ORBIT Radio Grid Emulator
Modeling & Scenario Creation

Roy Yates
Some ORBIT Project Objectives

- **Realistic Experiments**
  - Real radios transmitting bits over the air
  - Real network nodes with full protocol stacks

- **Repeatable Experiments**
  - Requires repeatable wireless network topologies
  - ORBIT Approach: Radio Grid Testbed
ORBIT Radio Grid

n nodes

Management plane Ethernet switch

Data plane Ethernet switch

Virtual Mobiles: Mobile Nodes / Mobility Controllers

Open Interface Mobile Node

Testbed Controller

Configuration Cluster

Spectrum Measurement

Interference Sources

Virtual Mobiles:

- MN1/MC1
- MN2/MC2
- MN3/MC3
- MCL/MNL

m nodes
ORBIT Radio Grid

The 400 node question:
What network topologies are possible?
Sample Grid

- N x M Grid of Nodes
- Choose
  - a set of communicators
  - a set of noise interferers
  - node transmit powers
- Determine acceptable quality links
  - Based on receiver SNR > threshold
  - One at a time transmissions
- Graph the “topology” of acceptable links
Sample network (1)

- ● = Communicator
- ■ = Interferer
- _ = Acceptable Link
Pictures are pretty, but ...

- Are they representative of any actual wireless networks?
- What are the constraints on modeling networks on the grid?
Building a K Communicator Topology

- K communicators ⇒
  - K-1 link SNRs for each transmitter
  - N-K interference sources
  - K-1 equations, N-K free variables

- Solution possible for K<N/2, if
  - Transmit Powers are continuously variable
  - Interferers are programmed for each communicator
    - If interferer powers held constant:
      - K(K-1) equations, N-K free variables
      - Solution possible if N \geq K^2
  - Needs low level control of card (eg CSMA off)
External Programmable Interference

- 2-8 programmable interference sources
  - Provide precise control of interference, including waveform generation
  - Limited Variety of Topologies
Model Scenarios

- **Physical Scenarios**
  - sensor network, K terminals in a lecture hall, neighborhood rooftop network, open space, in an office building

- **Abstract Scenario Model**
  - Mathematical Channel Models for given environment (indoor, outdoor, LOS, NLOS etc)
    - Distance dependent losses
    - Spatially correlated shadowing

- **Grid configuration consistent with model?**
Grid Consistency

- Definition of consistency?
  - Real network instances are stochastic
  - Grid instances are intentionally repeatable

- MAC Layer Consistency
  - For each subset of active transmitters,
    - Which links are reliable?
    - Which links are above the noise floor?
  - MAC Layer consistency depends strongly on physical geometry
Separation Anxiety

- Practice: Link gains can vary by 60+ dB
- Reuse depends on relative link gains
- N \times M \text{ grid, spacing } d
- Max relative link gain is \( R = \left( N^2 + M^2 \right)^{a/2} \)
  - 20\times20 \text{ grid: } a=4, R=58 \text{ dB or } a=2, R=29 \text{ dB}
  - For fixed area \( A=NM \), \( R \) is minimized by \( M=N \)
- Spreading/Coding can be used to enhance separation
  - 1 \text{ Mb/s } 802.11\text{b} enhances separation by 10 dB
Grid Mobility

Discrete Grid Mobility

- Virtual Mobiles use radio grid nodes as transceivers via network drivers
- Virtual mobiles move by changing radio grid assignments
Discrete Grid Mobility

- As virtual mobiles move (on the grid), topology changes depend on spatial correlations of radio link gains
  - Difficult (impossible?) to precisely control radio link quality over space.
  - Characterization of the actual grid radio channel?

- P2P Mobile Infostations
  - Communication between neighbor nodes on the grid
  - Larger $R$ implies more simultaneous exchanges.
Conclusions

- Configuring the grid topology is a research problem.
- We will quickly generate a few representative scenarios
- Scenarios without significant isolation should not be very hard.