Experimental Investigation of PHY Layer Rate Control and Frequency Selection in 802.11-based Ad-Hoc Networks

Zhibin Wu, Sachin Ganu, Ivan Seskar
Dipankar Raychaudhuri

WINLAB, Rutgers University
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Motivation

- **802.11-based Ad-hoc Network**
  - Wireless Mesh network
    - Multi-hop flow for individual transfer
  - Performance
    - Network capacity
    - End-to-end throughput

*Courtesy: Microsoft*
Cross-layer Design

- Tight coupling effects among PHY, MAC and Routing
- Two-tier approach
  - Incorporate PHY/MAC parameters into routing metric
  - Adaptive control of PHY/MAC components to meet the end-to-end performance demands
- Investigate the PHY Design Potentials of 2\textsuperscript{nd} tier
PHY Design Components

- **Frequency/Band**
  - Orthogonal **802.11b/g** (2.4GHz) channels: 3
    - Channel number: 1, 6, 11
  - Orthogonal **802.11a** (5GHz) channels: 12
    - Channel number: 36 40 44 48 52 56 60 64 149 153 157 161

- **Rate Settings (raw channel rate)**
  - **802.11b/g** rates: 1, 2, 5.5, 11Mbps
  - **802.11a/g** rates: 6, 9, 12, 18, 24, 36, 48, 54Mbps

- Existing a large design space
ORBIT Testbed

- 8 X 8 grid (64 radio nodes)
  - Each node has two 802.11 radios
  - Space between neighboring nodes: 3 feet
- Four AWGN noise injection antennas
Emulating Different Link Quality

- Varying link quality by adjusting the AWGN noise power
- PER measurement experiment
  - 2 minute test duration
  - Fixed 24Mbps channel rate.
  - Packet size is 512 Bytes
Experiment 1: Baseline Scenario

- Four-node, three-hop CBR flow.
- All radios working in the same channel
- Inject noise at channel 48 to vary link quality
- Measure end-to-end throughput
- Use default auto-rate adaptation algorithm
Experiment 2: Frequency Selection

- Place three links in orthogonal channels
- Injected noise affecting only 2nd Hop
IEEE 802.11 Rate Adaptation

- Unspecified by IEEE 802.11
- Simple Rate Adaptation schemes are used by chip manufacturers
- Test
  - Simple 1-to-1 topology.
  - Show channel rate variation in time
  - Long-term rate stability?

Test 1: -16dBm noise
Test 2: -12dBm noise
Experiment 3: Rate Control

- Noise level is fixed at -6dBm in Channel 48
- Auto Rate vs. Fix Rate
- Auto-rate schemes performs worse than some fixed-rate settings

With fixed rate settings

Ch. 36  Ch. 48  Ch. 64

Rate setting combo: (r₁, r₂, r₃)

Maximum Throughput achieved for different rate settings

Auto Rate: (6, 6, 6) (12, 12, 12) (18, 18, 18) (24, 24, 24) (36, 36, 36) (48, 48, 48) (54, 54, 54)
Cross-layer PHY Control Framework

- Control Overlay
  - Configurable PHY components
  - Optimization algorithm
  - Control signaling

- How to optimize
  - Determine optimization goal
    - High rate with 10% loss or low rate with 1% loss?
  - Collect measurements
    - From neighbors and itself
    - From PHY, MAC and application-level statistics
    - Probe
  - Choose Best Setting

Desirable performance goal
Measurement feedback
Conclusion & Future Work

- Experiments show promising performance gain
  - 4x improvement with orthogonal channel configuration
  - 3x Improvement with explicit rate control

- Cross-layer design proposal
  - General framework for dynamic channel assignment and rate control

- Future work
  - A more comprehensive and detail solution
    - Control algorithm to combine rate control & channel allocation
    - System-level evaluation
  - Another PHY design component: transmit power
Related Work

- **Cross-layer Design**

- **IEEE 802.11 Rate Adaptation**
  - M. Lacage, M. H. Manshaei, and T. Turletti, ”IEEE 802.11 Rate Adaptation: A Practical Approach,” MSWiM’2004

- **Emulate Ad-hoc Network in ORBIT Testbed**