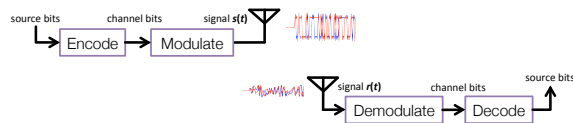


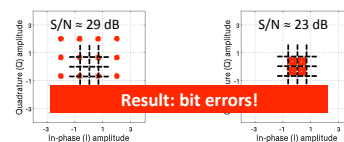
Agenda

- Recap: simple fading channel model
- Successive interference cancellation** [Halperin, Anderson, Wetherall, MobiCom '08]

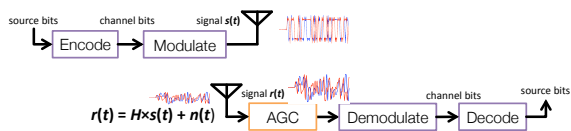
Review: simple fading channel model



Simple fading channel model: $r(t) = H \times s(t) + n(t)$, (H real)

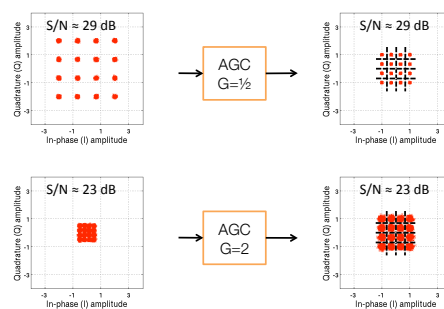


Our revised receiver for the fading channel



AGC output = Gain $G \times$ input = $1/H \times$ input
SNR stays the same

Automatic gain control example



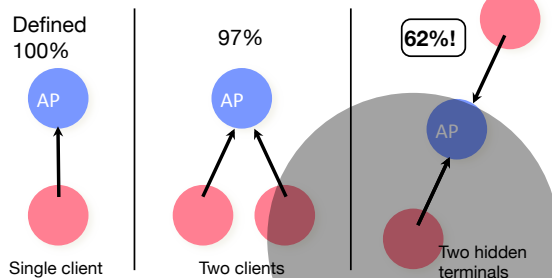
Agenda

- Recap: simple fading channel model
- Successive interference cancellation** [Halperin, Anderson, Wetherall, MobiCom '08]

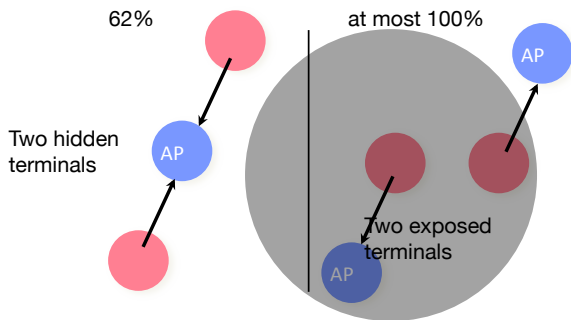
[Slides: parts adapted from D. Halperin, MobiCom '08]

Carrier sense doesn't avoid collisions

Measure goodput during TCP file transfer [Sheth '06]



Carrier sense prevents spatial reuse



Interference cancellation (IC)

- Turn off carrier sense!
- Increases capacity in multiuser networks
- Context matters:
 - **Cellular networks**: centralized control over hardware, power, rate; synchronized transmitters
 - **WiFi-like networks** are **chaotic** – bursty, unmanaged, unlicensed

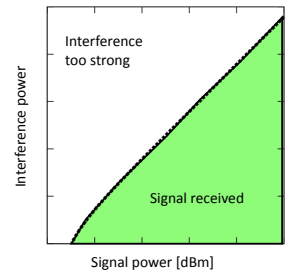
Paper contributions

- **Adapt IC for wireless LANs**
- Prototype **implementation** and experimental evaluation in an 11 node ZigBee software radio testbed
 - Cancel 30 dB from interfering signal
- In our testbed, cancellation **reduces** hidden terminal **loss** from 14% to 7% and **increases** median **delivery** by 1.8x

The SINR model

Signal
Noise + \sum Interference

- When relative power of desired signal is large enough, signal received
- Line shows threshold between **reliable** and **lossy** links



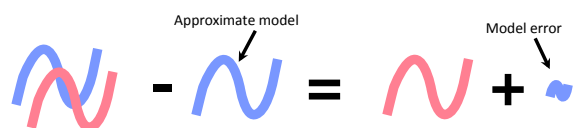
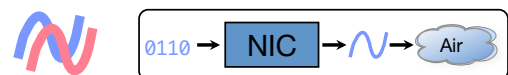
The SINR model is overly simplistic

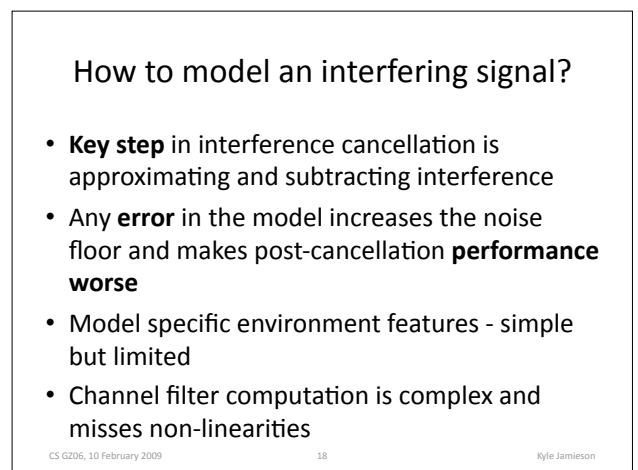
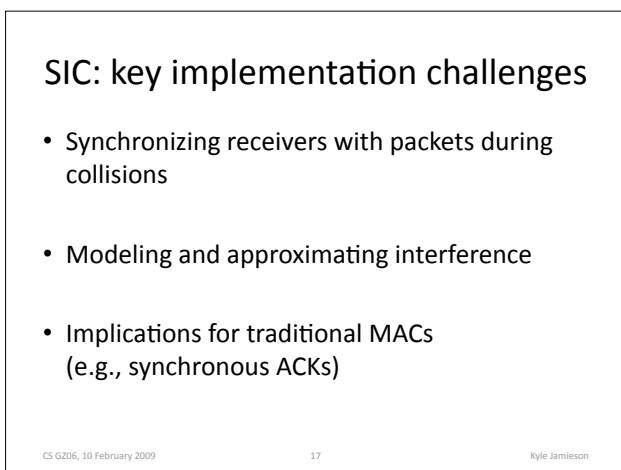
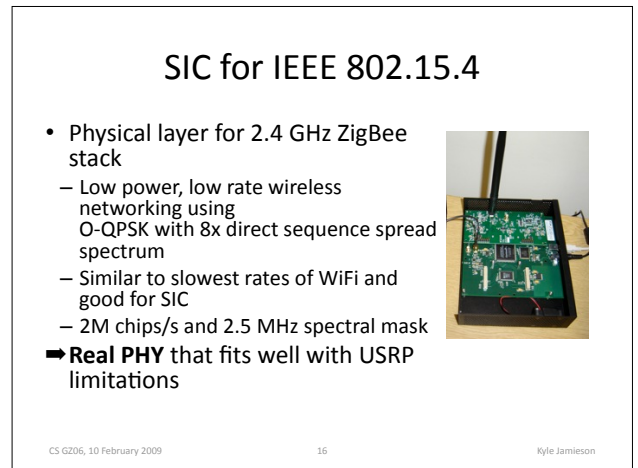
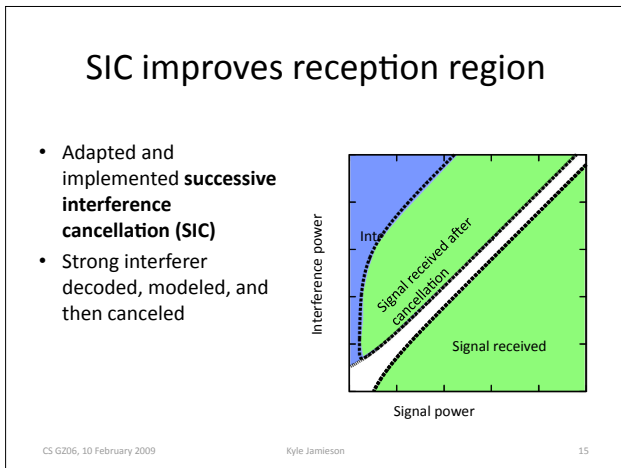
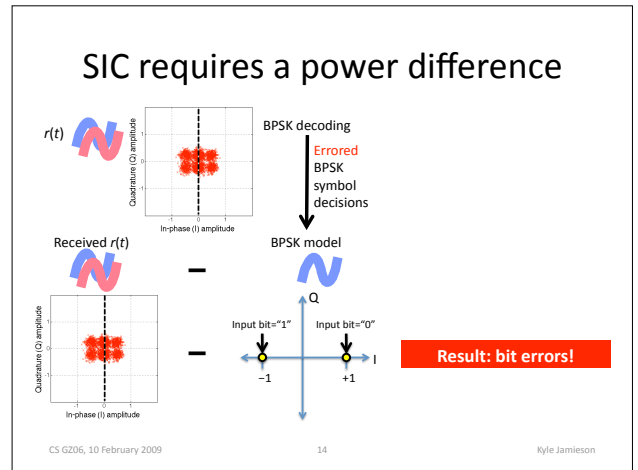
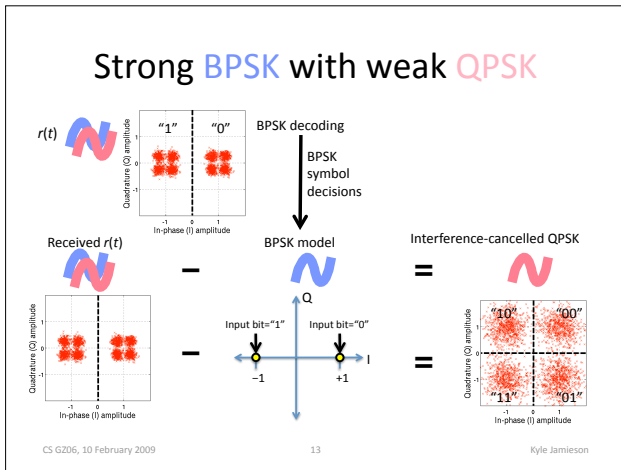
- SINR treats interference and noise as **equally** detrimental
- Noise is **random**, but interference has **structure** intended to communicate data

Key point: exploit structure of interference to overcome its effects

How successive IC (SIC) works

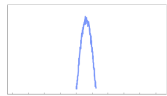
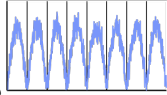
$$\text{Received} = \text{Noise} + \sum \text{Distorted Signals}$$





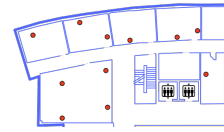
Data-dependent models by averaging

- Symbols blended in time by filters and channel; received at time i depends on $\dots, i-1, i, i+1, \dots$
- Build an RF template for each bit pattern by averaging received waveforms
- Uncorrelated noise, interference will average out
- We use 3 consecutive symbols (6 bits; 64 models)



Experimental setup

- Deployed an 11-node wireless testbed at UW
- Non-LOS, co-channel WiFi APs, varying environment
- Connectivity between nodes ranges from perfect communication to completely hidden

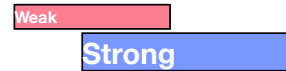


Experimental methodology

- Implemented three ZigBee receivers
 - Two conventional single-packet receivers
 - Successive interference cancellation
- Generate random two-packet collisions for all pairs of senders while logging digitized, raw RF at other 9 nodes
- Replay logs to each receiver to allow direct comparison

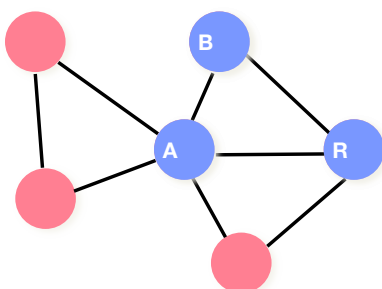
Baseline receiver implementation

- By locking onto one transmission, **conventional receiver** misses a second, stronger packet:



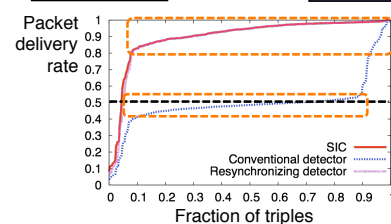
- **Resynchronizing receiver** abandons weaker for stronger
- Observed commercial hardware of both types
- We compare SIC against both

Experiment analysis

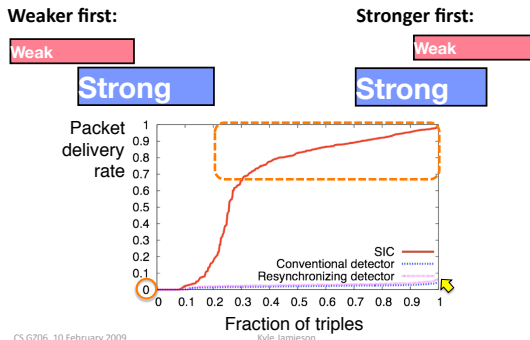


For the stronger transmitter (lower loss link)

Weaker first: Stronger first:



SIC wins big for the weaker transmitter



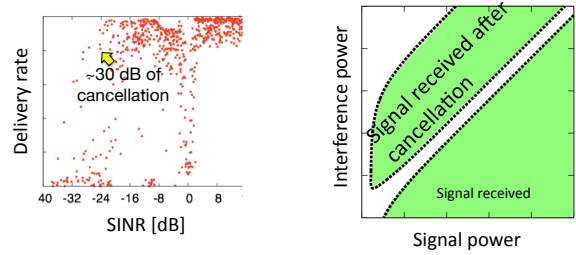
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Delivery vs SINR (interference cancellation)

$$\text{SINR [dB]} \approx \text{Signal power [dB]} - \text{Interference power [dB]}$$

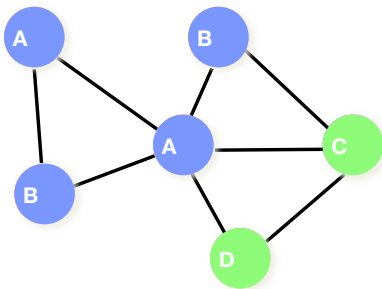


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Experiment analysis

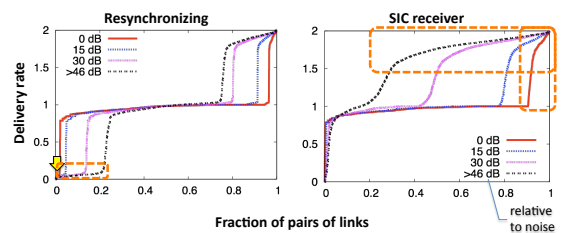


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Performance varying carrier sense



- Sensitive CS (red): SIC **reduces** hidden terminal loss
- CS off (black): SIC increases **spatial reuse**

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Caveats

- Prototype, evaluation limited by platform
 - Real-time MAC prevented by long processing time and large communication latency; unable to implement full network stack
- Can't always cancel, worse for higher rates
 - But, existing work shows opportunities for capture and spatial reuse in WiFi

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Conclusions and future work

- Our data-dependent averaging method is effective: reduces power of interfering signal by **~30 dB**
- We found successive interference cancellation is **practical and performs well** in our ZigBee testbed
 - Reduces hidden terminal loss from 14% to 7% and increases delivery during collisions by 1.8x
- Cancellation is part of a **broader solution**
 - Here, SIC allows us to vary carrier sense threshold; also enhances techniques like CMAP [Vutukuru '08]

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