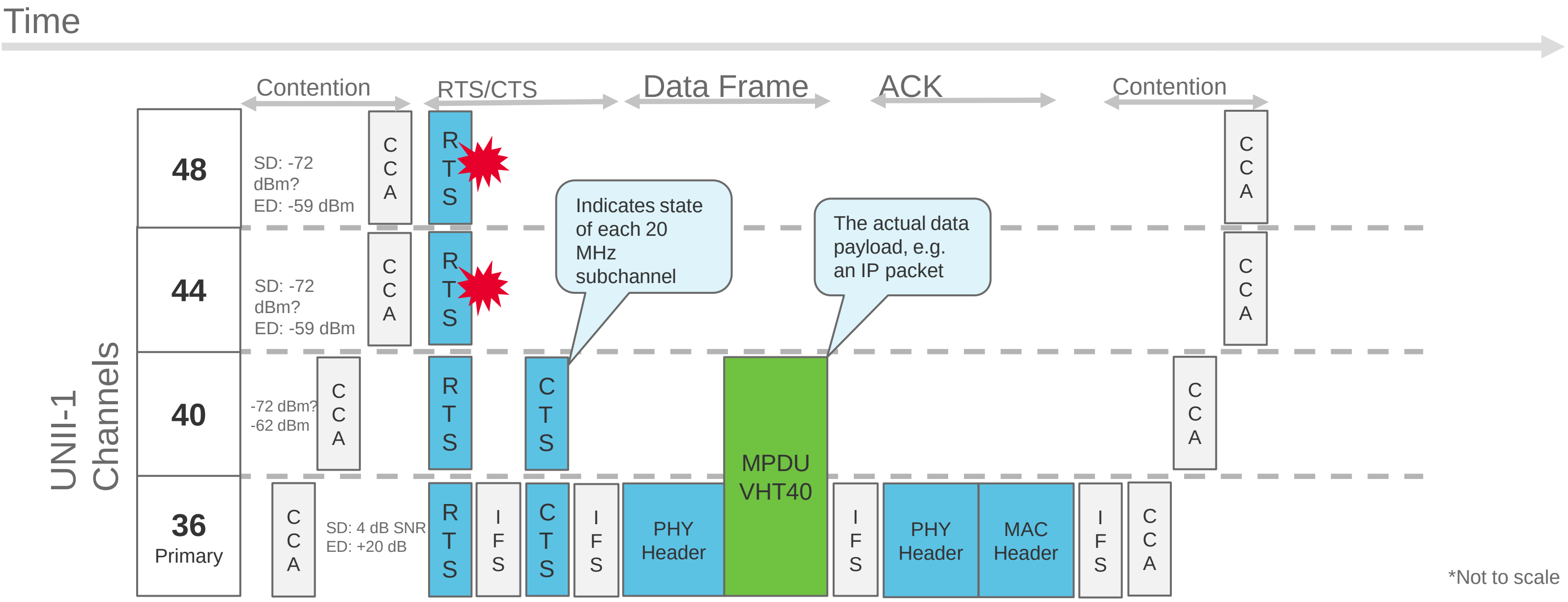


802.11 Necessary Inefficiency

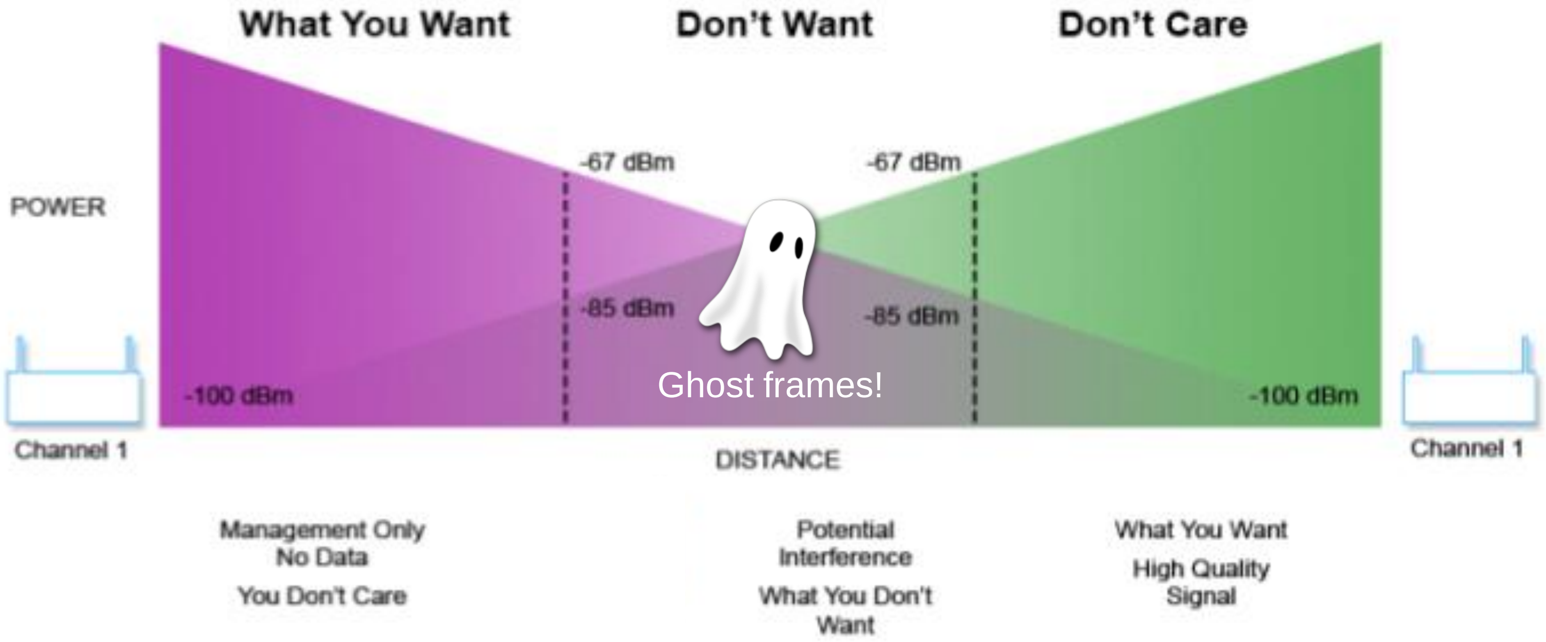


*Not to scale

802.11ac Dynamic Bandwidth Operation



Contention Areas



Contention Areas

Contention area: Low RSSI, but loud enough for CCA-SD

Contention Areas

Proper Design Reduces CCI, Optimizing EDCA

- No CCI
- Contention area is contained
- Better RSSI in rooms

Design Considerations

- **Design, design, design!**
- Break up the contention domains to avoid CCI
- More contention domains means more net capacity as more stations can Tx simultaneously
- Smaller channel widths means more available contention domains
- CCI is a bigger problem than it appears
  - Range of CCA-SD (preambles)
  - Client CCI from clients on the edge of the cell increase CCI range of channel

Wi-Fi 6/802.11ax

- OFDMA Operation
  - It's not "a switch" or "switch-like." Air traffic controller is a better analogy.
  - Scheduled channel access like cellular
  - Multiple stations can Tx/Rx at the same time during OFDMA
  - But… the AP must win the channel first through EDCA, then it begins OFDMA
    - Must compete with legacy clients for channel access first
- Spatial Reuse OBSS CCA thresholds and Dual NAV timers

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QUESTIONS AND ANSWERS

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Thank you!

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Every Friday at 12 pm Eastern