Living with Interference in Unmanaged Wireless Environments

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This talk

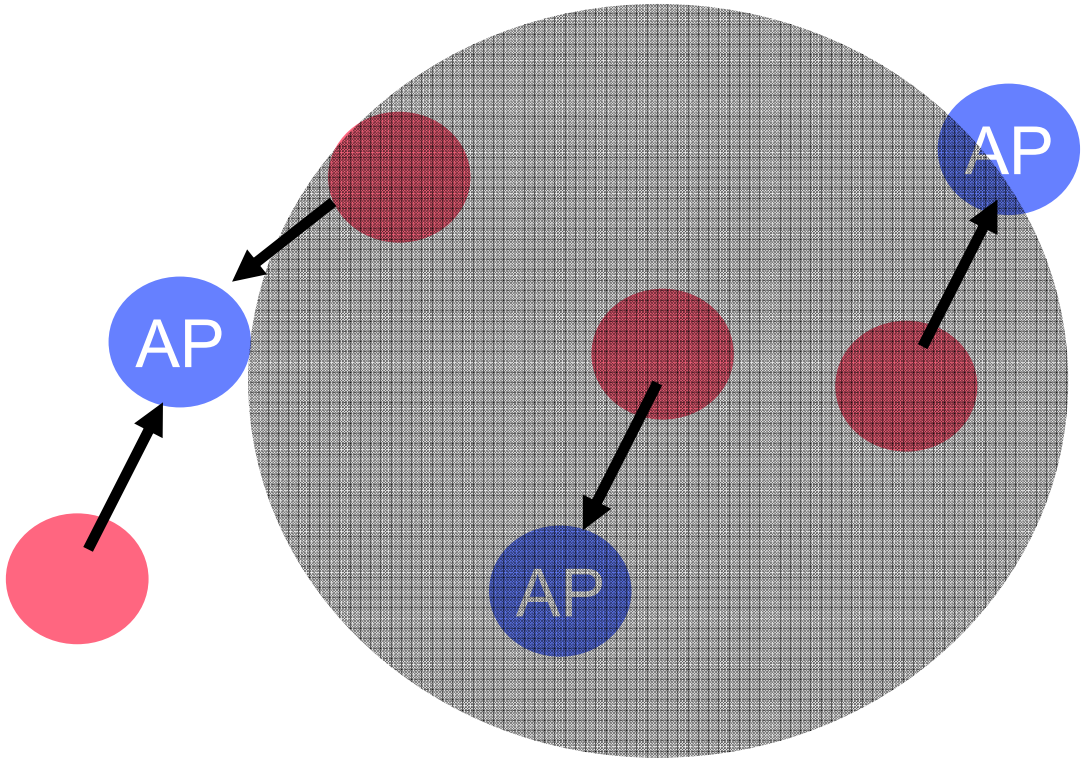
1. The problem: inefficient spectrum scheduling in wireless LANs
2. Successive Interference Cancellation (SIC) as part of the solution
3. Our USRP-based SIC prototype and experiments

See also:

- Daniel Halperin's demo/poster of this work
- Michael Buettner's USRP-based UHF RFID reader

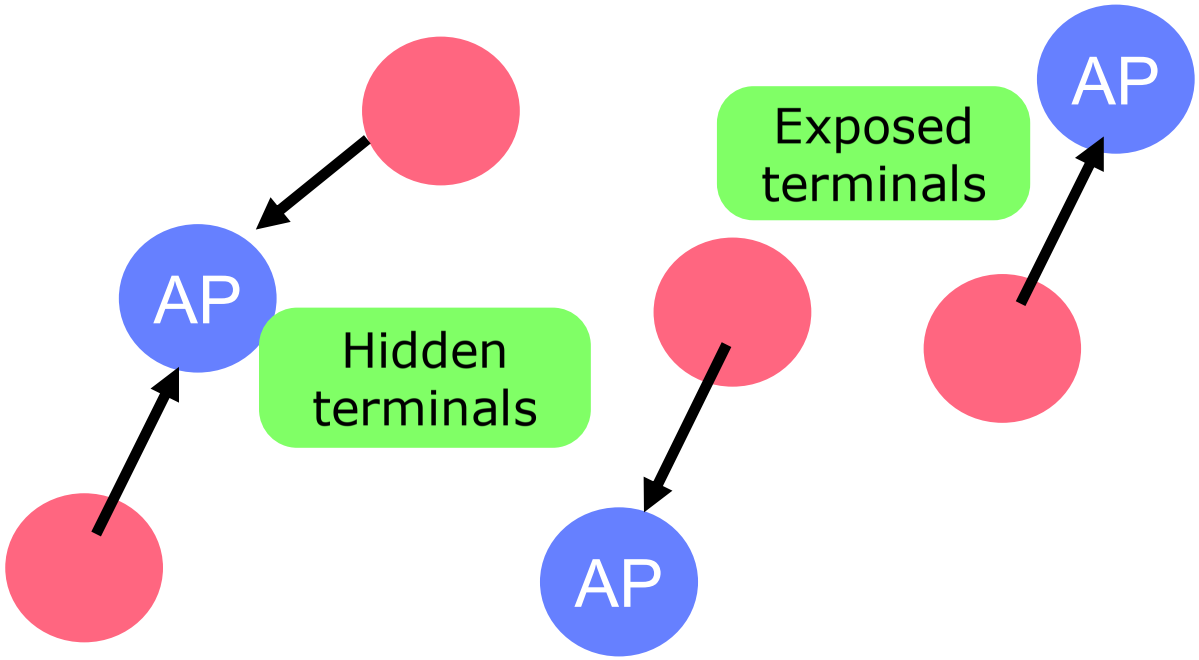
1. Spectrum scheduling via carrier sense

- Carrier sense (CSMA/CA) used to serialize in-range transmissions
- Widely used foundation of wireless LANs



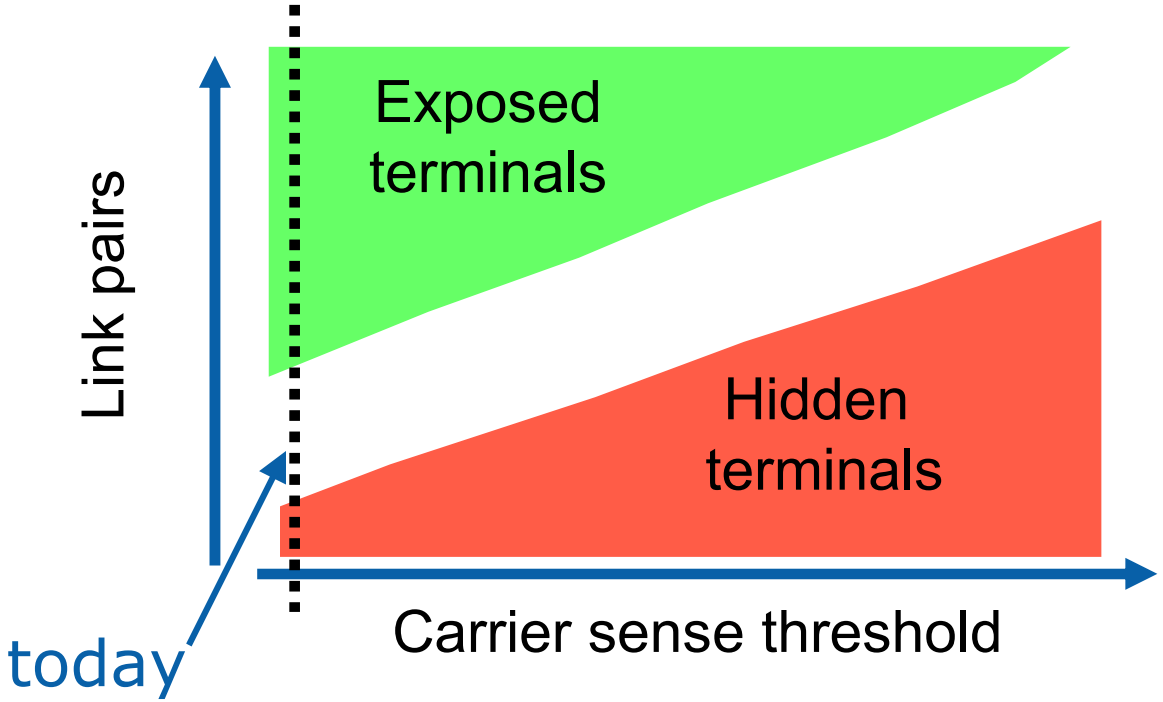
But CSMA/CA has known inefficiencies

• Too aggressive in some cases (hidden terminals increase loss) and too conservative in others (exposed terminals lower throughput)



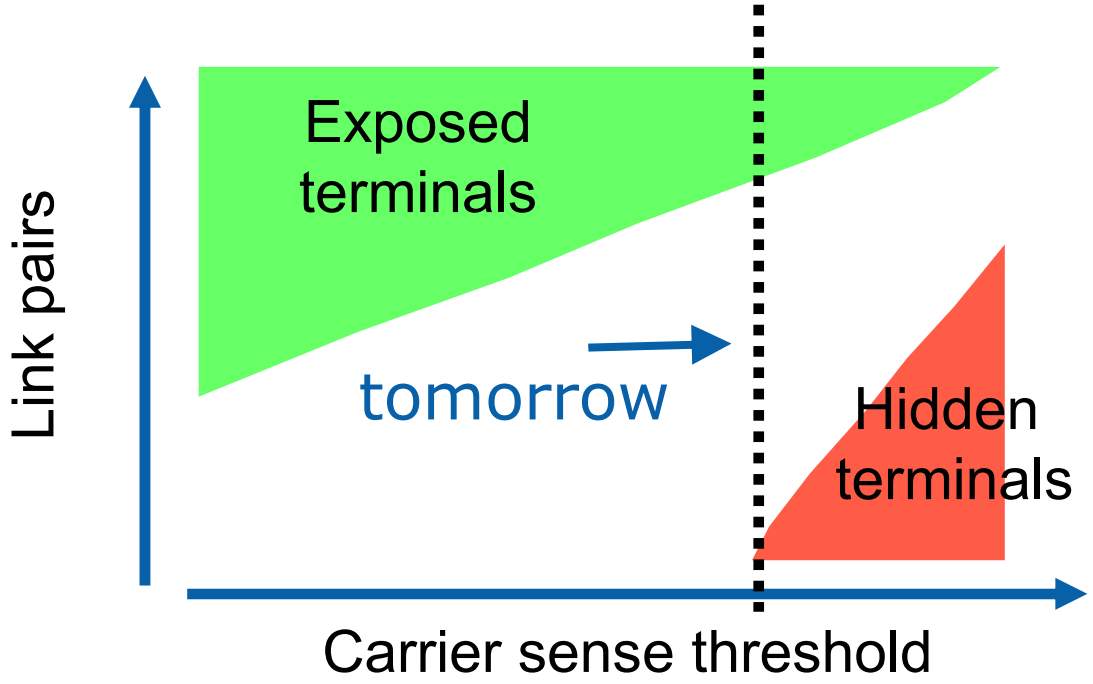
The costs of CSMA/CA

- Tweaks mostly trade hidden and exposed terminal cases
- Today, operate to minimize hidden terminals



Towards living with interference

• Want to increase concurrent transmissions (to boost performance) but mitigate cases with harmful collisions (to reduce loss).



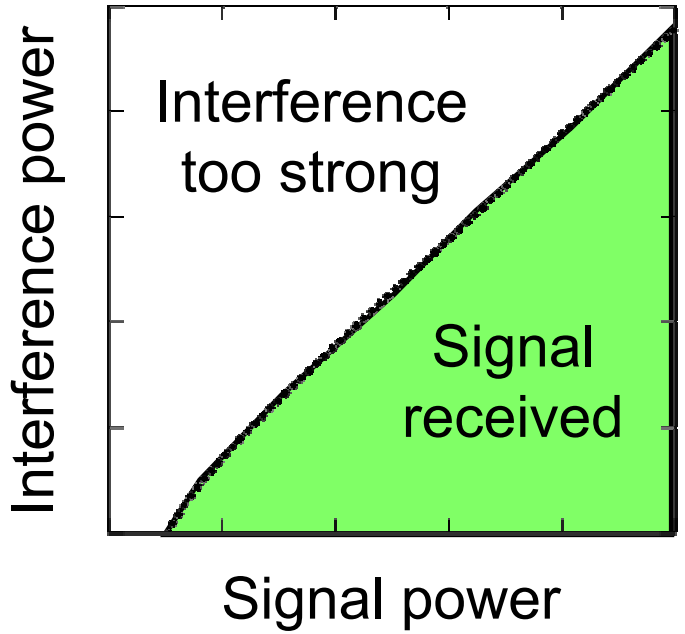
How? Interference cancellation will get us there!

2. Conventional SINR Decoding with two transmissions (~+~)

Decoding successful (green region) if signal is stronger than combined power of interference and noise:

$$\mathrm{SINR} = \frac{\mathrm{Signal}}{\mathrm{Noise} + \sum \mathrm{Interference}}$$

$$= \frac{\sim}{\sim + \mathrm{Noise}} > T$$

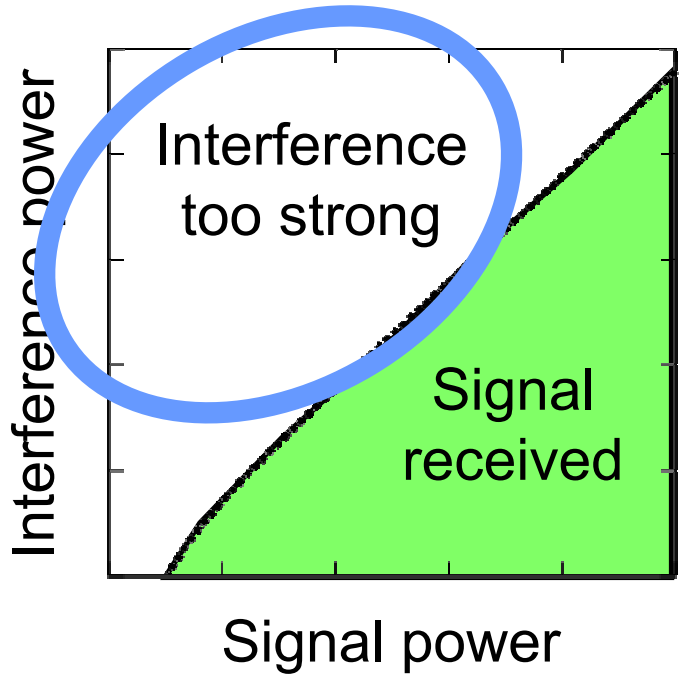


Conventional SINR Decoding

Decoding unsuccessful (white) if signal is weaker than combined power of interference and noise:

$$\mathrm{SINR} = \frac{\mathrm{Signal}}{\mathrm{Noise} + \sum \mathrm{Interference}}$$

$$= \frac{\sim}{\sim + \mathrm{Noise}} < T$$

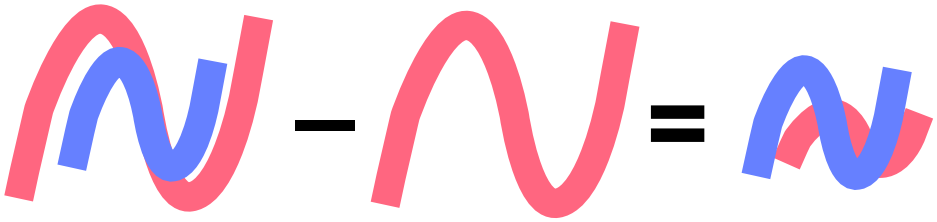


Misses an opportunity – interfering signal not random noise!

Successive Interference Cancellation (SIC)

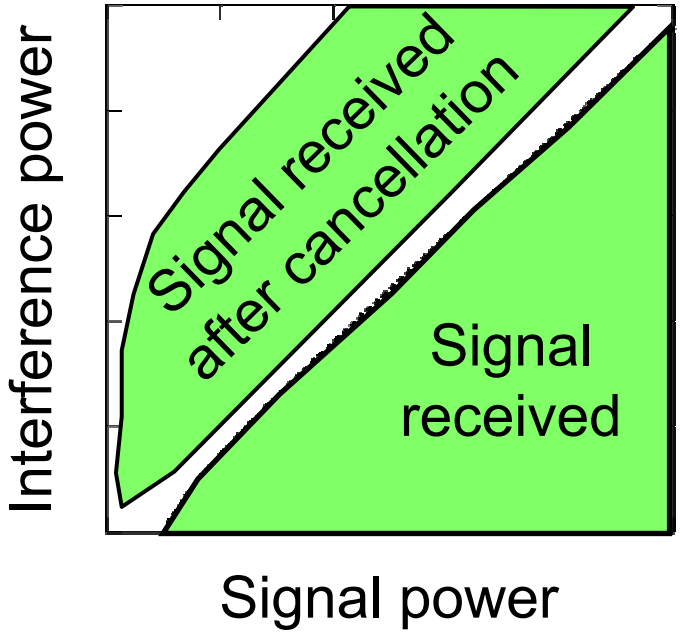
Decode signal with sufficient SINR as before, then model and cancel it, and decode remaining signal. Repeat.

Cancellation:



Next decode:

$$\text{SINR} = \frac{\sim}{\sim + \text{Noise}} > T$$



SIC can decode multiple packets in a collision!

Potential benefits of SIC

SIC can successfully decode multiple packets (versus zero or one) during collisions. This has several effects:

- Reduces loss
- Improves fairness and predictability
- Increases overall throughput at the cost of peak individual rate

3. SIC Prototype

Adapts SIC for bursty, chaotic networks such as 802.11

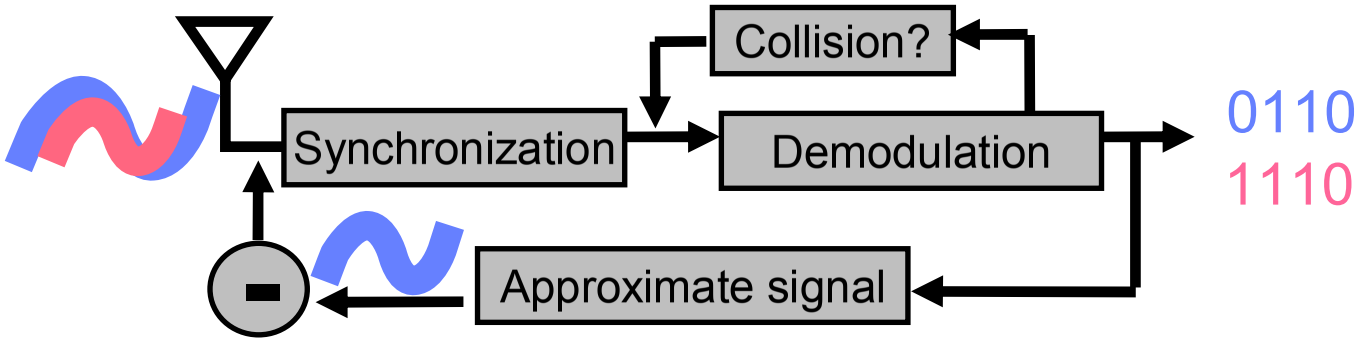
- No synchronization, weak knowledge of channel state, multiple receivers

Implemented on USRP platform

- Zigbee-like PHY coding, similar to low-rate 802.11
- Both conventional and SIC detector for comparison

USRP-related limitations

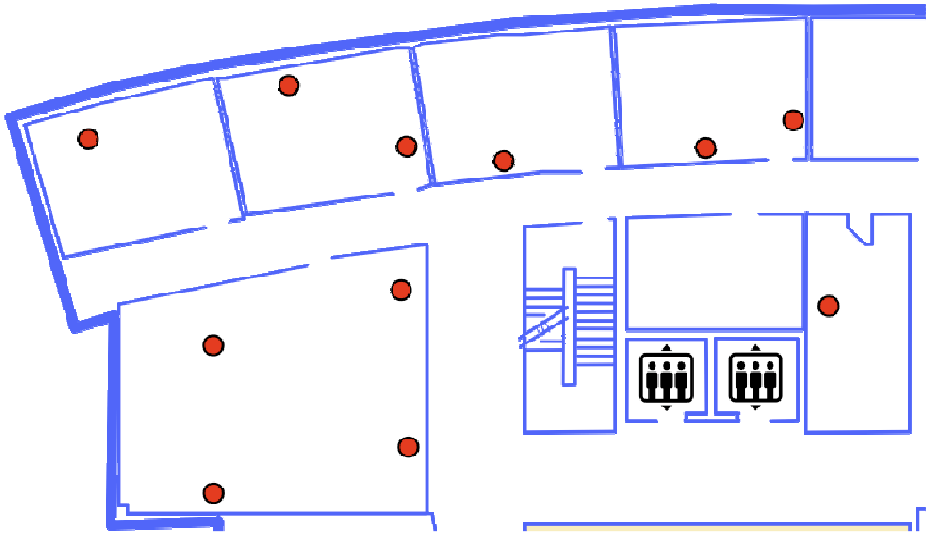
- No carrier sense; simulate based on measured behavior
- No ACKs due to long rx/tx turnaround time



Experimental setup & methodology

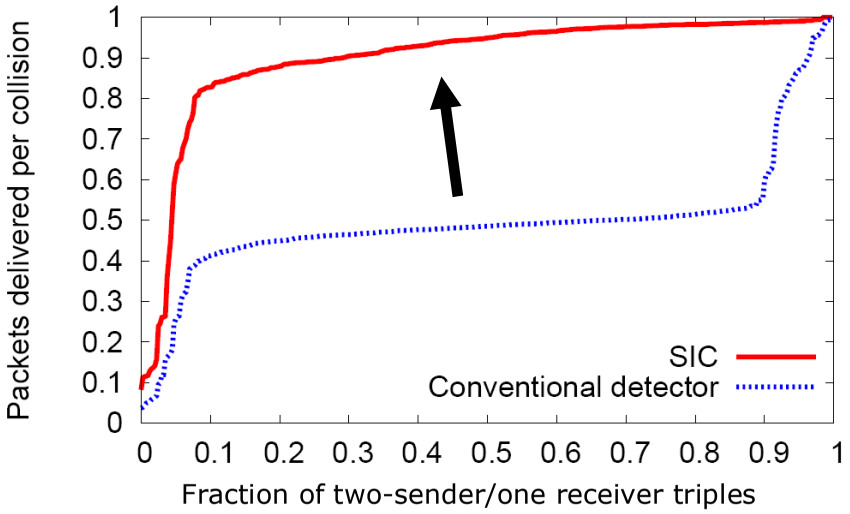
Pairs of nodes send packets with fixed rate and power

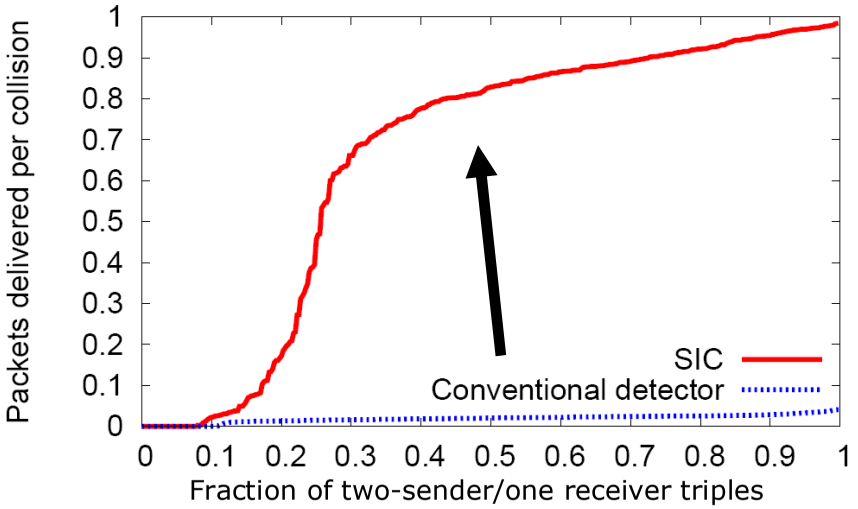
- Workload is set to two-packet collisions at random offsets
- Consider only "feasible links" with >75% delivery
- Log waveforms and run through SIC and conventional receivers
- Use measurements to extrapolate CSMA performance



11 node wireless testbed (PC + USRP) in UW Allen (CSE) building

Measured delivery under interference (two senders and one receiver)

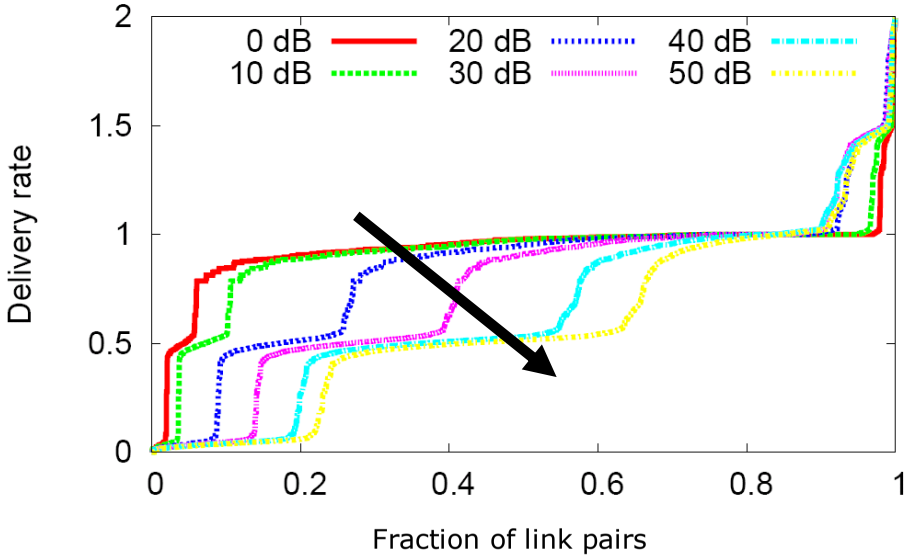


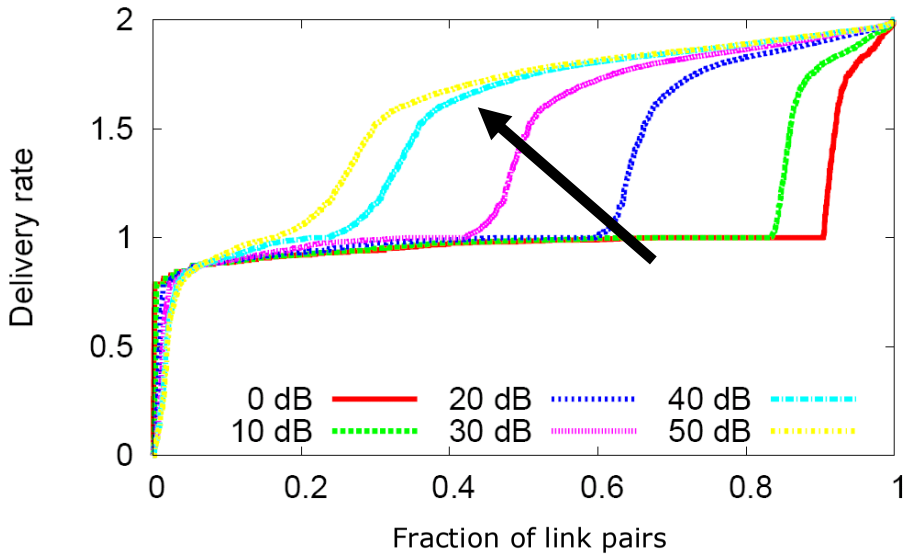


- Higher SINR sender received reliably because SIC includes resynchronization; otherwise half the time by conventional detector

- Lower SINR sender recovered by SIC most of the time; nearly always lost by conventional detector

Extrapolated network behavior with CSMA (two competing links)





- Conventional receiver sees many worse links and few better links with more spatial reuse (CS threshold).

- SIC receiver sees many better links and few worse links with more spatial reuse (CS threshold).

Conclusions

Successive Interference Cancellation (SIC) can improve the use of spectrum by simplifying the wireless LAN scheduling problem

- Improves performance, adds robustness to CSMA/CA

Early stage, simple experiments on software-defined radio platforms show this benefit.

- Assessing feasibility of extending into 802.11n NICs

Thank you!