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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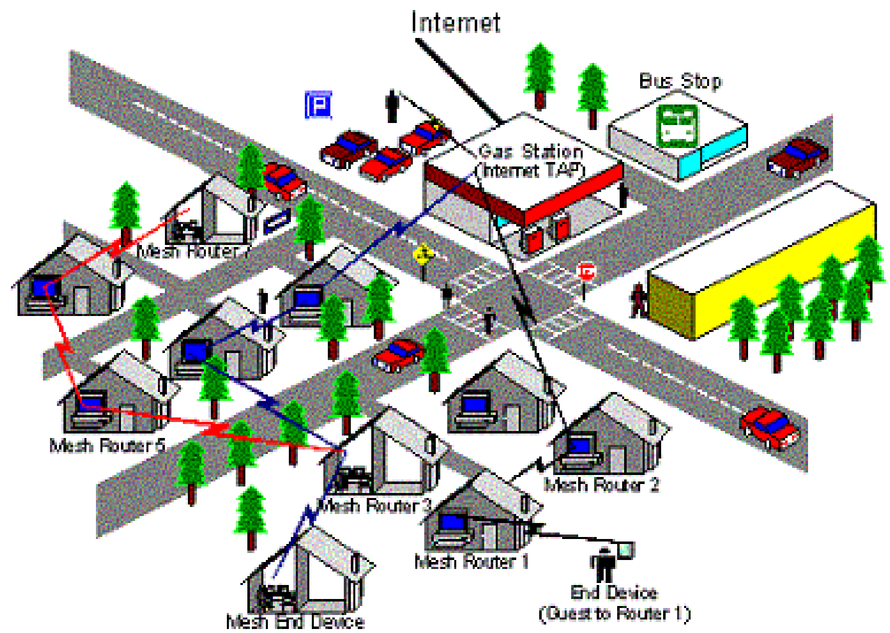
Motivation

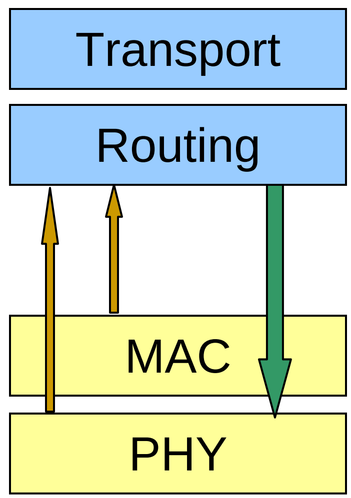
- 802.11-based Ad-hoc Network
  - Wireless Mesh network
    - Multi-hop flow for individual transfer
  - Performance
    - Network capacity
    - End-to-end throughput



Courtesy: Microsoft

Cross-layer Design

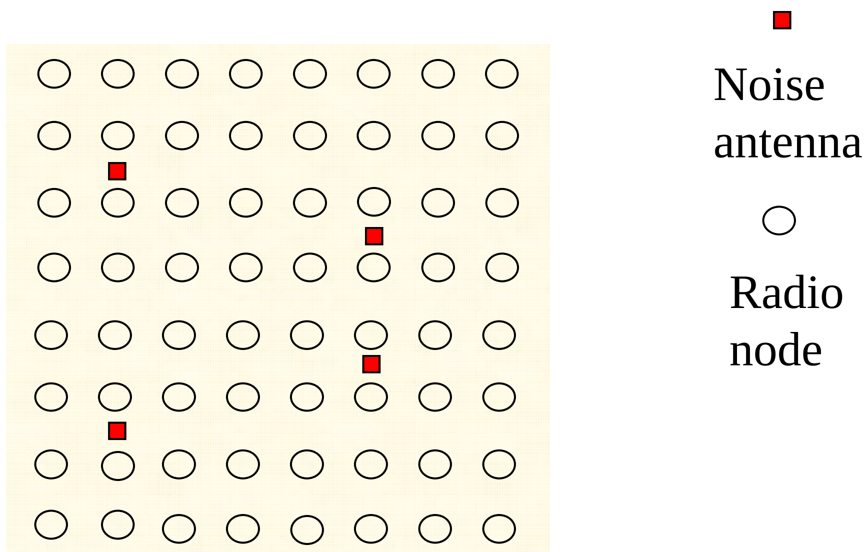
- Tight coupling effects among PHY,MAC and Routing
- Two-tier approach
  - Incorporate PHY/MAC parameters into routing metric
  - Adaptive control of PHY/MAC components to meet the end-to-end performance demands
- Investigate the PHY Design Potentials of 2nd tier



PHY Design Components

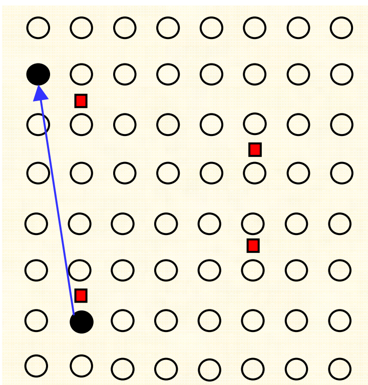
- Frequency/Band
  - Orthogonal *802.11b/g* (2.4GHz) channels: *3*
    - Channel number: 1, 6, 11
  - Orthogonal *802.11a* (5GHz) channels: *12*
    - Channel number: 36 40 44 48 52 56 60 64 149 153 157 161
- Rate Settings (raw channel rate)
  - *802.11b/g* rates: 1, 2, 5.5, 11Mbps
  - *802.11a/g* rates: 6, 9, 12, 18, 24, 36, 48, 54Mbps
- Existing a large design space

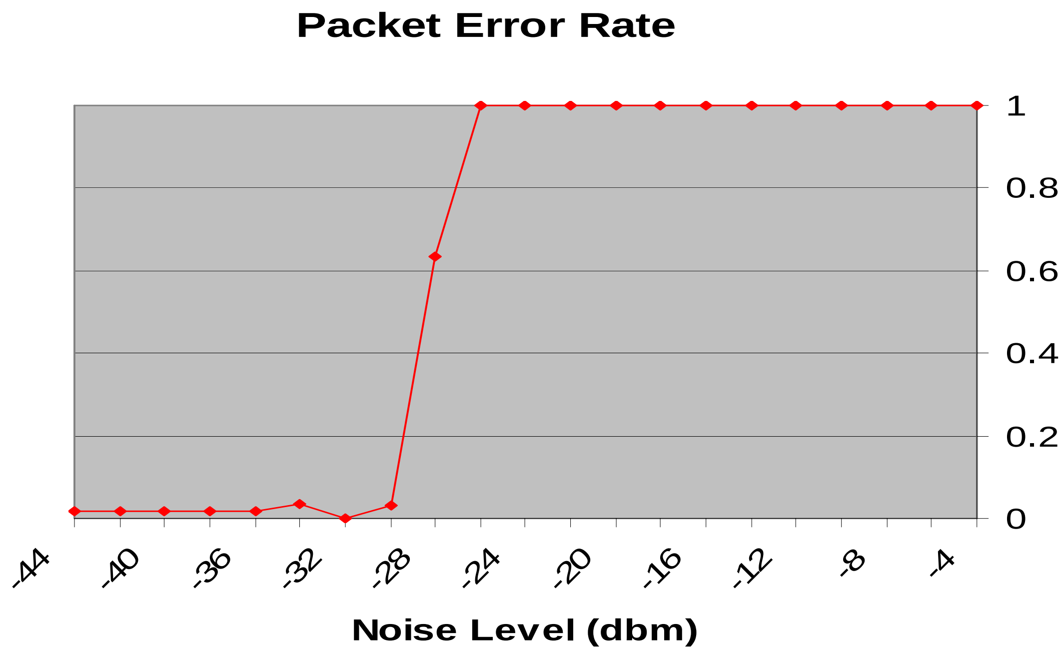
ORBIT Testbed



- 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

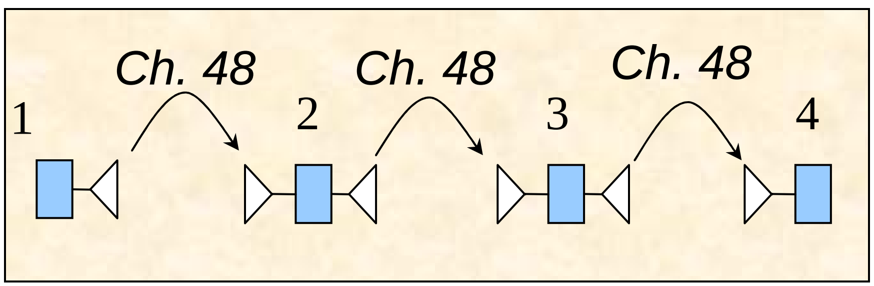


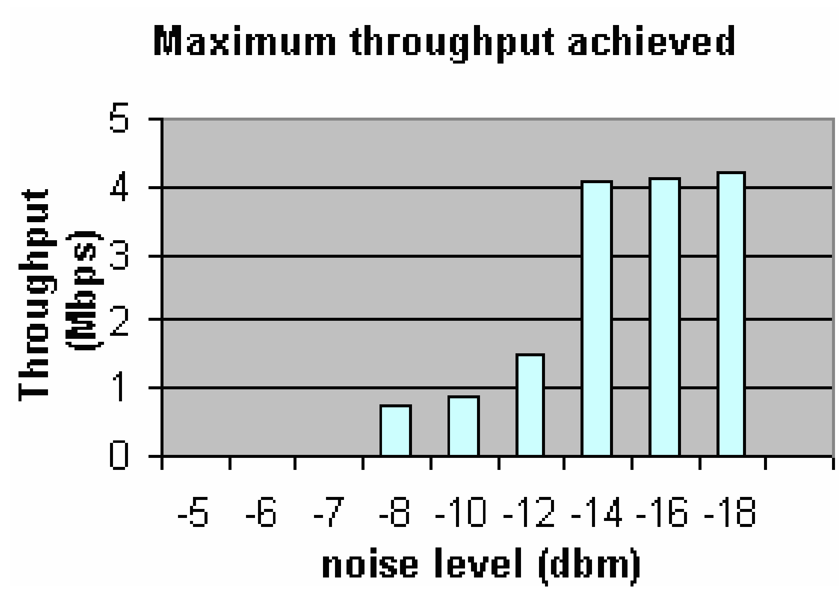


- Varying link quality by adjusting the AWGN noise power
- PER measurement experiment
  - 2 minute test duration
  - Fixed 24Mbps channel rate.
  - Packet size is 512 Bytes

Experiment 1: Baseline Scenario

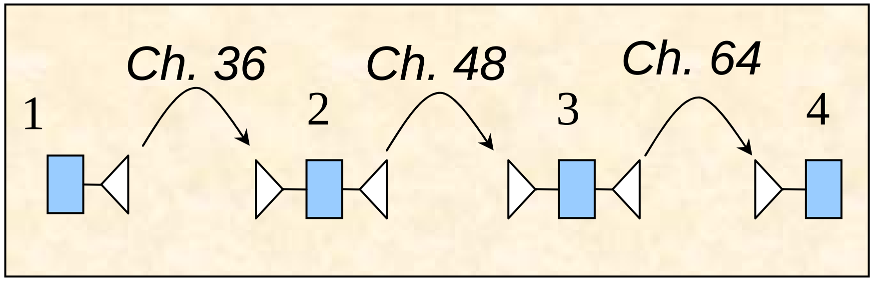
- Four-node, three-hop CBR flow.
- All radios working in the same channel
- Inject noise at channel 48 to vary link quality
- Measure end-to-end throughput
- Use default auto-rate adaptation algorithm

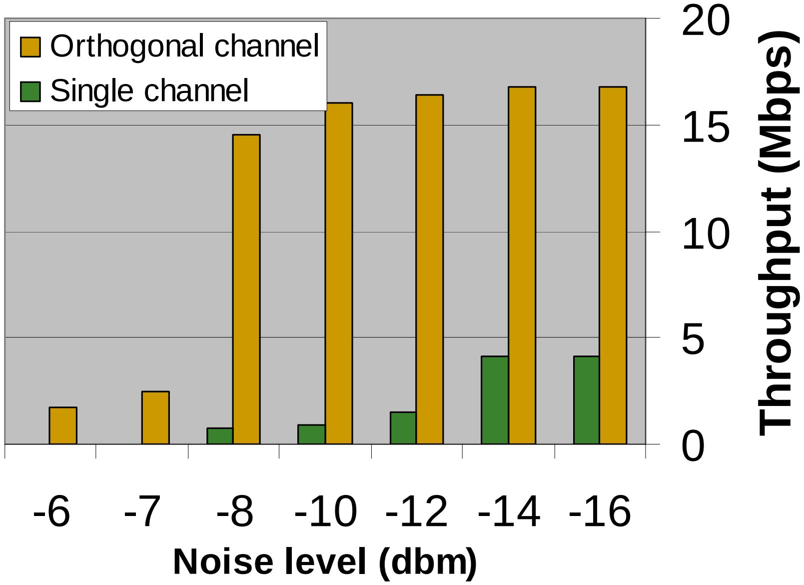




Experiment 2: Frequency Selection

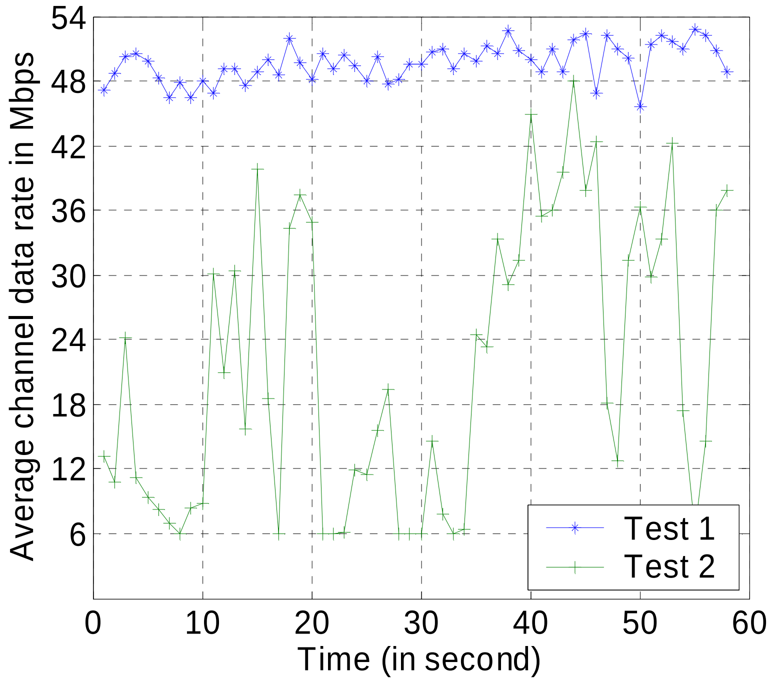
- Place three links in orthogonal channels
- Injected noise affecting only 2nd Hop





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?



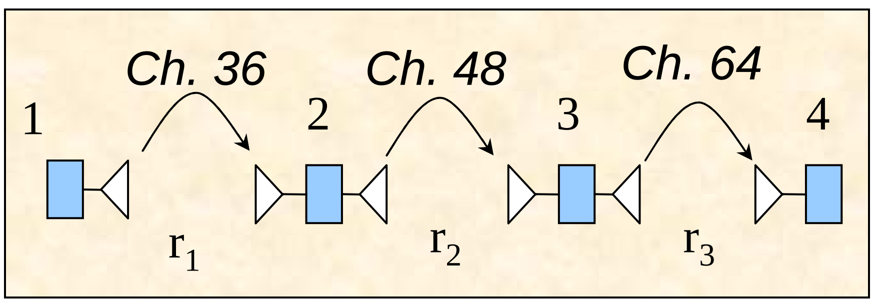
Test 1: -16dBm noise

Test 2: -12dBm noise

Experiment 3: Rate Control

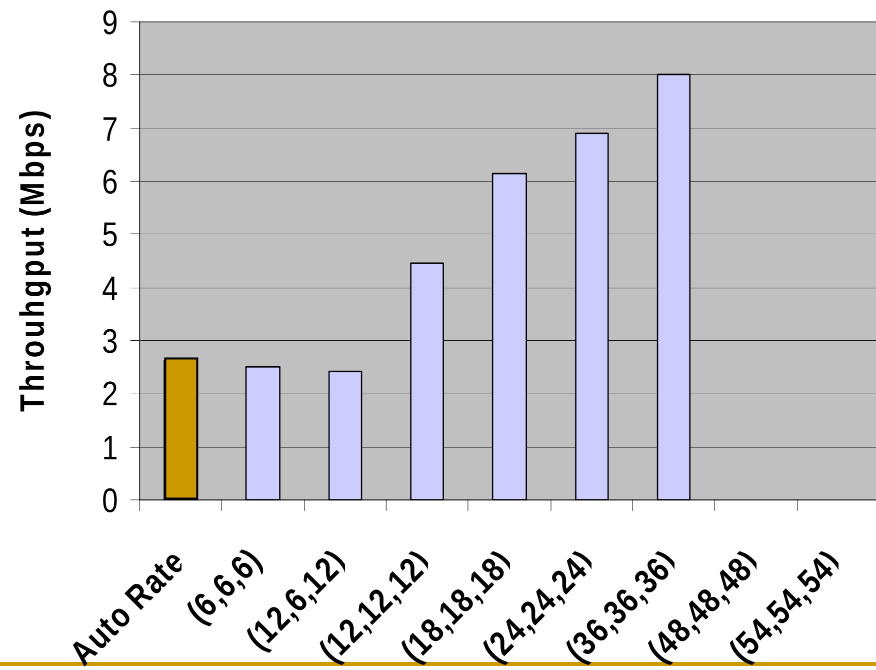
- Noise level is fixed at -6dBm in Channel 48
- Auto Rate .vs. Fix Rate
- Auto-rate schemes performs worse than some fixed-rate settings

With fixed rate settings



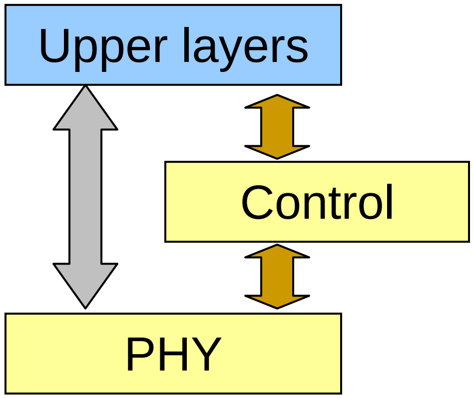
Rate setting combo: (r_1, r_2, r_3)

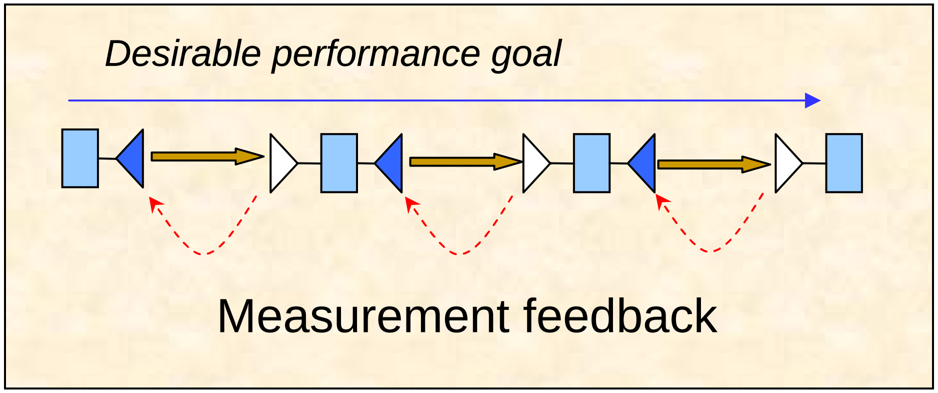
Maximum Throughput achieved for different rate settings



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





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**
  - R. Draves, J. Padhye, and B. Zill, “Routing in multi-radio, Multi-hop Wireless Mesh Networks”, ACM MobiCom 2004
  - S. Zhao, et al. “PARMA: A PHY/MAC Aware Routing Metric for Ad-Hoc Wireless Networks with Multi-Rate Radios”, WoWMoM’05
  - A. Raniwala and T. Chiueh, “Architecture and Algorithms for an IEEE 802.11-based Multi-channel Wireless Mesh Network”, IEEE Infocom,2005
- **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**
  - J. Lei, R. Yates, L. Greenstein, H. Liu, "Wireless Link SNR Mapping Onto An Indoor Testbed", *IEEE Tridentcom 2005*