

Wi-Fi Performance Related to CC

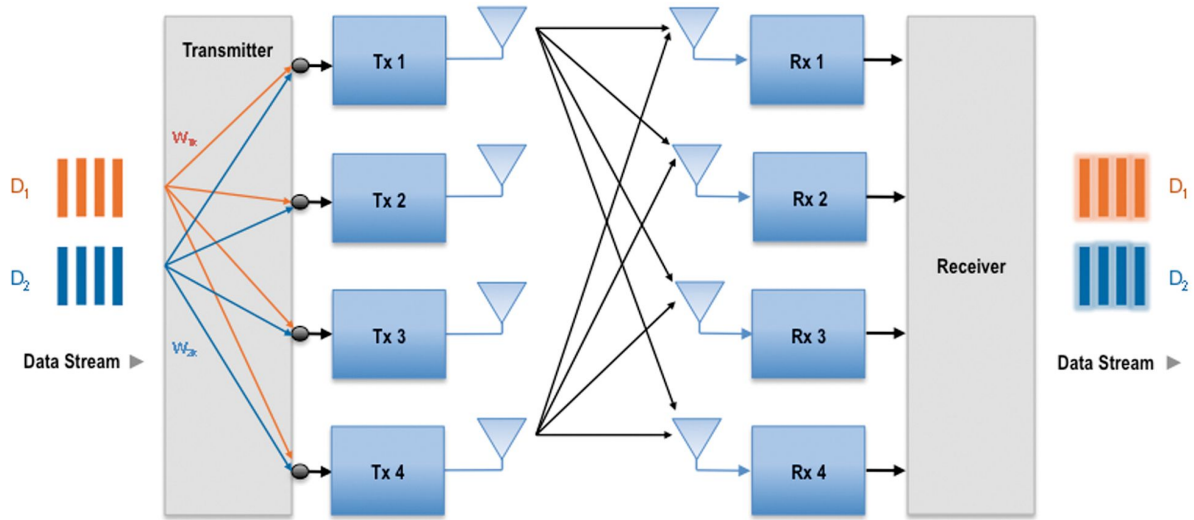
Robert McMahon

IETF 121 Dublin November 2024

Some characteristics of Wi-Fi

- Listen before talk (collision avoidance via MAC EDCAs)
 - Energy detect (ED)
 - **EDCAs are probabilistic**
 - LBT Costly (100 usecs on avg w/BE or 10,000 TXOPs per second)
- Packet aggregations desired (32-64), impacts packet pacing goals
- Link level (802.11 frame) retries (both within a TXOP and across)
- High variability in PHY rates ([maybe too many choices](#))
- High variability in media access
- Half duplex
- Power imbalance (between AP/STAs, causes need for RTS/CTS)
- Power save modes (sleeps per being battery powered, AP buffers)
- Small TCP acks expensive (per consuming a TXOP)

A Basic MiMo Model



Transfer Matrix

$$\begin{bmatrix} R1 \\ R2 \\ R3 \\ R4 \end{bmatrix} = \begin{bmatrix} D1 & 0 & 0 & 0 \\ 0 & D2 & 0 & 0 \\ 0 & 0 & D3 & 0 \\ 0 & 0 & 0 & D4 \end{bmatrix} \times \begin{bmatrix} h11 & h12 & h13 & h14 \\ h21 & h22 & h23 & h24 \\ h31 & h32 & h33 & h34 \\ h41 & h34 & h43 & h44 \end{bmatrix} \times \begin{bmatrix} D1' & 0 & 0 & 0 \\ 0 & D2' & 0 & 0 \\ 0 & 0 & D3' & 0 \\ 0 & 0 & 0 & D4' \end{bmatrix} \times \begin{bmatrix} S1 \\ S2 \\ S3 \\ S4 \end{bmatrix}$$

- S-Matrix is the transmitted signal (or energy) per antenna
- R-Matrix is the received signal
- D-Matrices are the cables and attenuators between the antenna and the H-Matrix (one for source and one for sink)
- H-Matrix is the MiMO “channel” (signal mixing, e.g butler matrix, splitter/combiner, power divider, MuMimo midbox)

Wi-Fi Throughput Vectors

- [MCS](#) (QAMs & Spatial Streams)
- Chanspec (bandwidth)
- AMPDU Aggregation
- Packet Error Rate (PER)
- SW FIFO empty (Transport's not filling host driver)
- Frame bursting
- Air competition (misnomer)

Wi-Fi Latency Vectors

- MCS (QAMs & Spatial Streams)
- EDCAs (AIFS, CWmin, CWMax, TXOP)
- Air competition
- Chanspec (bandwidth)
- AMPDU Aggregation
- Packet Error Rate (PER) / SINR
- Other BSS traffic
- **SW FIFO empty** (Transport's not filling host driver)
- Frame bursting

Direction and device matters

- Wi-Fi link origin src typically has flow control (at driver level)
- Wi-Fi link downstream from src (CCA/pacing)
- AP transmit has more power
- AP has more radios for multi user tx/rx
- One way delay $\neq \frac{1}{2}$ RTT

