

Experimenting with a Multi-Radio Mesh Networking Testbed

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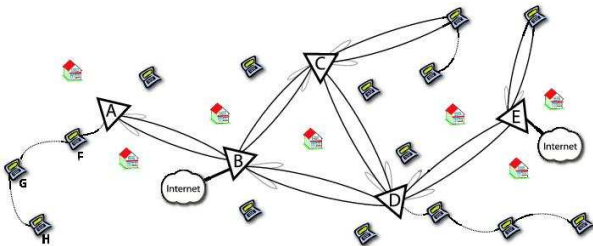
²Intel Research Cambridge

³Intel Research

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Mesh Networking Background

- Create a multi-hop wireless backbone with limited wired gateways
- **Objectives:** high bandwidth, high availability, cheap deployment
- Use multiple radios



Related Work - Mesh Networking Testbeds

- Roofnet (MIT)
 - One radio
 - Link-layer measurements
- Technology for All (Houston)
 - One radio, community mesh network
- Microsoft Research
 - Two radios (a/g)
 - Studied routing
- Hyacinth (Stony Brook)
 - Two radios, 802.11a
 - Channel assignment study

Take a Step Back

- Usual method:
 - Choose AP platform
 - Discover poor performance
 - Propose MAC/Routing/TCP modifications
- We focus on the design of the access point
- Highlight challenges that simulation will not predict

Design Factors

- Off-the-shelf hardware
- Number of radios
- Antenna separation
- Channel selection

Our goal is to measure and quantify the impact of these factors

Experimental Setup

- Dell PCs with 4 PCI slots
- Linux, kernel 2.4.26
- Netgear MA311 PCI cards (802.11b)
- HostAP driver, version 0.1.3



Experimental Parameters

- Simulation
 - NS-2, version 2.27
 - No channel fading model
 - Does not simulate multiple interfaces or RF channels
- Hardware
 - Nodes 20m apart
 - Forced multi-hopping
 - All data transmitted at 11Mbps
 - 5 trials, 10 seconds each
 - All other APs turned off
- Always backlogged UDP flows

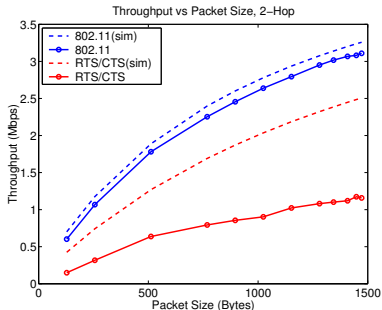
Multi-hop

- Begin with simplest scenario
- 3 node chain
- One interface active on each node
- One shared channel (11)
- Expect approx. half the throughput of single-hop

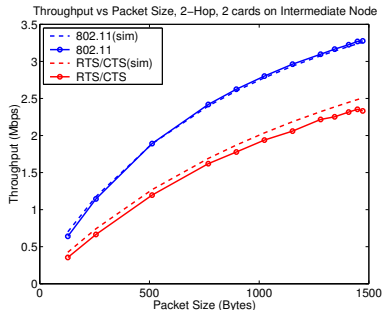


Multi-hop Results

- RTS/CTS performs poorly with only one interface active
- Two interfaces on the same channel helps
 - one only receives, the other only sends



One interface active



RX/TX split into two interfaces

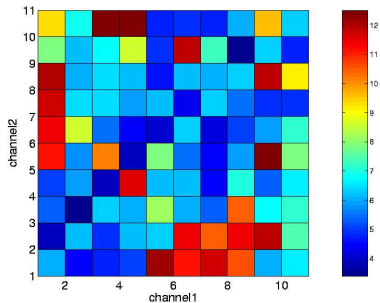
Analysis of 2-hop Performance

- Low throughput due to long periods of idle time
- Simulation inaccurate?
 - Very simple scenario
 - Agrees with intuition
- Hardware problem?
 - Not individual card failure
 - Results different if TX/RX functions performed on separate cards
- Next Steps
 - Try other wireless cards (Cisco, Orinoco, etc.)
 - Need to see why card delays transmission

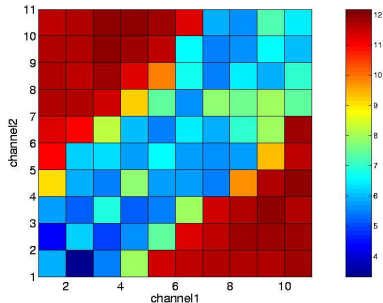
Are there really three orthogonal channels in 802.11b?

- Two cards in one node, both transmitting
- Vary the channel separation between cards
- Expected aggregate throughput:
 - Same channel, same as baseline
 - 1-4 channel separation, lower than baseline
 - 5-10 channel separation, twice baseline

Channel Separation Results



Standard antenna configuration



Antenna separation > 35 dB

Channel Separation Hypothesis

- One card introduces large amounts of noise at the other card
- Carrier sense test more likely to trigger delay
- Noise comes from?
 - Transmitted energy overflowing 22MHz band width
 - Too much energy in RF chain causing distortions

Conclusions

- Physical constraints limit access point design
- Antenna separation crucial for multi-radio systems
- Need transparent MAC to troubleshoot issues
- Not easy to build off-the-shelf access points with multiple radios

Open Issues and Current Projects

- Custom hardware solutions required?
- TFA Wireless
 - Commodity hardware
 - Some nodes with multiple radios
- TAPs (Transit Access Points)
 - Custom architecture designed at Rice
 - Three MIMO air interfaces per node