

# Rethinking Wireless Access for the All-Wireless Home

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UW-MSR Institute '09

# Wide Spread Adoption of Wi-Fi in the Home

- Wi-Fi being rapidly integrated into a everyday consumer electronic devices in the home
- Enabling a range of novel applications and services being the home



Macworld » Mac IT

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Is it time to cut the Ethernet access cable?

« [Apple Boosts 802.11n Speed to 140 Mbps \(Asterisk\)](#)

SEPTEMBER 12, 2007

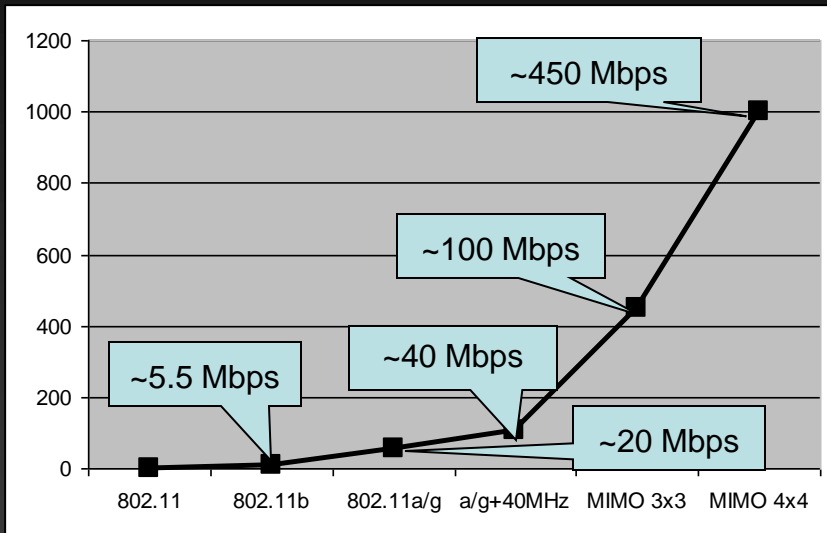
The End of Ethernet Because of N?

BY GLENN FLEISHMAN

At first, I thought this was link bait, but



# Superior Performance and Ease of Use



Network Magic



WPS Push-N-Connect



Wireless HD streaming	15 Mbps
Telepresence: Super HD (H.264, MPEG4)	50Mbps
Immersive 3D spaces	126 Mbps

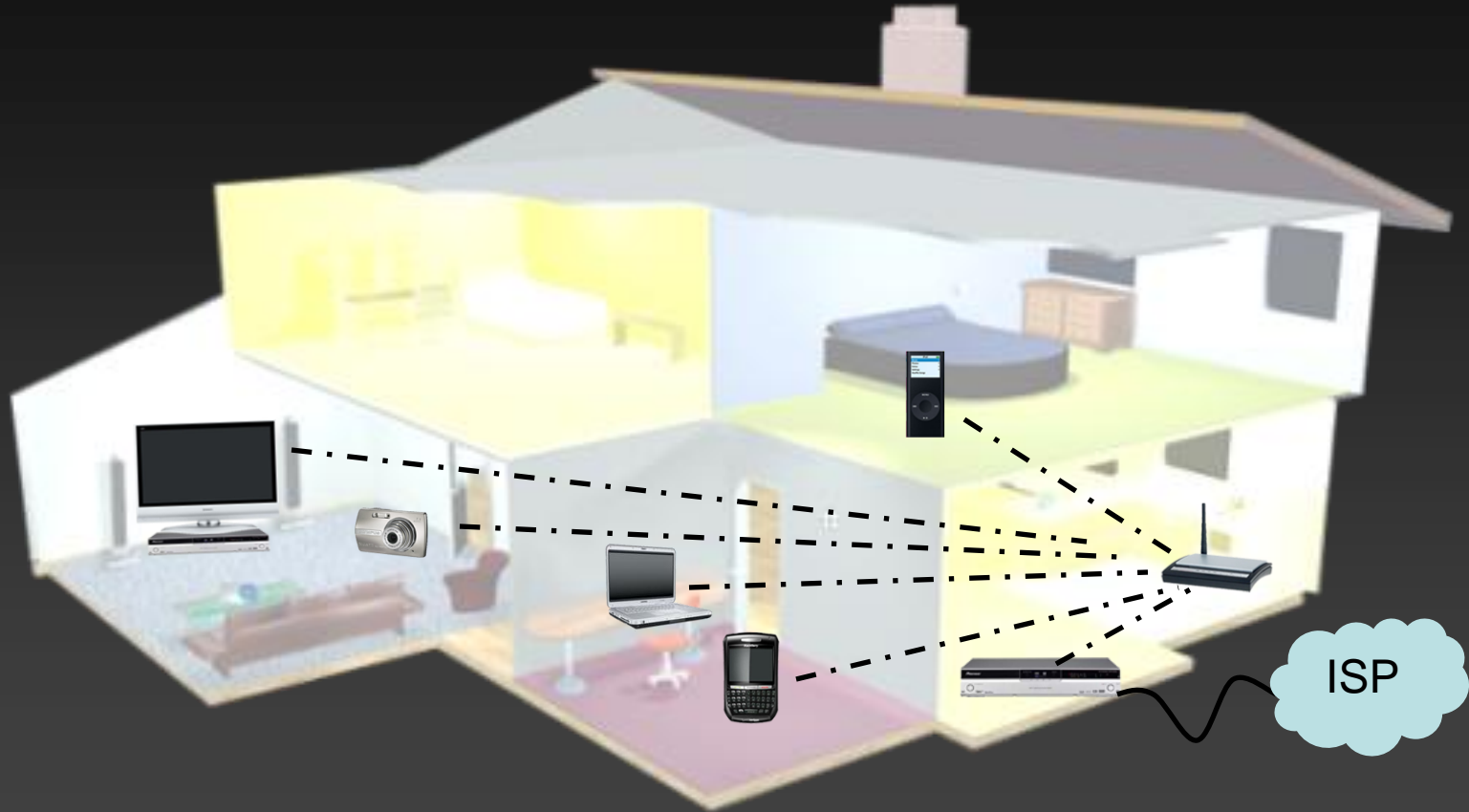


Apple's Airport Extreme

**Wi-Fi performance has crossed an inflection point**

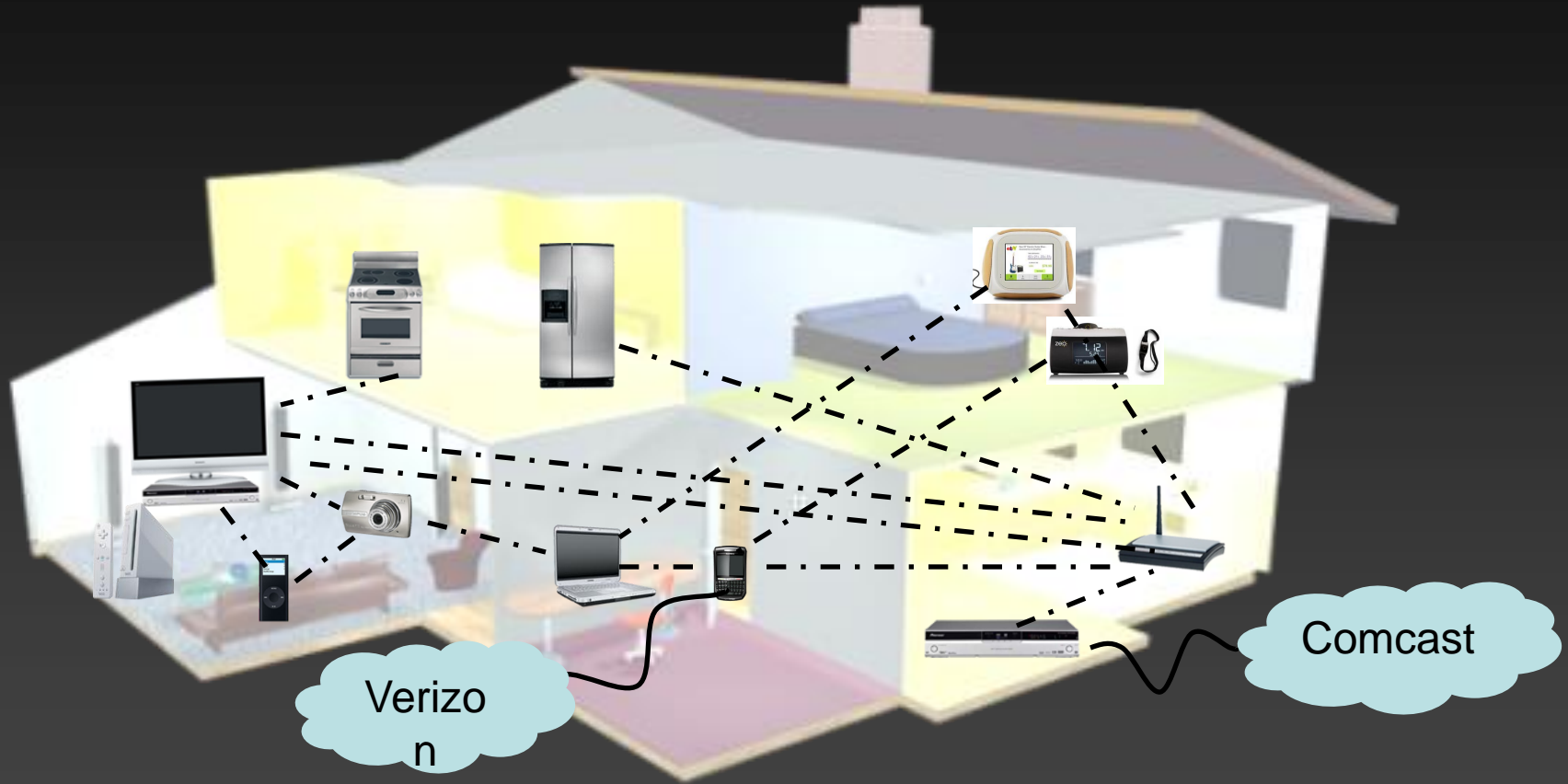
**Easier to create, manage and secure Wi-Fi networks**

# Typical Wireless Home of Today



**Sparse, medium range, low-bandwidth, noise limited and centrally controlled**

# All-Wireless Home of the Future



**Dense, short range, very high bandwidth, interference limited and not centrally managed**

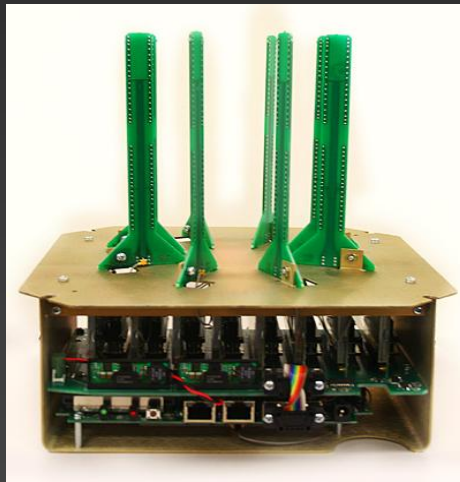
# Problems

- How do we provide users meaningful control over the Wi-Fi service areas?
  - “Provide Wi-Fi service to all devices located within my home”
  - “Provide Wi-Fi service to only the common areas of the house”
  - “Dock my laptop over wireless with the devices located on my desk”
- How do we manage interference to scale Wi-Fi performance across densely packed devices in the home?
  - Supporting simultaneous HD video streams
  - Multiple game consoles in the same area

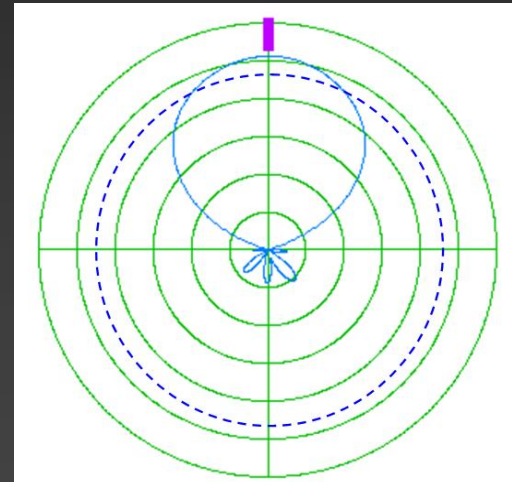
**Broadcast nature of the wireless medium makes it difficult to reason about coverage areas and interference**

# Beamforming Based Directional Antennas

- Multiple antenna based radio systems provide the ability to:
  - steer the Wi-Fi signal
  - control the signal spillage in unwanted regions



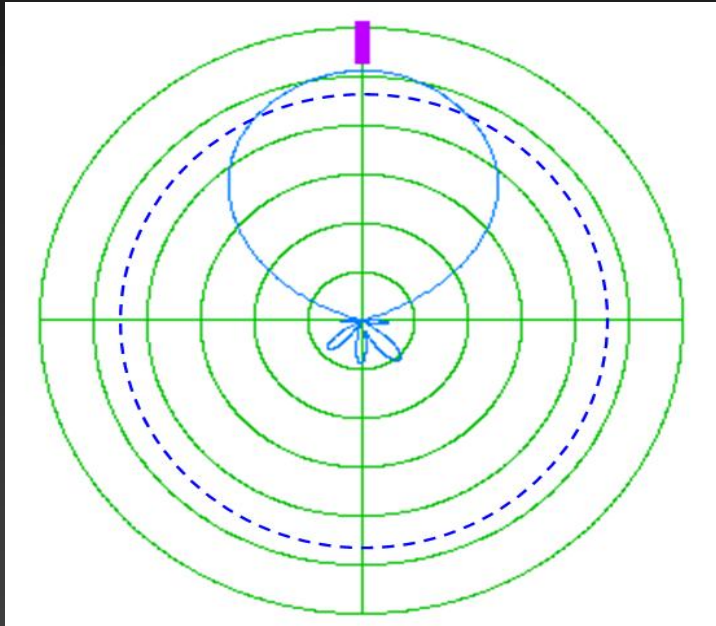
Phased-array antenna with 8 antenna elements



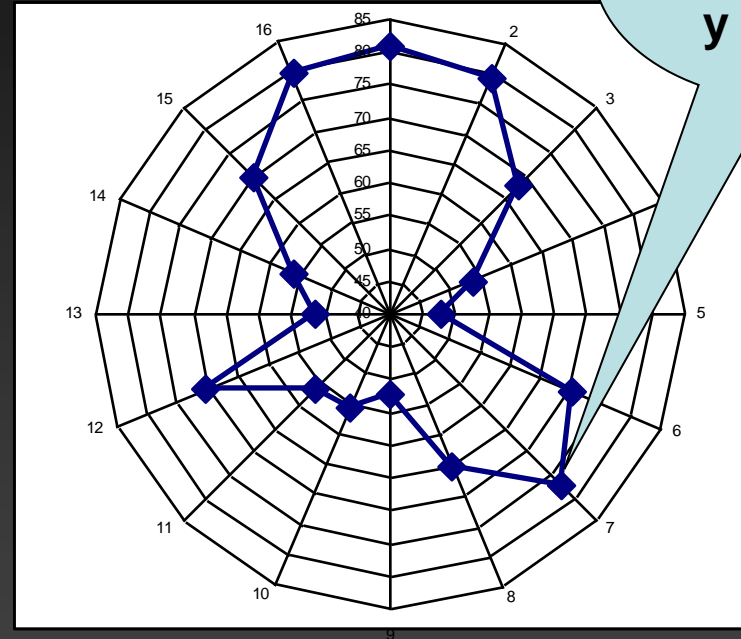
Antenna can be steered at angular displacement of 22.5 based on analog beamforming

**Are these antennas still useful in indoor environments?**

# Directional Antennas in Indoor Environments



Pattern in multipath-free environment.

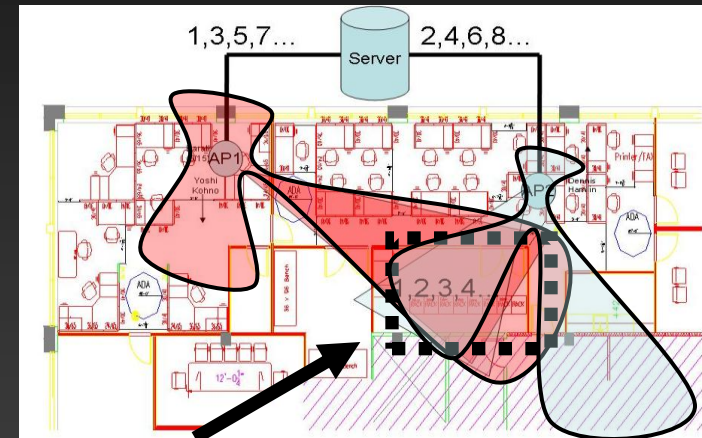


Measured pattern in a cluttered indoor environment

The irregular patterns create *secondary paths* that provide an *opportunity* to control the signal level across the devices in the home.

# Geo-fencing: Confine Wi-Fi Service Areas to Meaningful Physical Boundaries

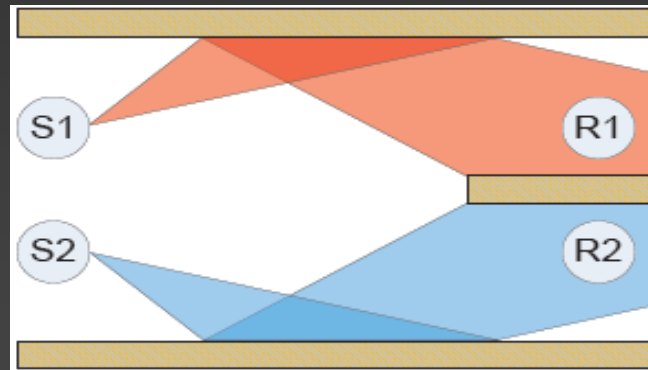
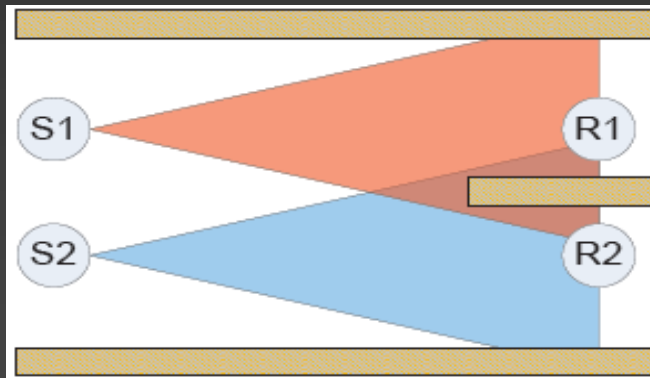
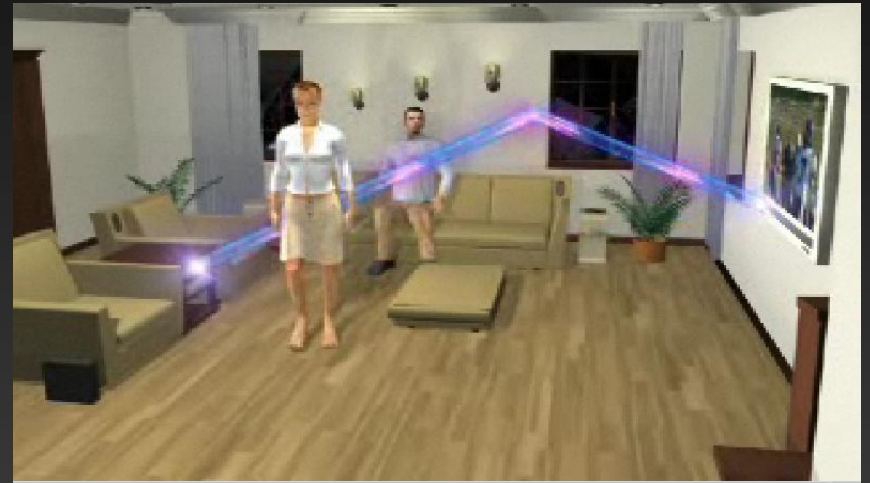
- Create controlled overlap between multiple directional antenna patterns
- Tie connectivity to the intersection of these overlapping patterns



Wi-Fi service  
confined to target  
region

**Simplifies access control and Strengthens privacy**

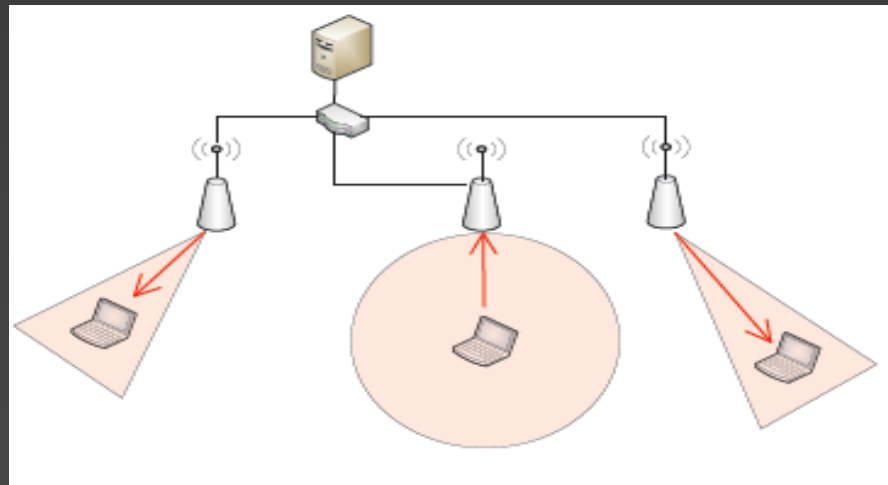
# Mitigating Wi-Fi Interference by Leveraging Spatial Reuse



**Scaling wireless capacity by the spatial reuse of “disjoint” secondary RF paths.**

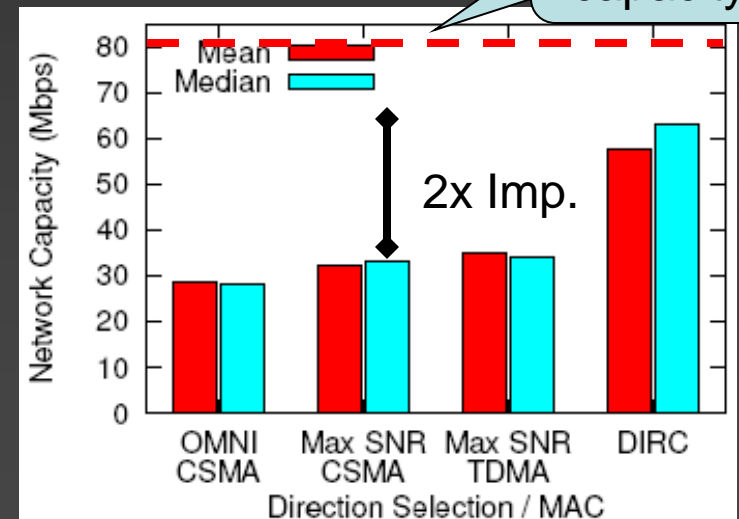
# Discovering and Using Alternate Spatial Paths

- Assumptions:
  - Rely on measurement based feedback from the distributed devices in the home.
  - A centralized controller to coordinate the distributed devices in the home.
- Challenges
  - Heuristics for orienting the antenna
  - Minimizing the search space
  - Dealing with mobility and changes in the environment



# Initial Results

- Geo-fencing [Pervasive '09]
  - Able to selectively provide service between adjacent nodes located ~ 5 ft. away from each other.
  - Able to form regions of varying shapes and sizes (single office desk to a large room sized region)
- Mitigating Wi-Fi Interference [Sigcomm '09]
  - Record signal strength across distributed devices.
  - Encode interfering antenna orientations in a conflict map
  - Schedule concurrent transmissions across interference-free antenna orientations
  - 100% improvement for UDP and ~45% for bidirectional TCP.



# Conclusion

- Broadcast nature of the wireless medium makes it hard to reason about the extent of wireless coverage areas
- Multiple antenna based radio systems provide significant control over wireless coverage areas
  - Enable users to control the Wi-Fi service areas to meaningful physical boundaries
  - Provide rich experiences by scaling wireless performance
- Early stage, simple experiments are promising
  - Assessing feasibility of using 802.11n MIMO based digital beamforming.

Thank you!!

Questions?