COPA

Cooperative Power Allocation for Interfering Wireless Networks

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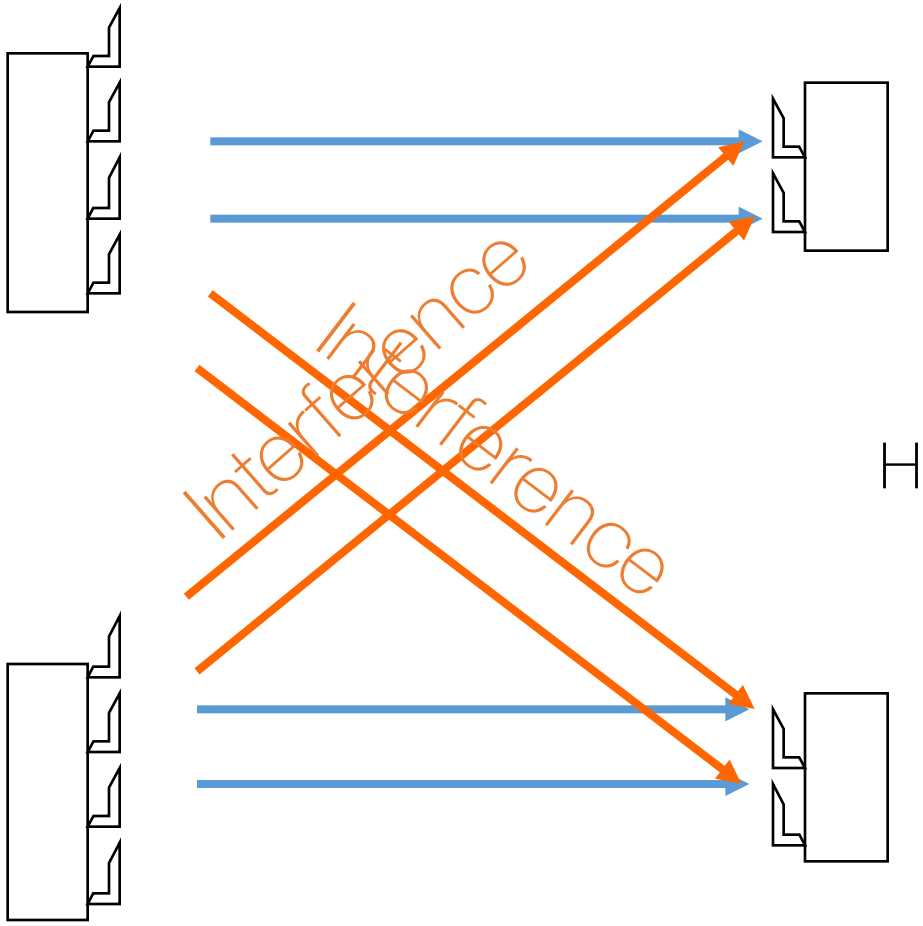
Wi-Fi's success a disaster!

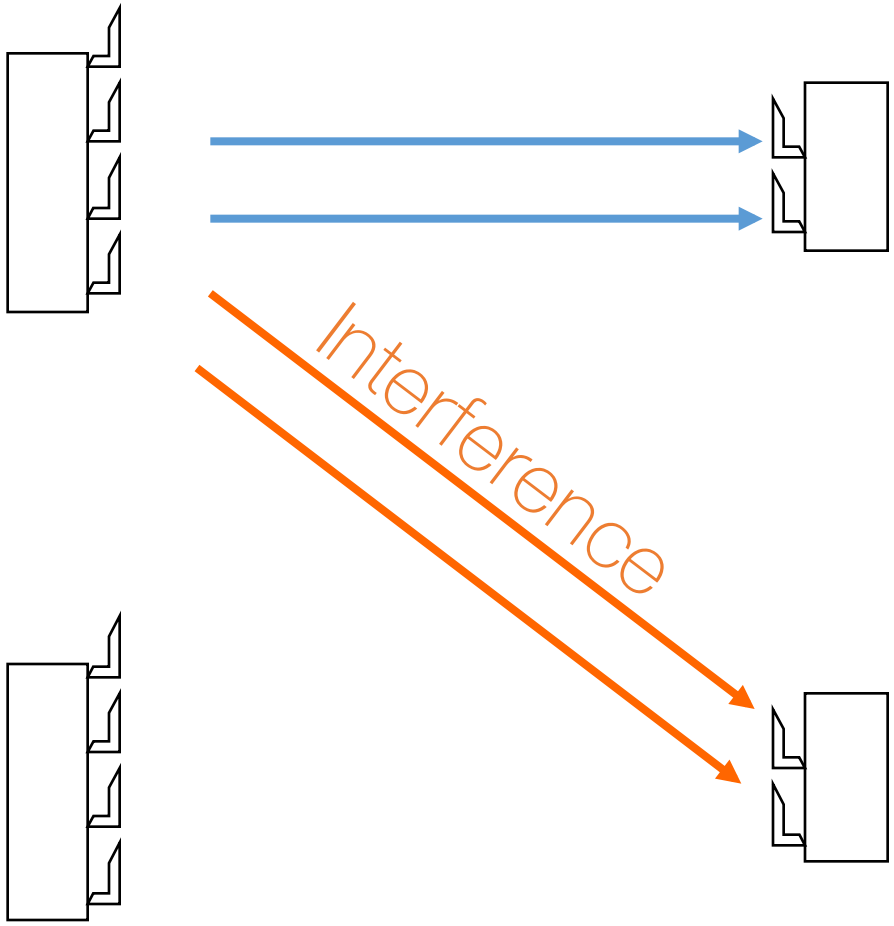
- ~100 million hotspots globally, 271% increase since 2013 (iPass)
- Limited bandwidth
- Interference: the bane of wireless networks

Carrier Sense Multiple Access



Hosts transmit 50% of the time

Nulling



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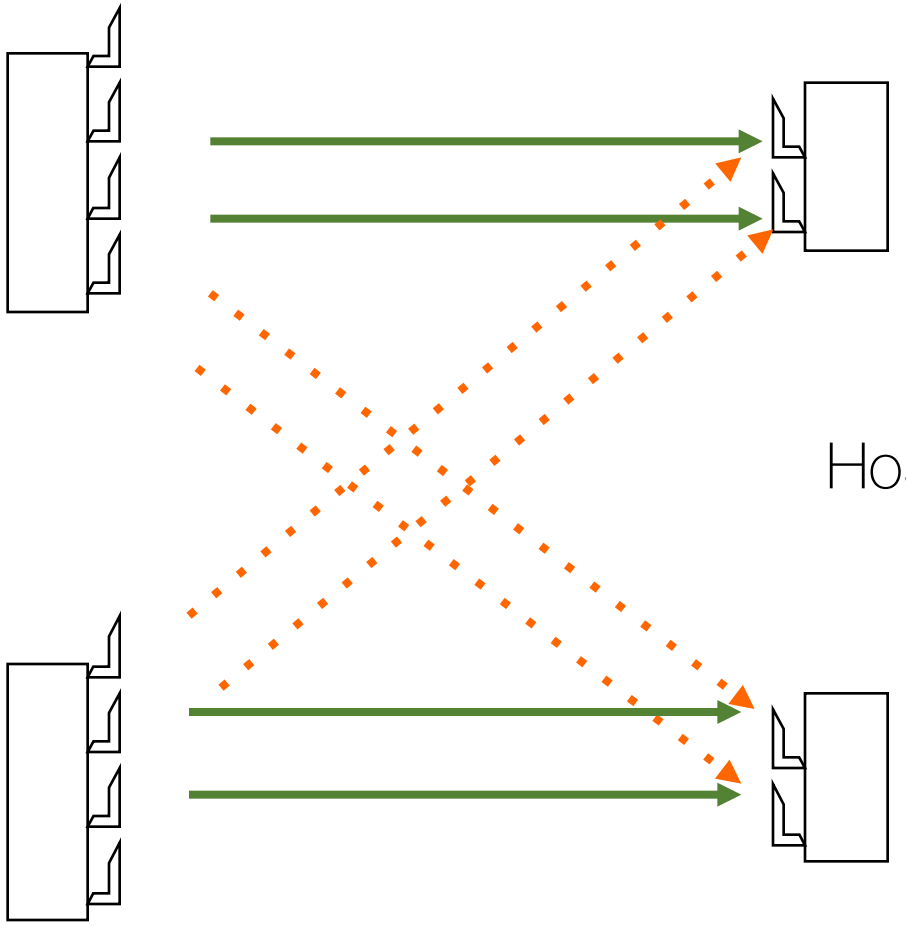
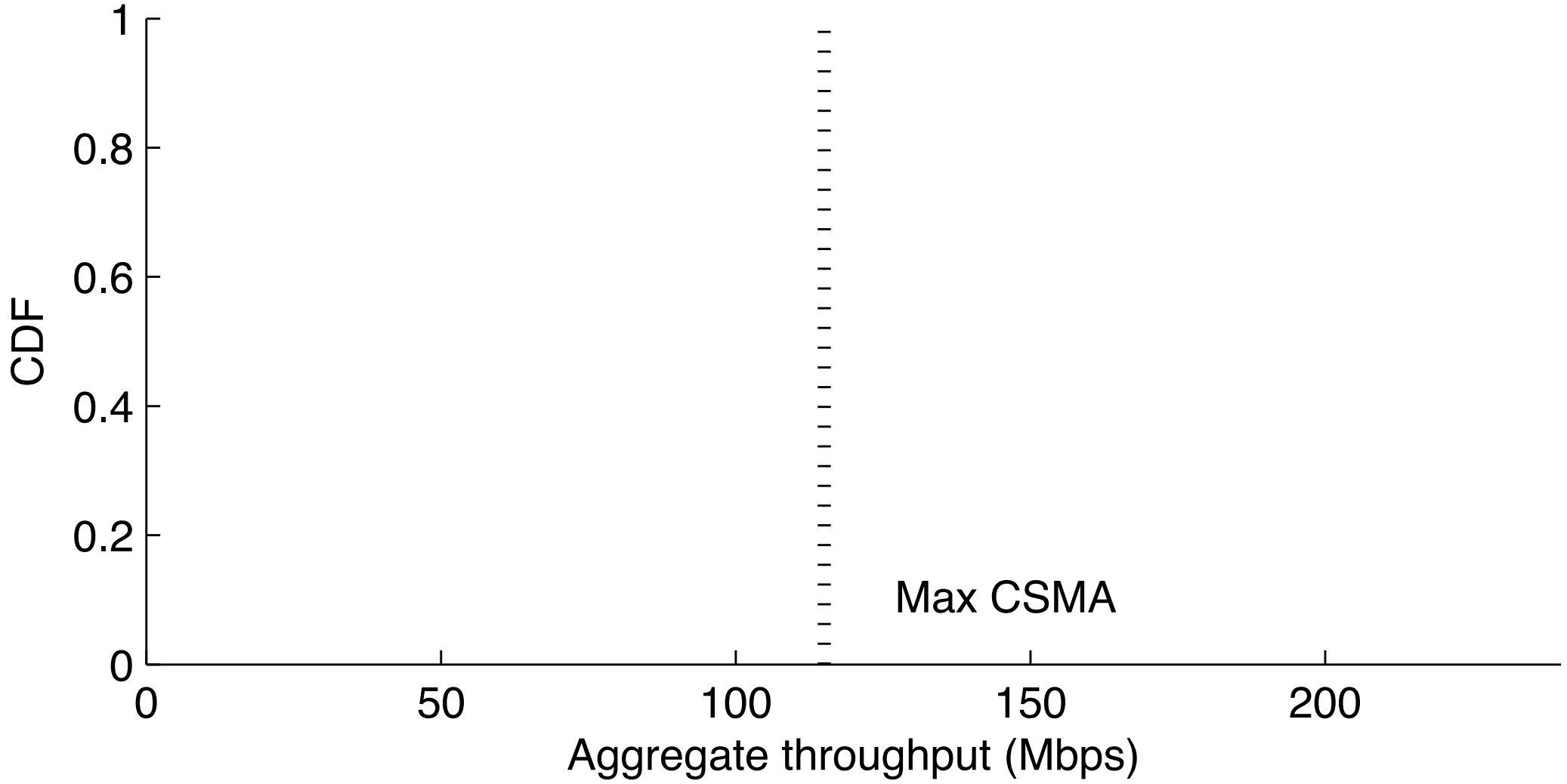
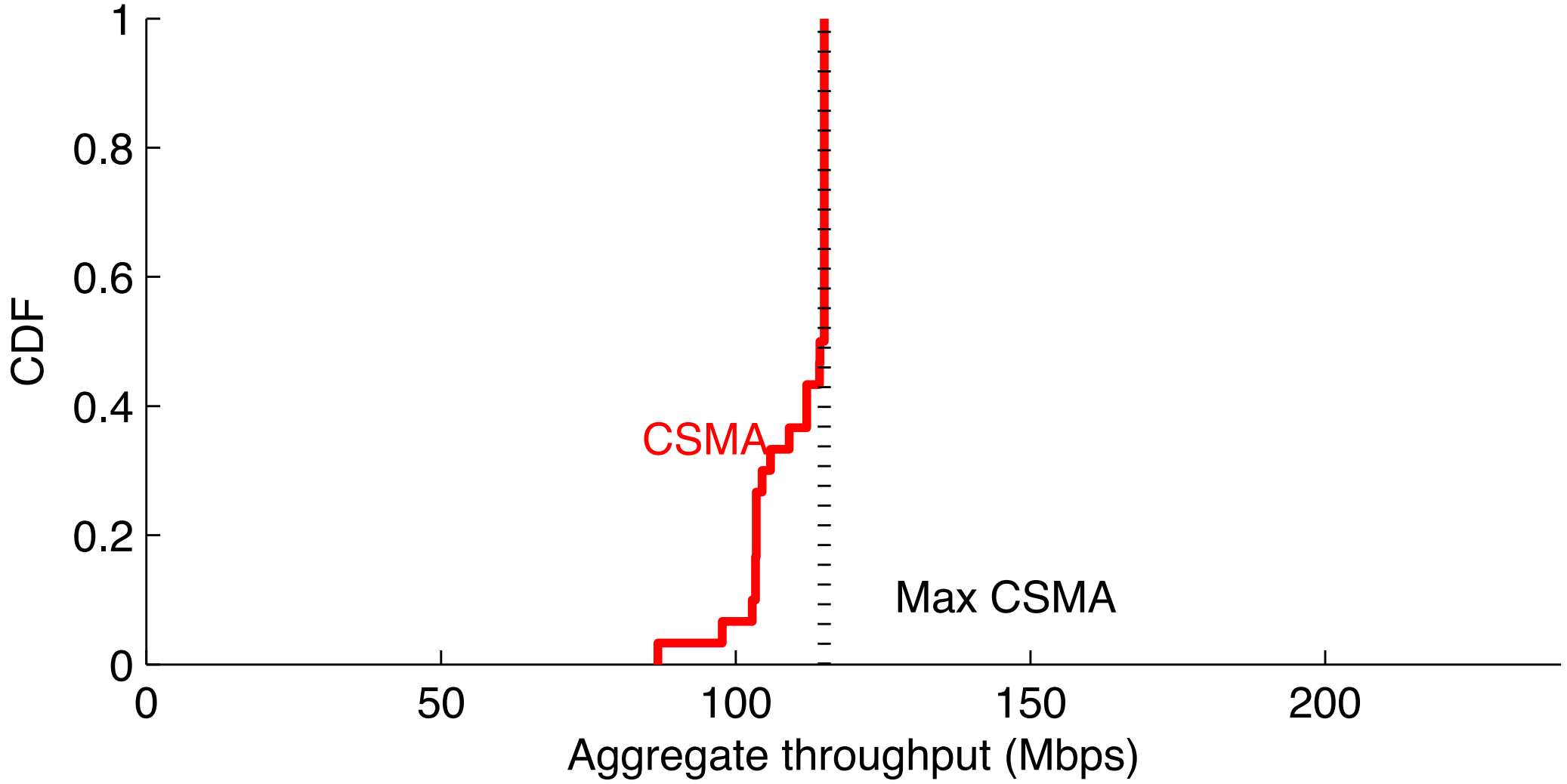


Hosts transmit ~100% of the time

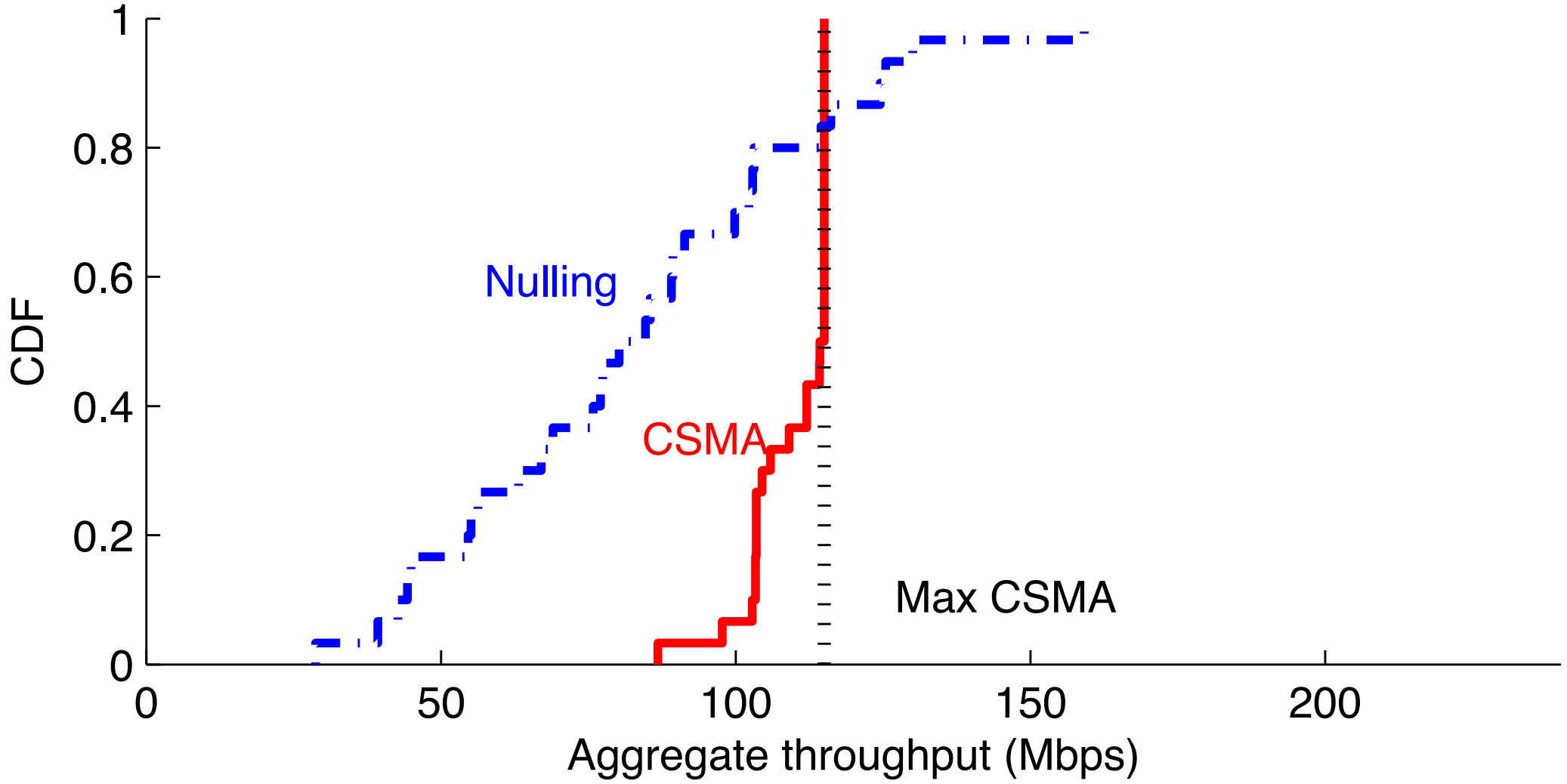
Bake-off: CSMA vs Nulling



Bake-off: CSMA vs Nulling



Bake-off: CSMA vs Nulling



SINR

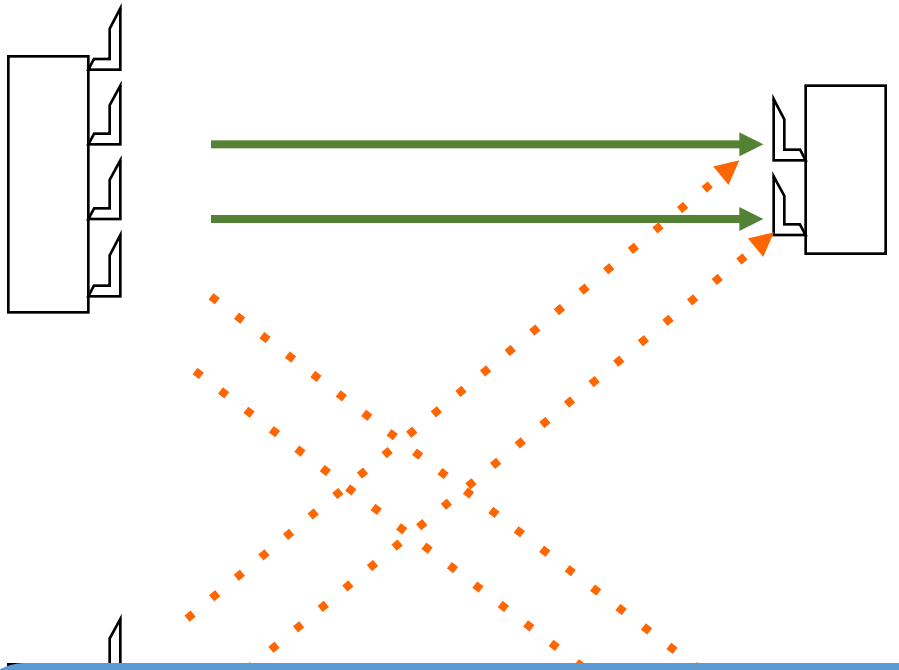
- Signal to Noise Ratio
- Capacity of stream -> Shannon equation

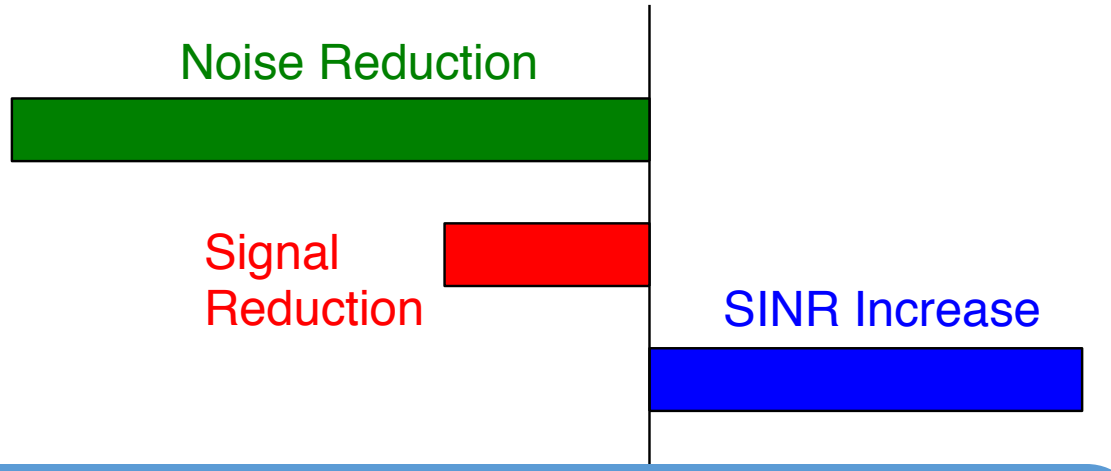
$$C = B \cdot \log_2\left(1 + \frac{S}{I + N}\right)$$

C: Capacity
B: Bandwidth

S: Power of signal of interest
B: Power of interference
I: Power of noise

Nulling improves SINR over beamforming



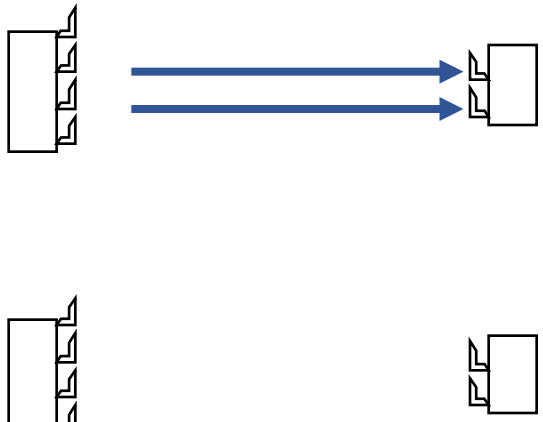


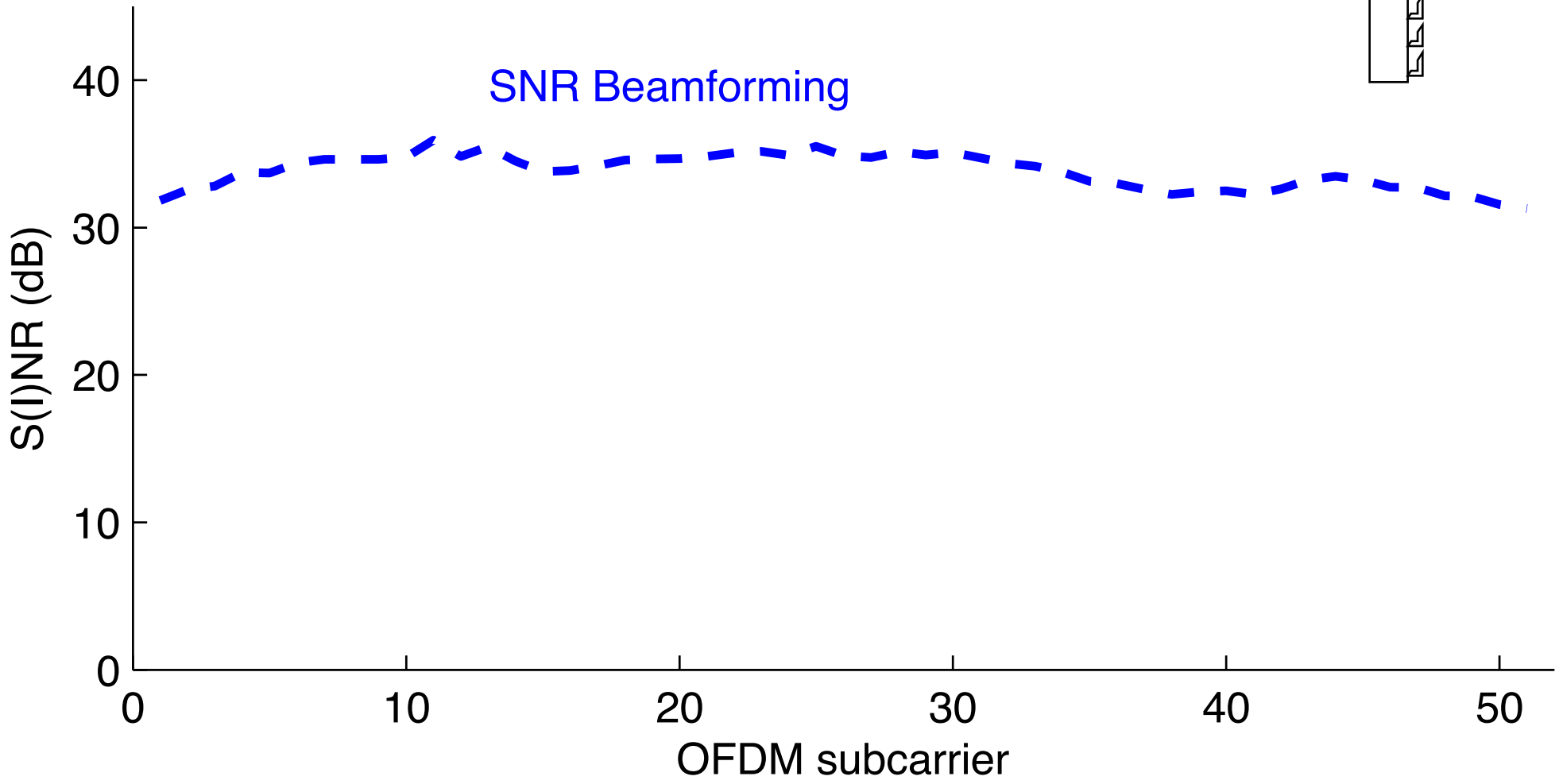
Hardware imperfections: Tx-Rx amplifier noise, power amplifier noise, phase noise, I-Q imbalance, carrier leakage, stale CSI…

Totals not the whole story

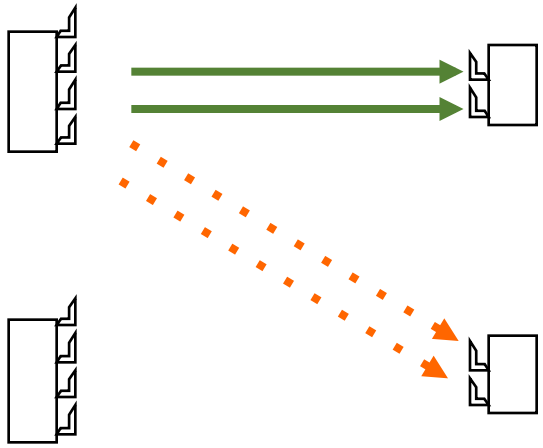
- 802.11 hosts use Orthogonal Frequency Division Multiplexing
- Split channel across frequency into subcarriers
- Transmit on each one in parallel

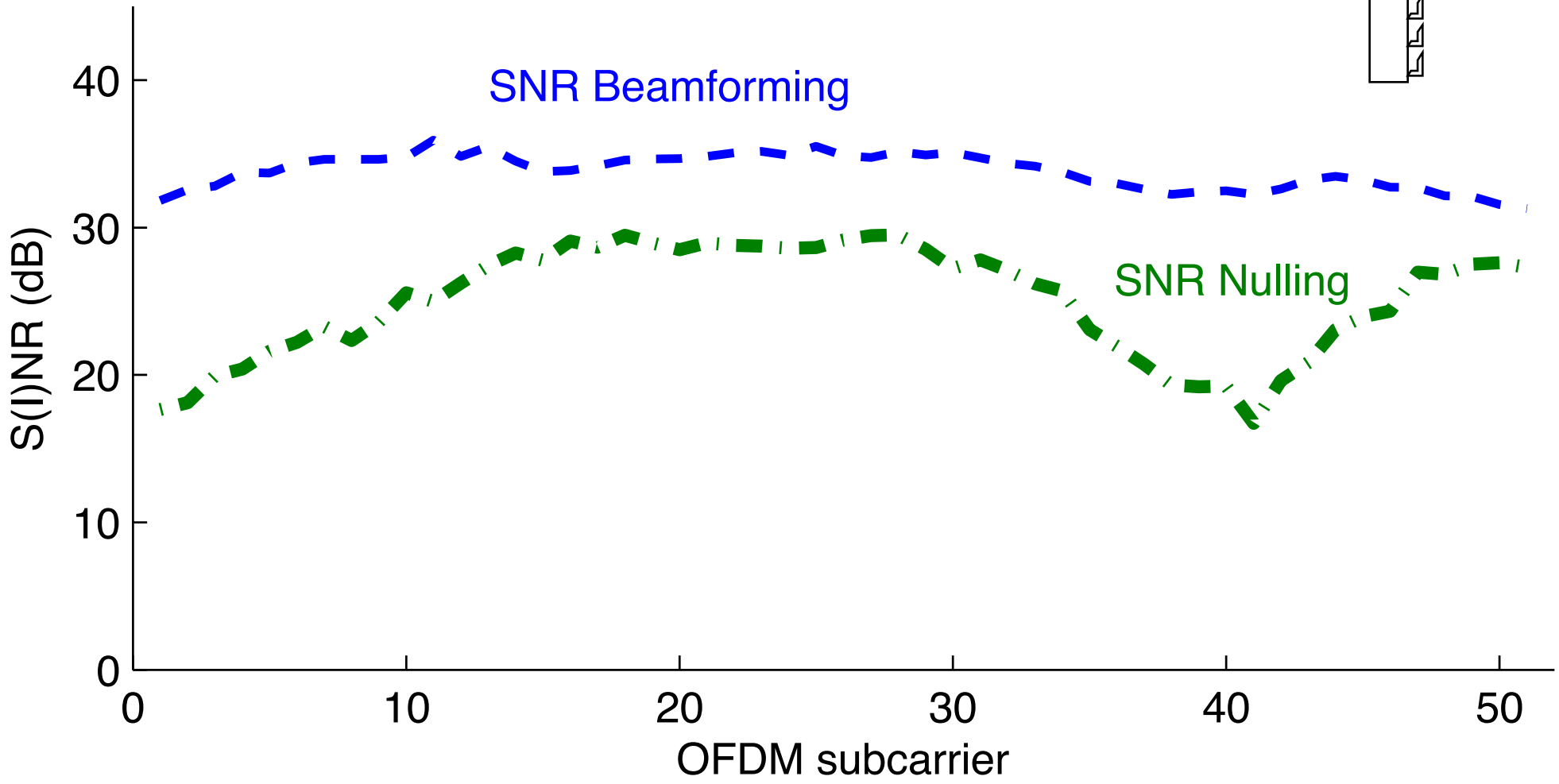
Channel varies across subcarriers



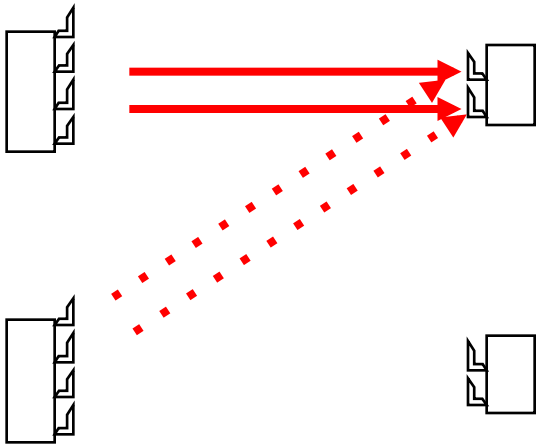


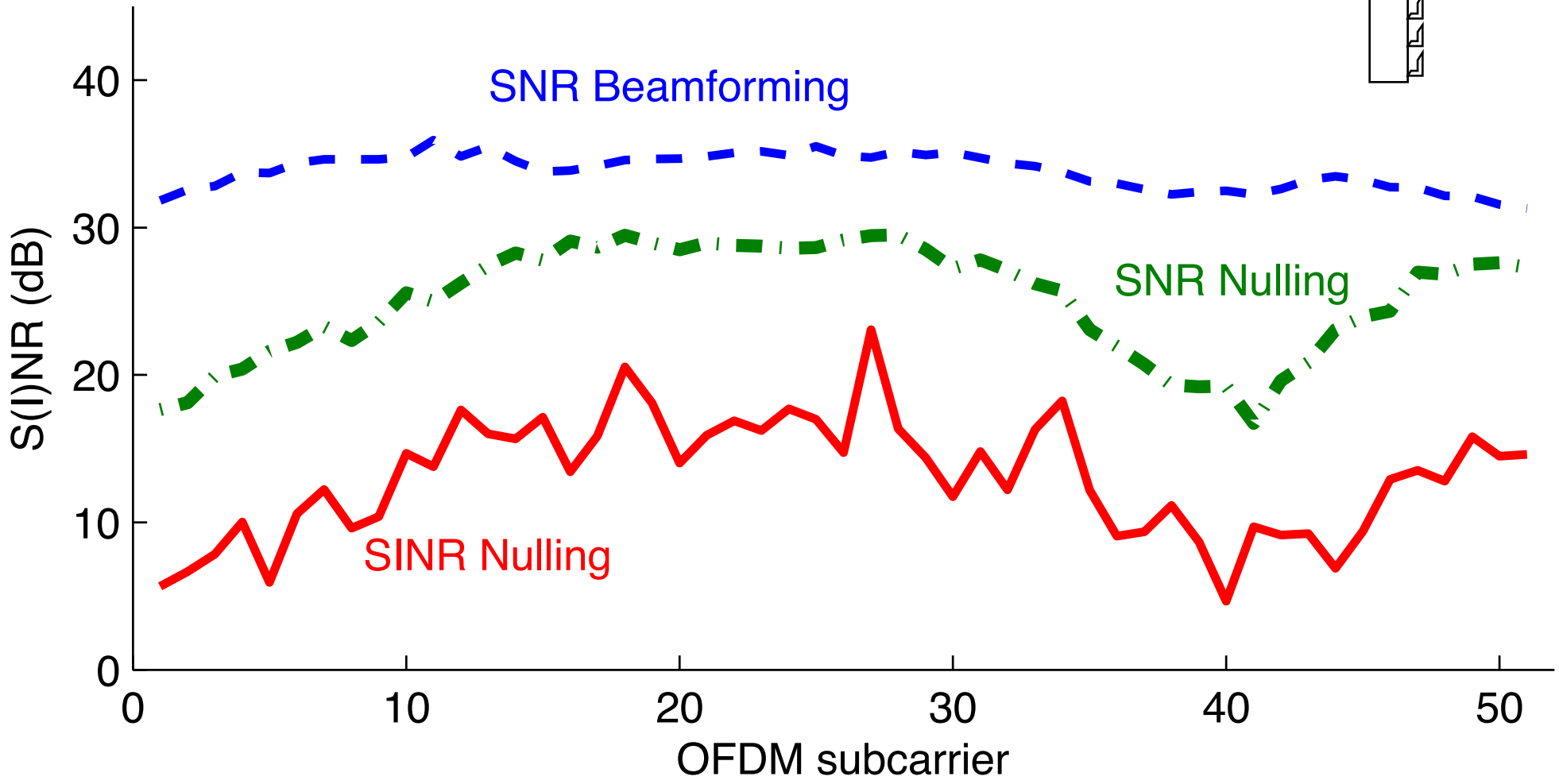
Nulling increases variation



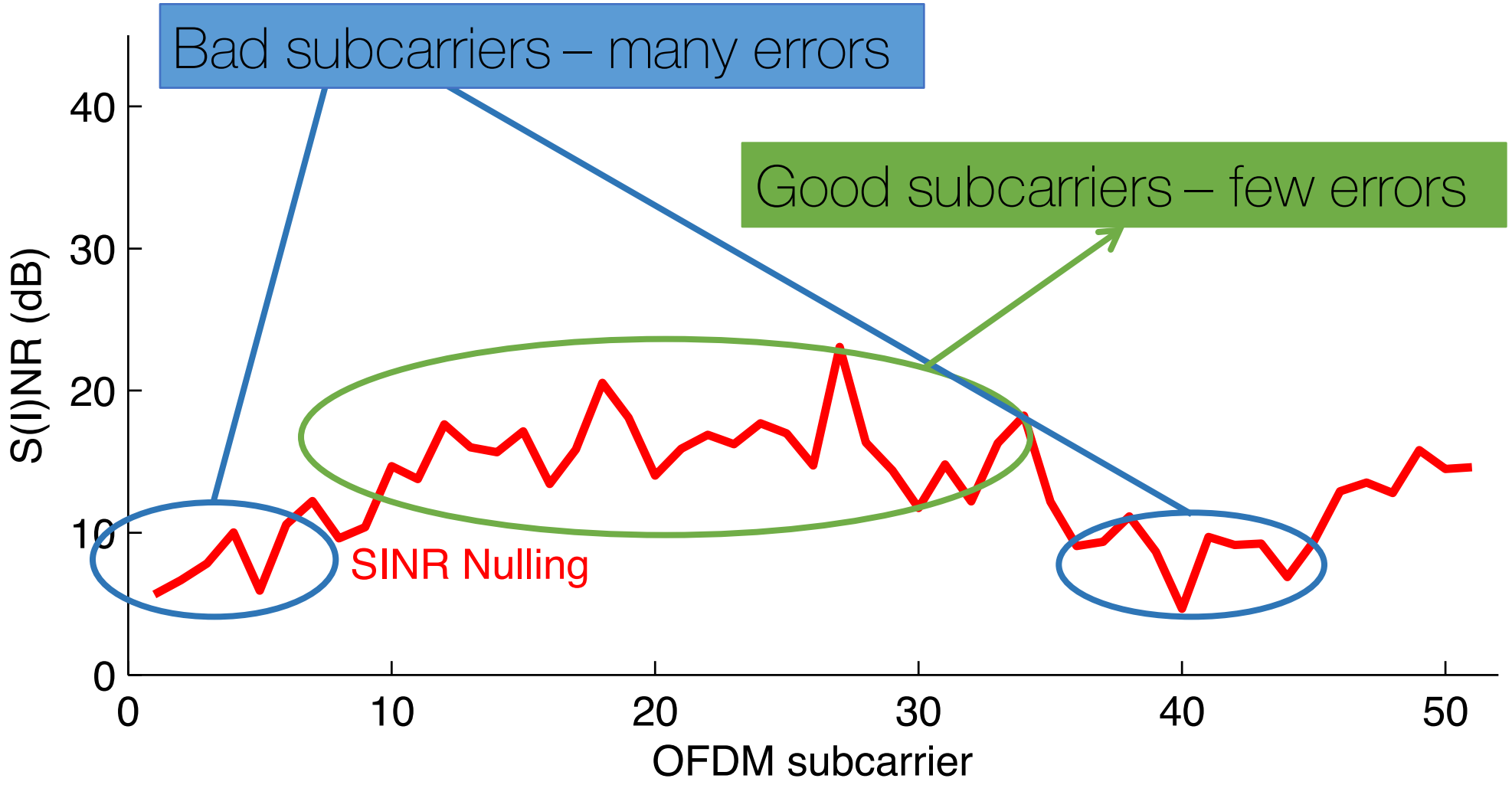


…and interference increases it even more





Variation reduces throughput



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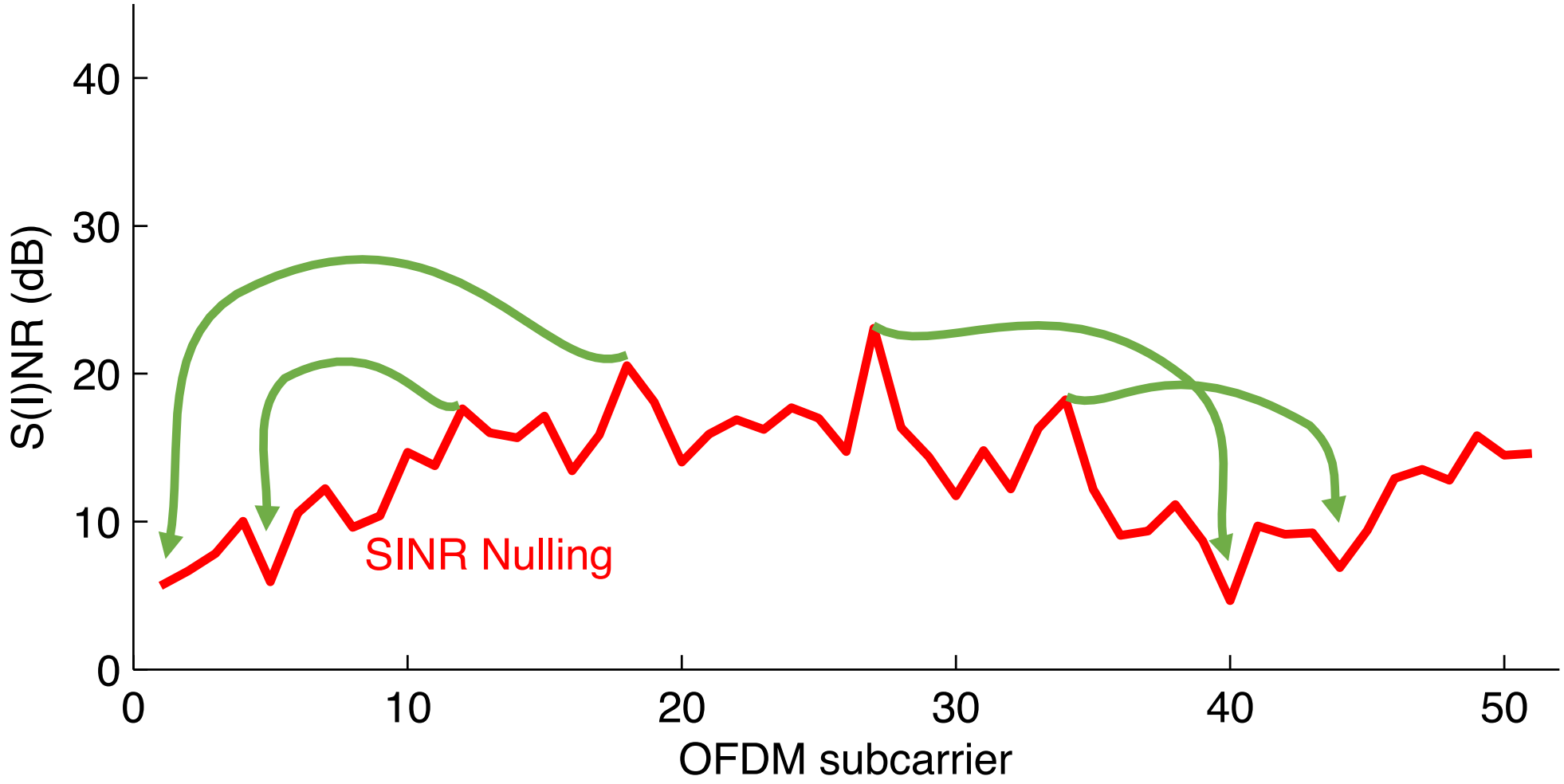
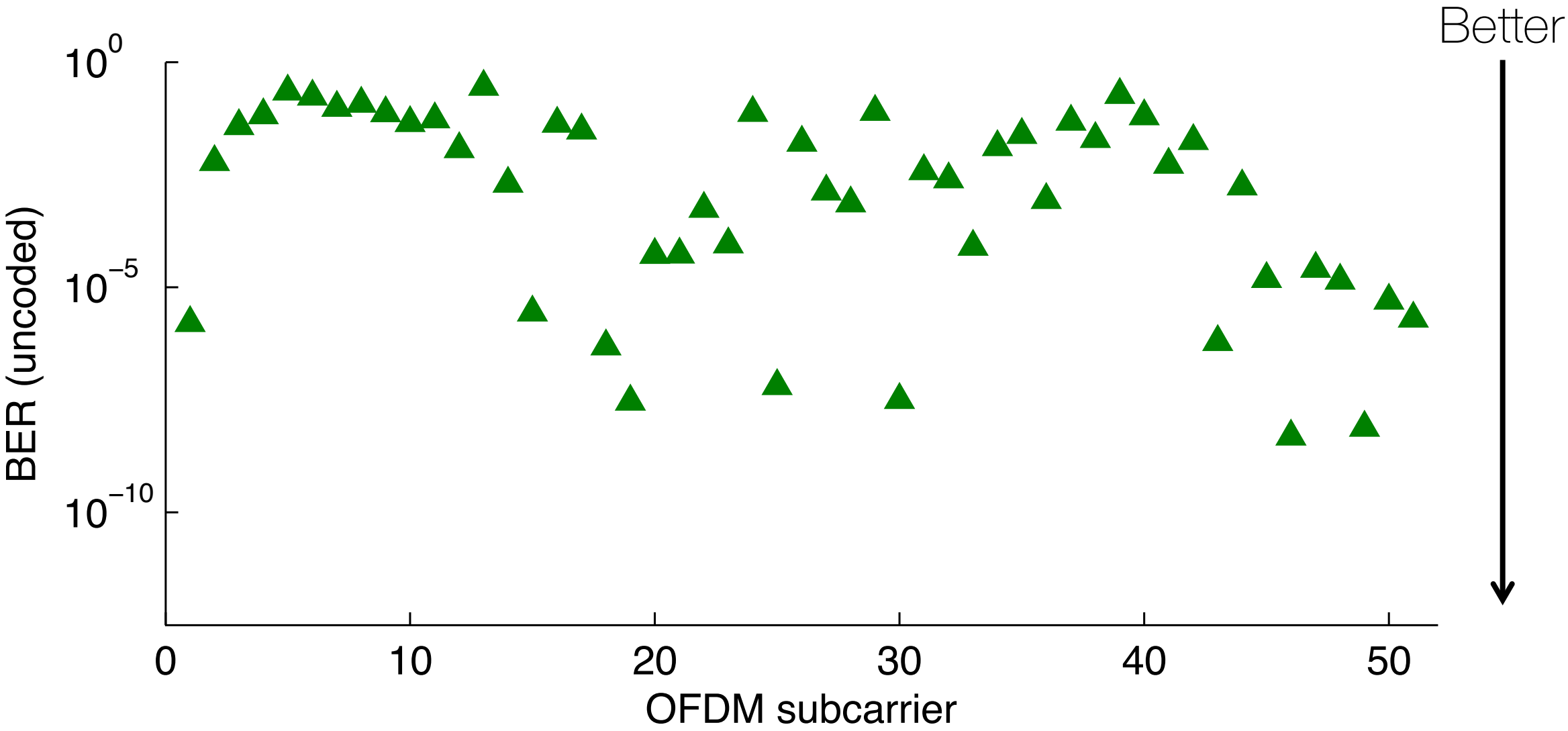


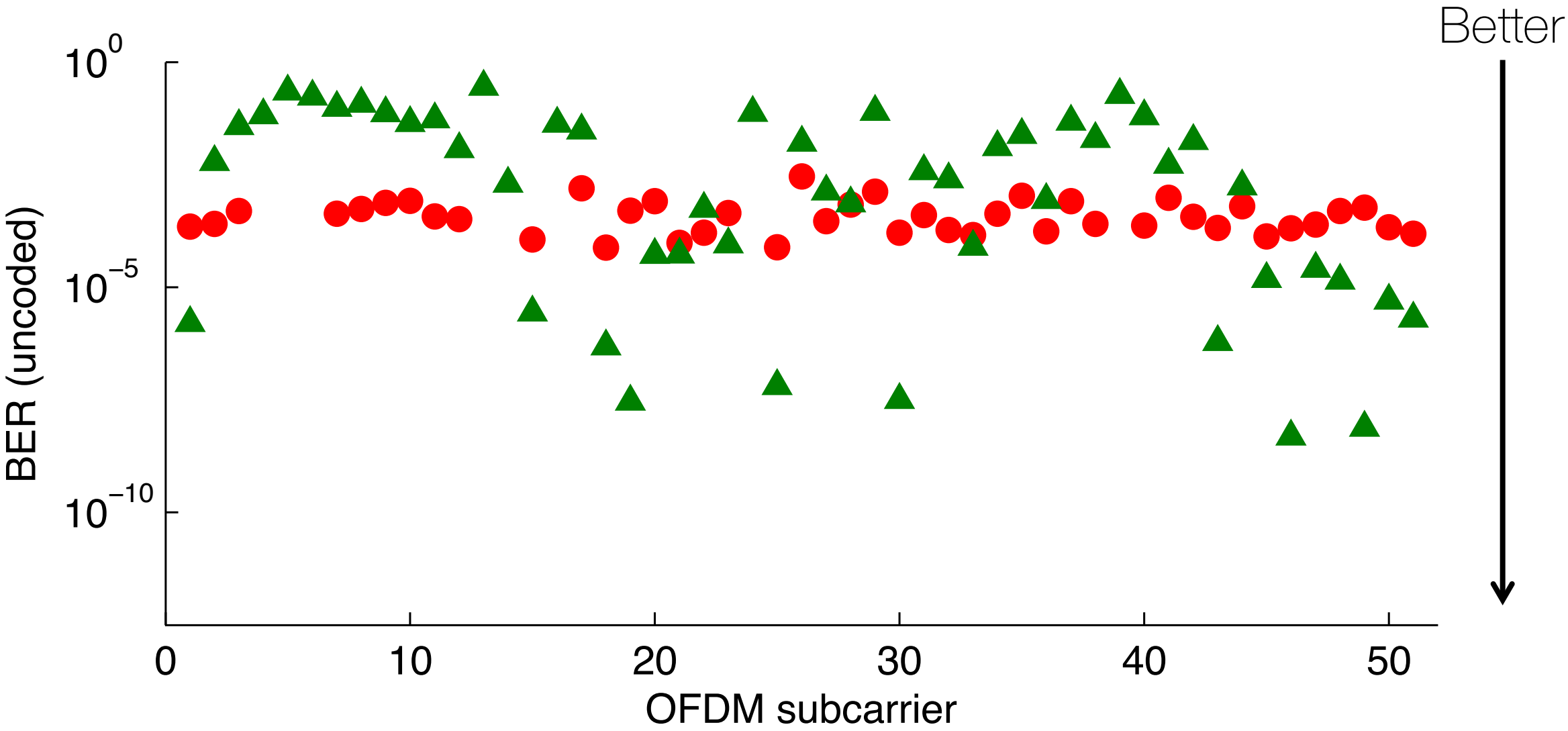
Co-Operative Power Allocation

- MAC protocol
  - Identify opportunities for cooperation
  - Disseminate necessary information for channel modeling
- Cooperate in how to distribute power
- Reduce SINR variability
- Avoid bad subcarriers
- Choose higher bitrate -> higher throughput

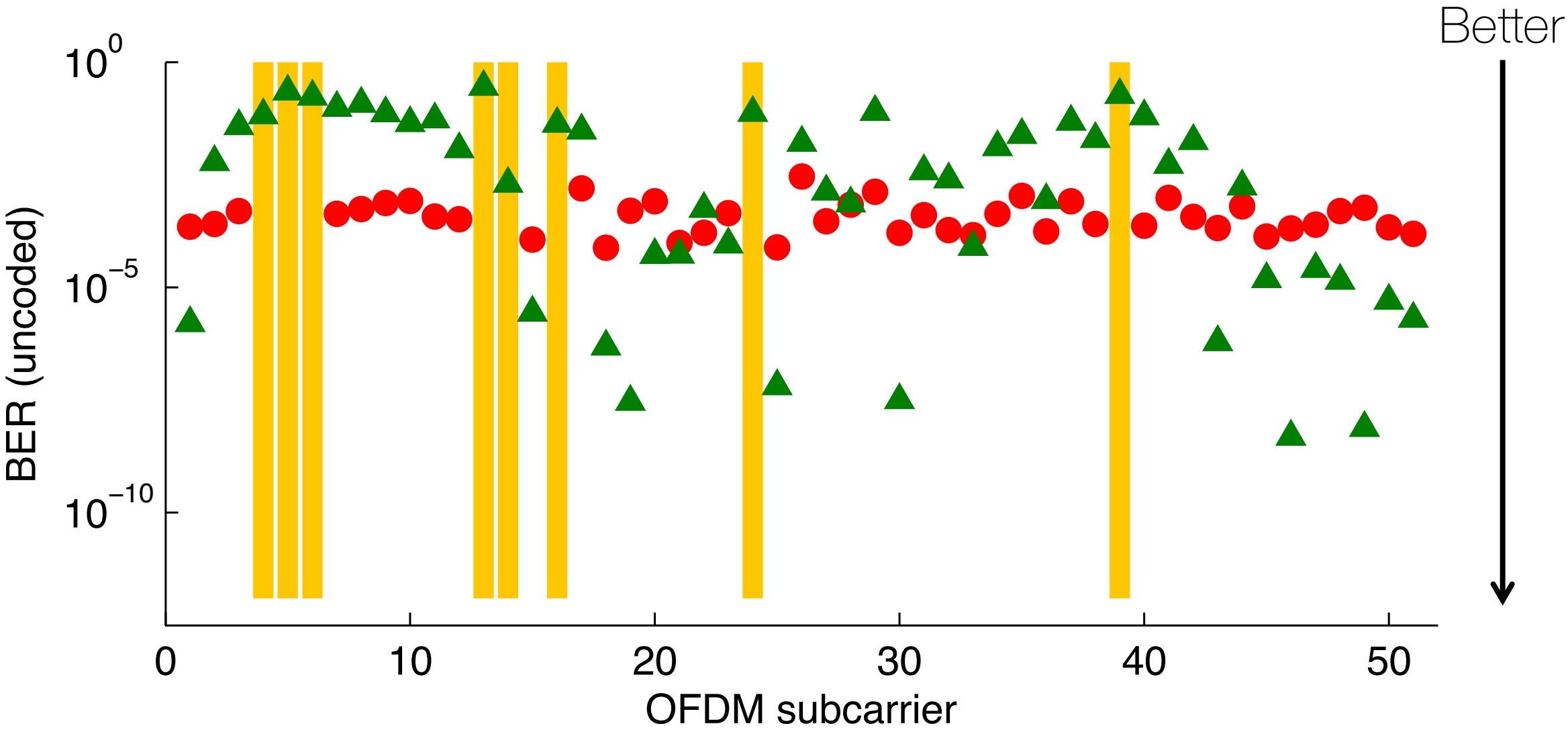
Large BER variation when nulling



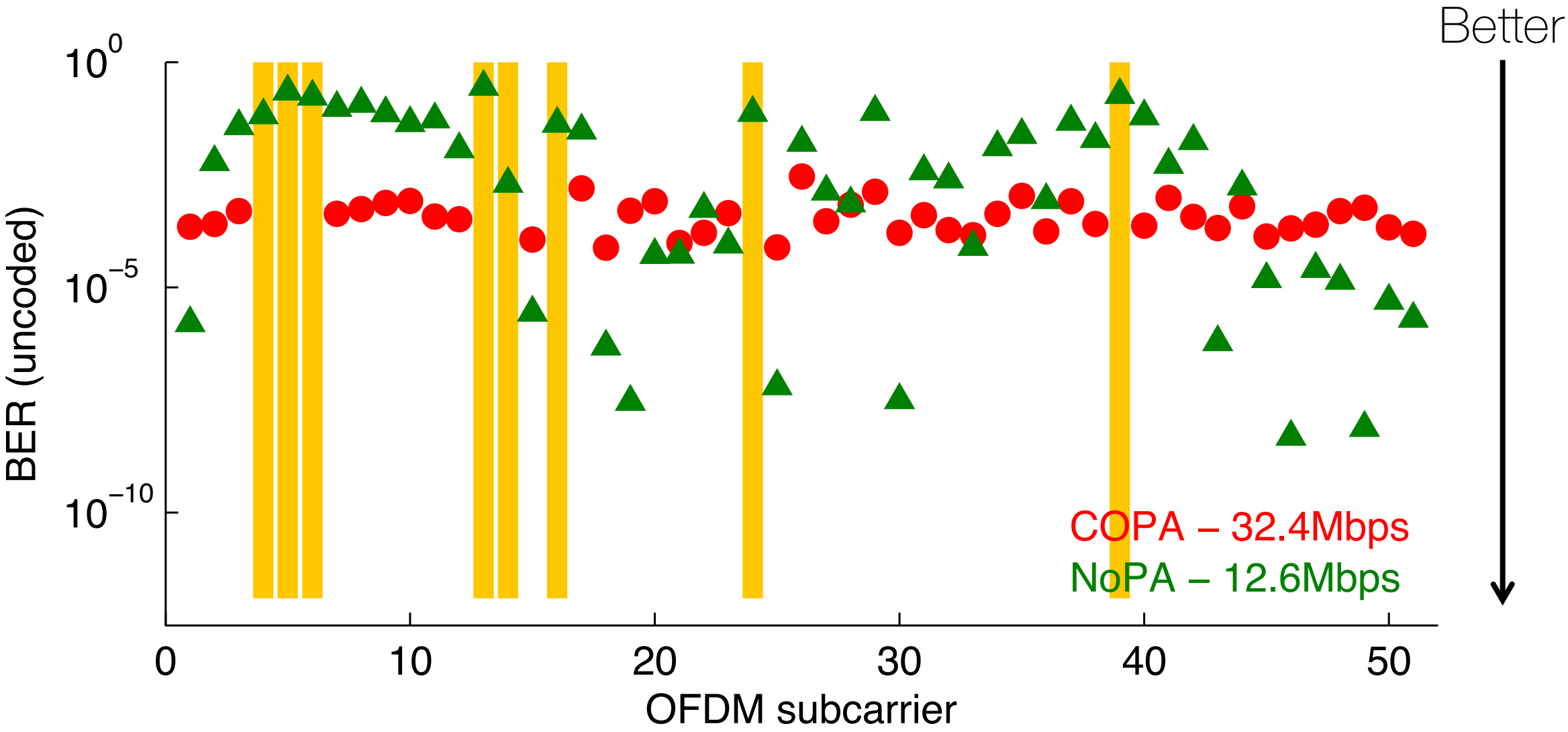
COPA reduces variation…



…drops bad subcarriers…

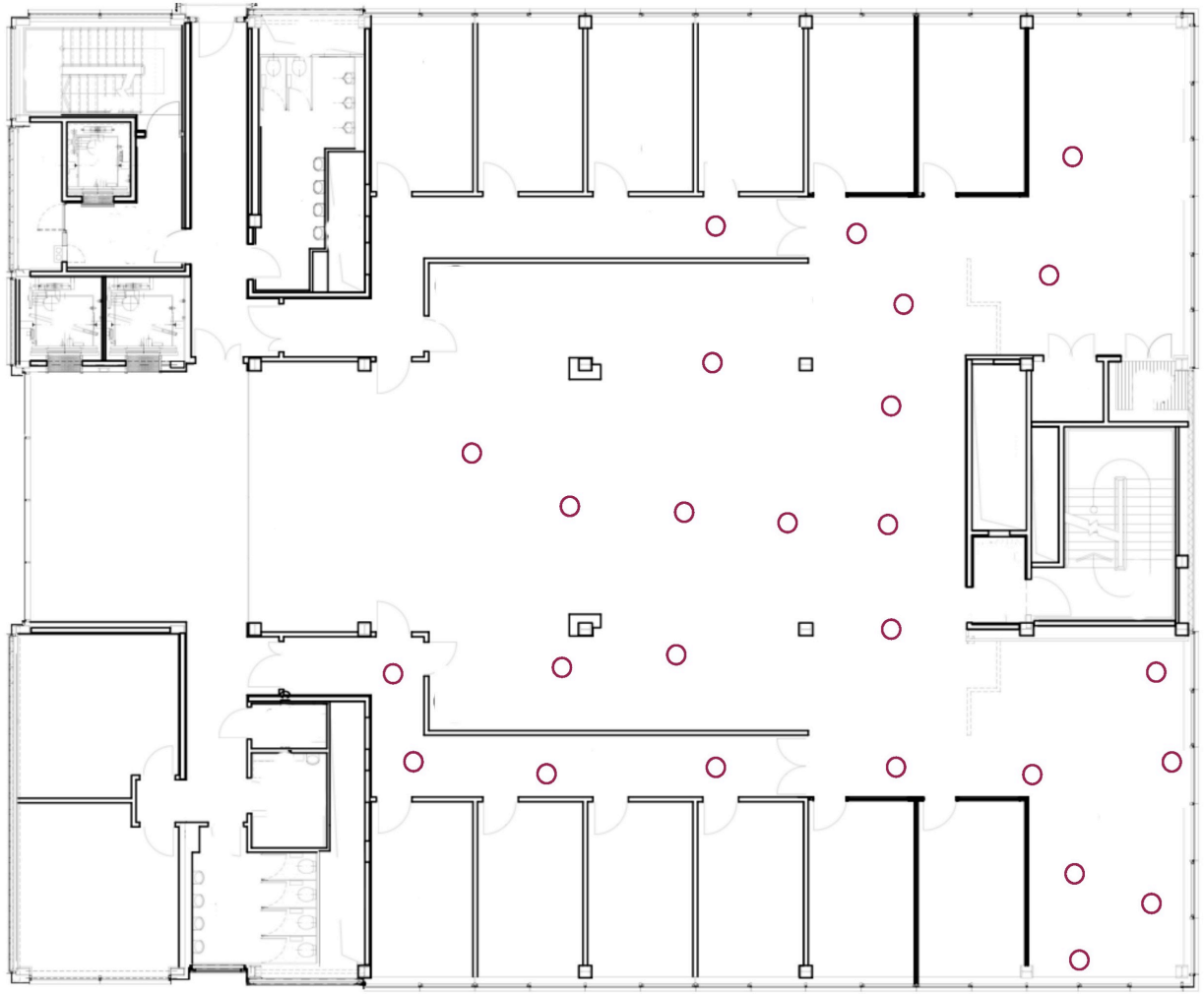


…and allows higher bitrates

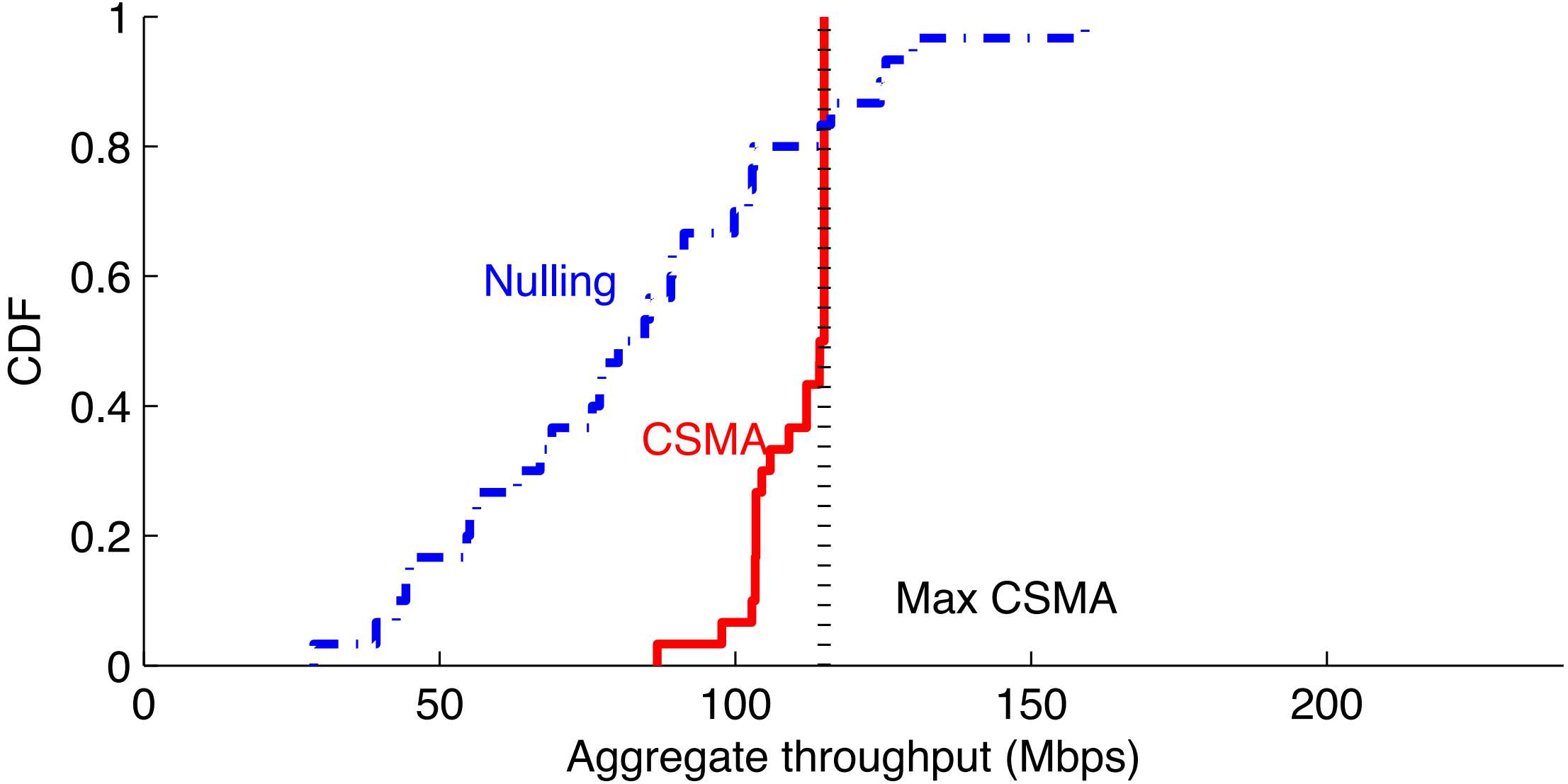


Experimental setup

- WARP v2
- 2.4GHz band
- 20MHz channel
- 4-tx antennas
- 2-rx antennas



4 tx-antennas, 2 rx-antennas*



WARP v2, 2.4GHz, 20MHz channel

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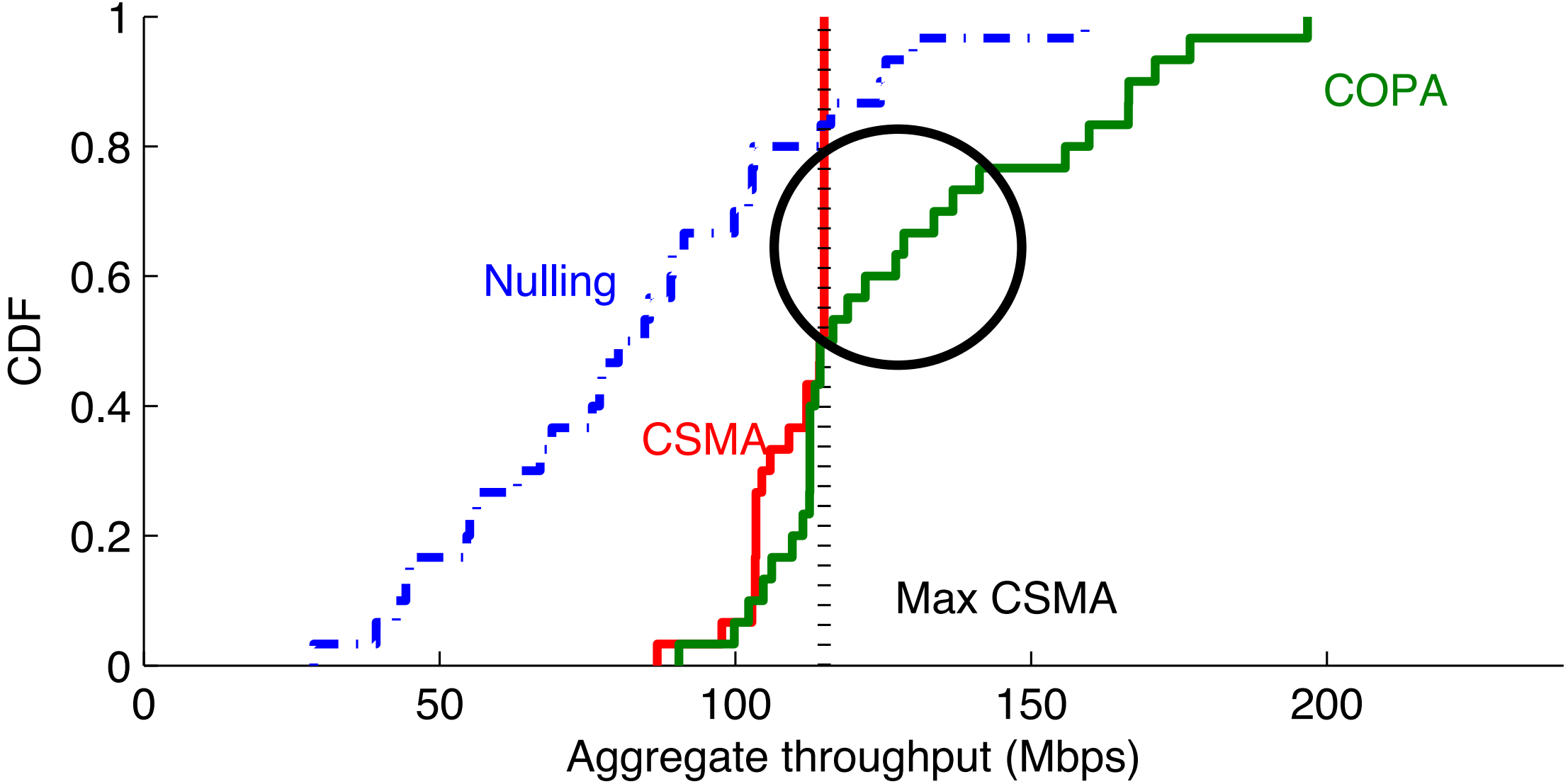
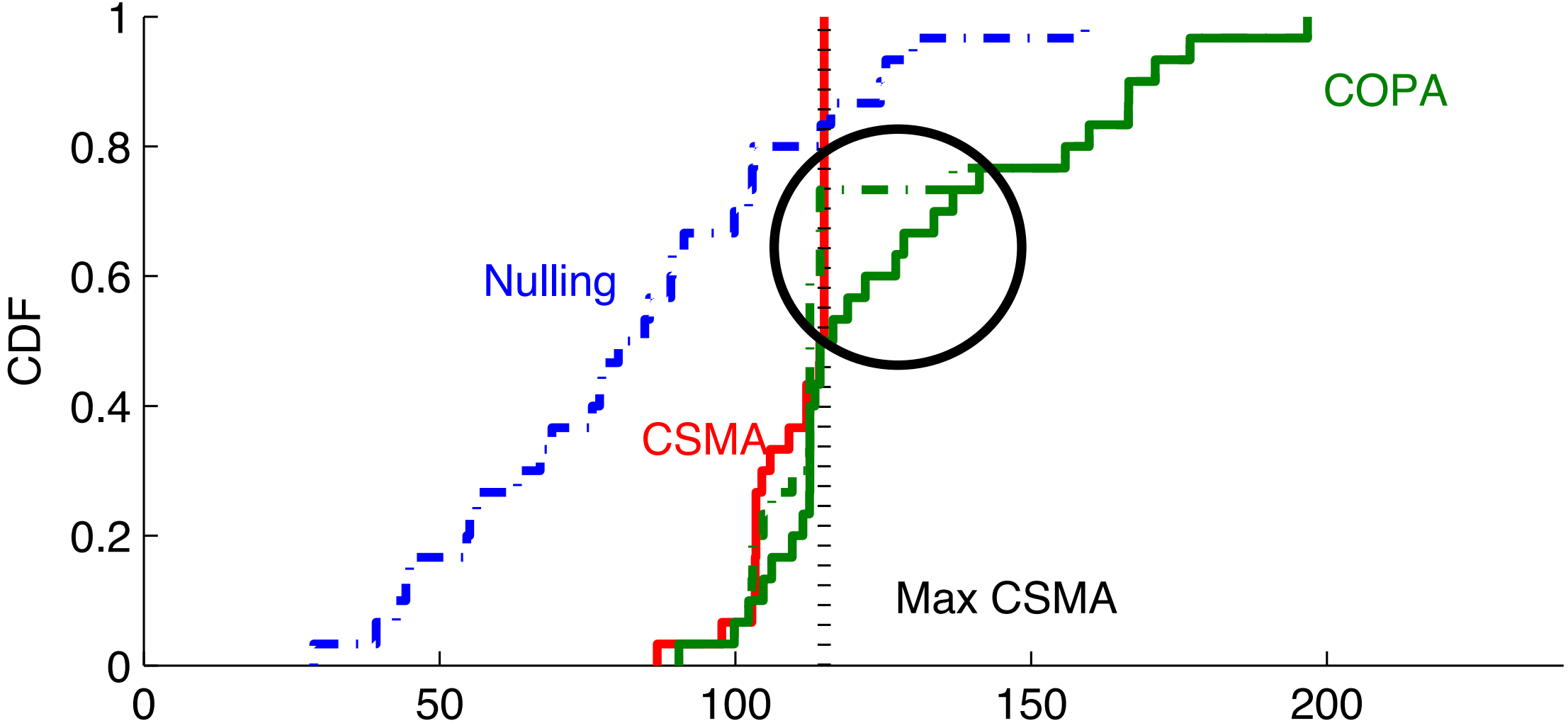


*WARP v2, 2.4GHz, 20MHz channel

Incentive compatibility

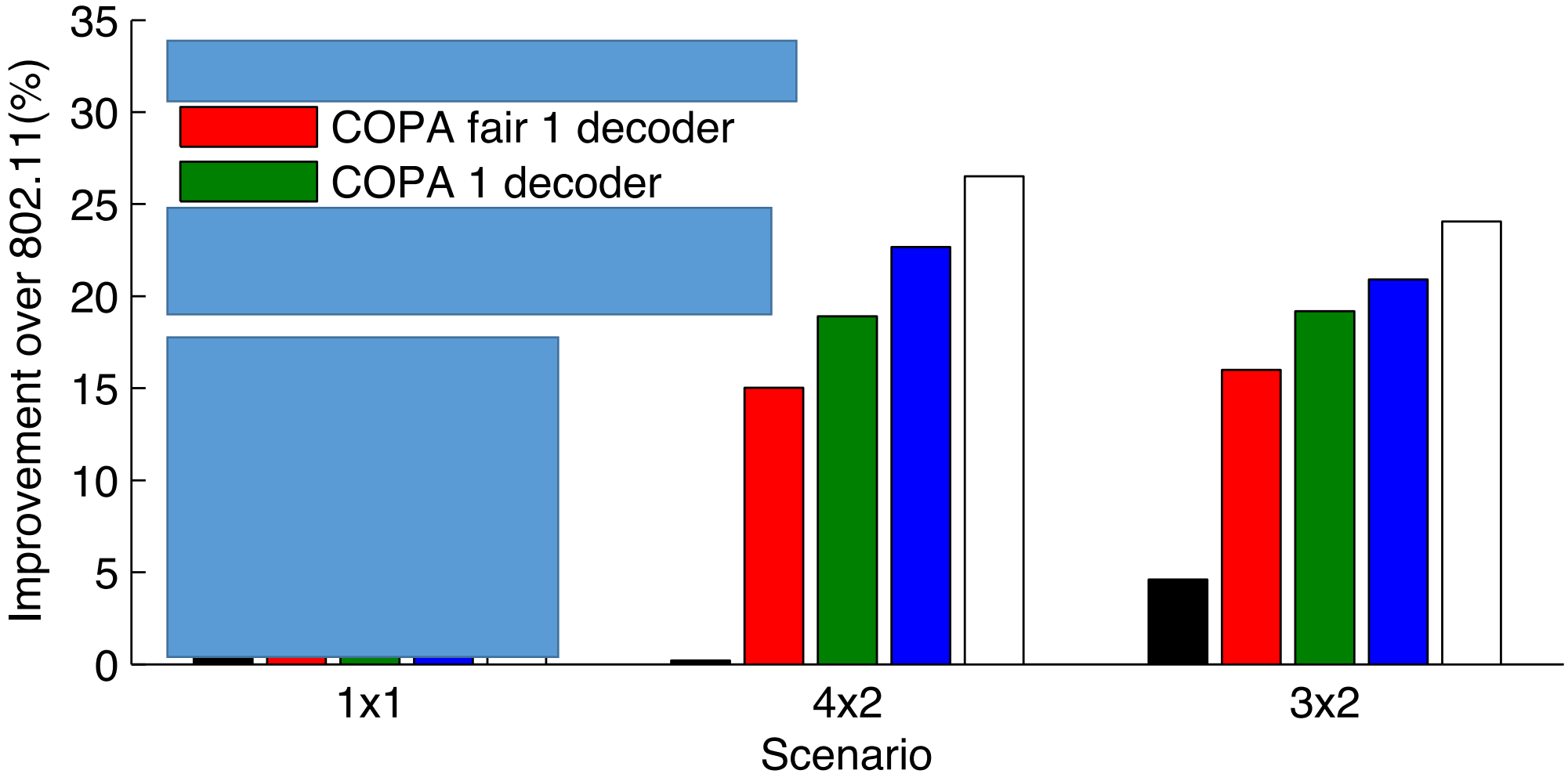
- Users might not want to sacrifice *any* own throughput
- Can add that as a constraint
- If either client's throughput decreases, revert to TDMA+Power allocation

4x2 scenario + incentive



**WARP v2, 2.4GHz, 20MHz channel*

Many more results: Single antenna, overconstrained, multiple decoders, other power allocations…



Conclusion

- Residual interference hurts nulling
- COPA reduces SINR variation and allows higher bitrates
  - Improvement in 80% of cases versus CSMA/Nulling in 4x2 scenario, 17% throughput improvement for those
- COPA offers an incentive-compatible variant
  - 57% of cases, 19% throughput improvement

Back-up slides

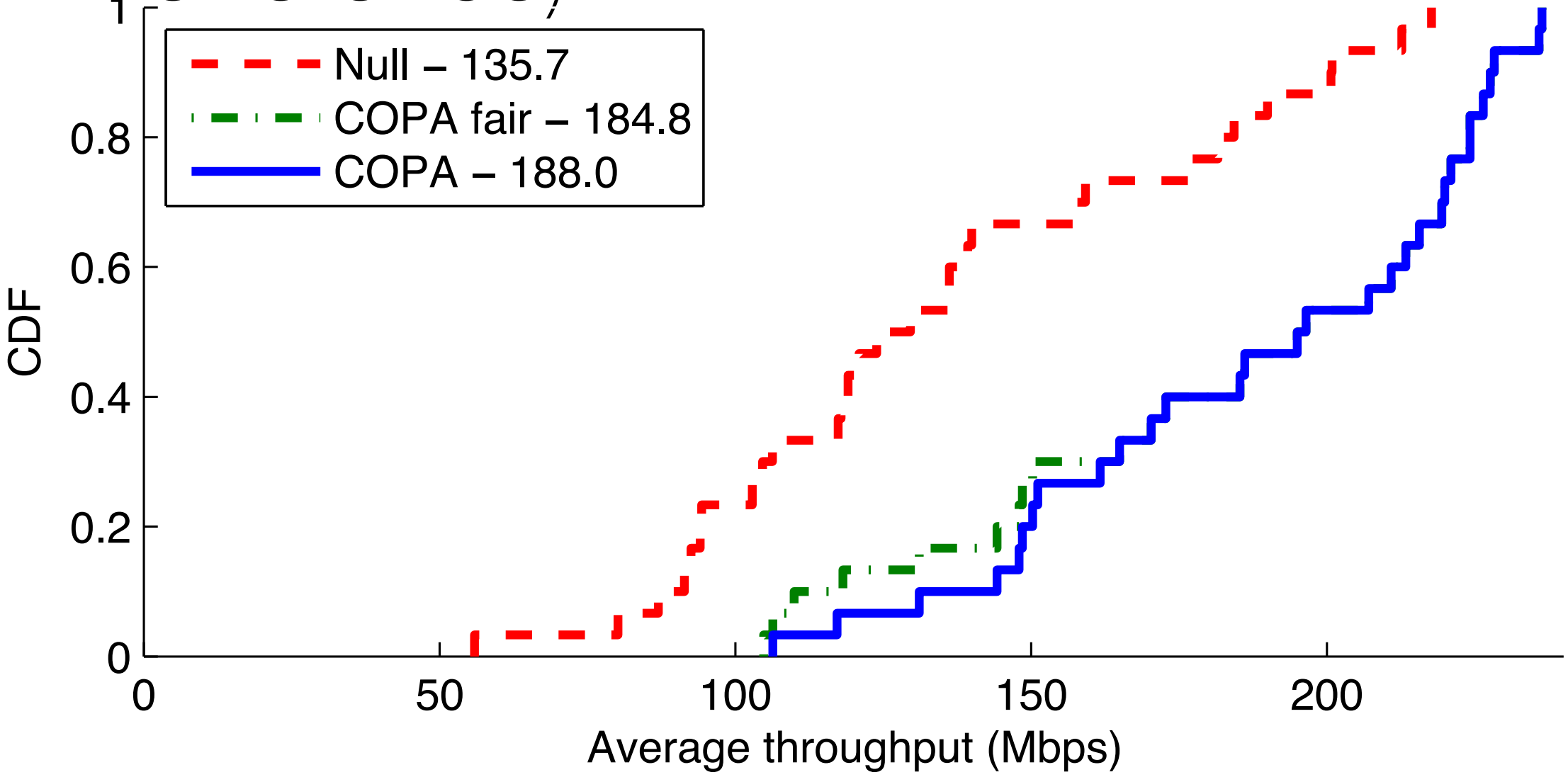
Practical implementation

- TDMA and concurrent nulling are computationally simpler and roughly equivalent to what multi-stream APs do today
- COPA is iterative, but only requires divisions and multiplications and a sort of ~50 items; should be of equal or lesser complexity to matrix operations for multi-stream

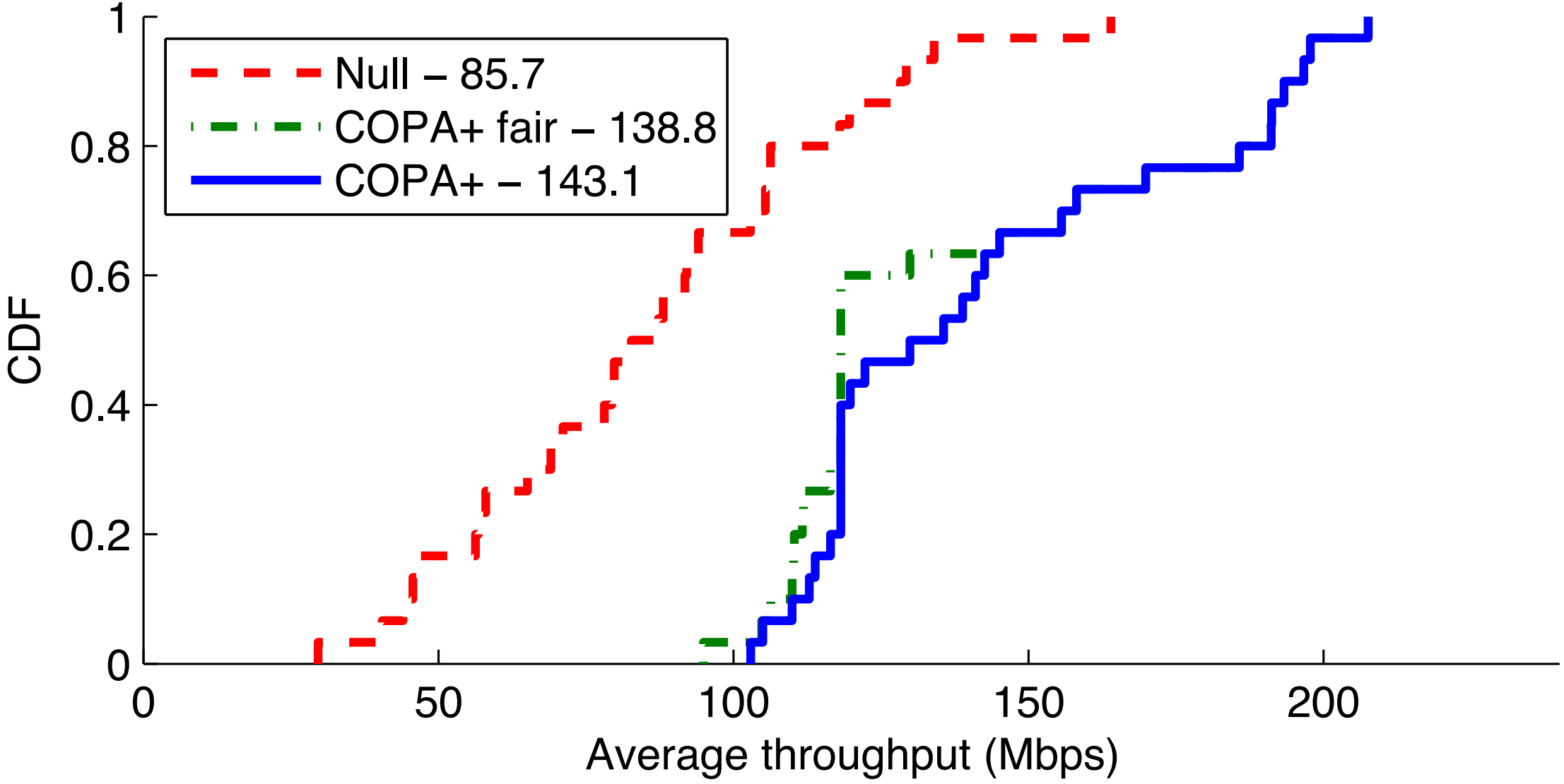
Power allocation methods

- Waterfilling optimal for Gaussian distributions
- Mercury/waterfilling optimal for discrete constellations
  - Computationally complex (but same order as waterfilling with our optimizations)
- Equalization suboptimal due to noise amplification
- Can be made better by dropping subcarriers
- COPA does *cooperative* allocation

4x2 scenario (lower cross-interference)



4x2 scenario (HgH2O)



S and I for our topologies