Self Management in Chaotic Wireless Networks

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Wireless Proliferation

- Sharp increase in deployment
  - Airports, malls, coffee shops, homes…
  - 4.5 million APs sold in 3rd quarter of 2004!
- Past dense deployments were planned campus-style deployments

Chaotic Wireless Networks

- Unplanned:
  - Independent users set up APs
  - Spontaneous
  - Variable densities
  - Other wireless devices
- Unmanaged:
  - Configuring is a pain
  - ESSID, channel, placement, power
  - Use default configuration

→ "Chaotic" Deployments

Implications of Dense Chaotic Networks

- Benefits
  - Great for ubiquitous connectivity, new applications
- Challenges
  - Serious contention
  - Poor performance
  - Access control, security

Outline

- Quantify deployment densities and other characteristics
- Impact on end-user performance
- Initial work on mitigating negative effects
- Conclusion

Characterizing Current Deployments

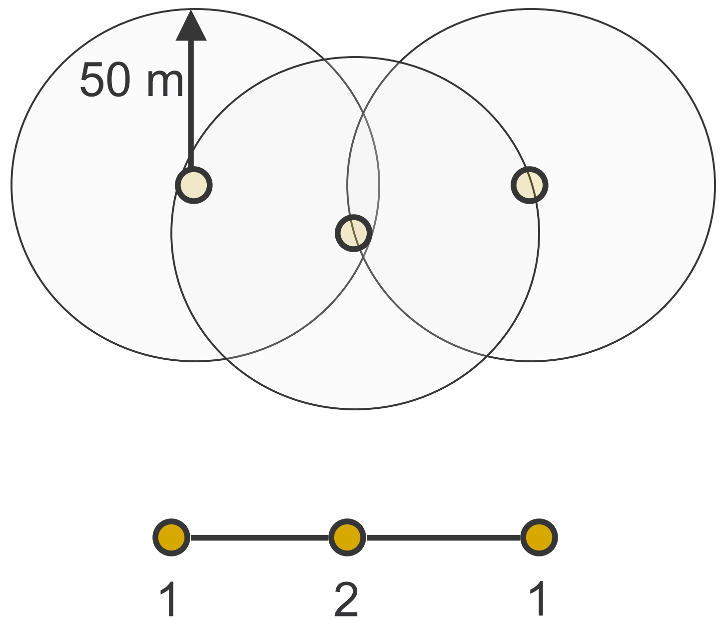
Datasets

- Place Lab: 28,000 APs
  - MAC, ESSID, GPS
  - Selected US cities
  - www.placelab.org
- Wifimaps: 300,000 APs
  - MAC, ESSID, Channel, GPS (derived)
  - wifimaps.com
- Pittsburgh Wardrive: 667 APs
  - MAC, ESSID, Channel, Supported Rates, GPS

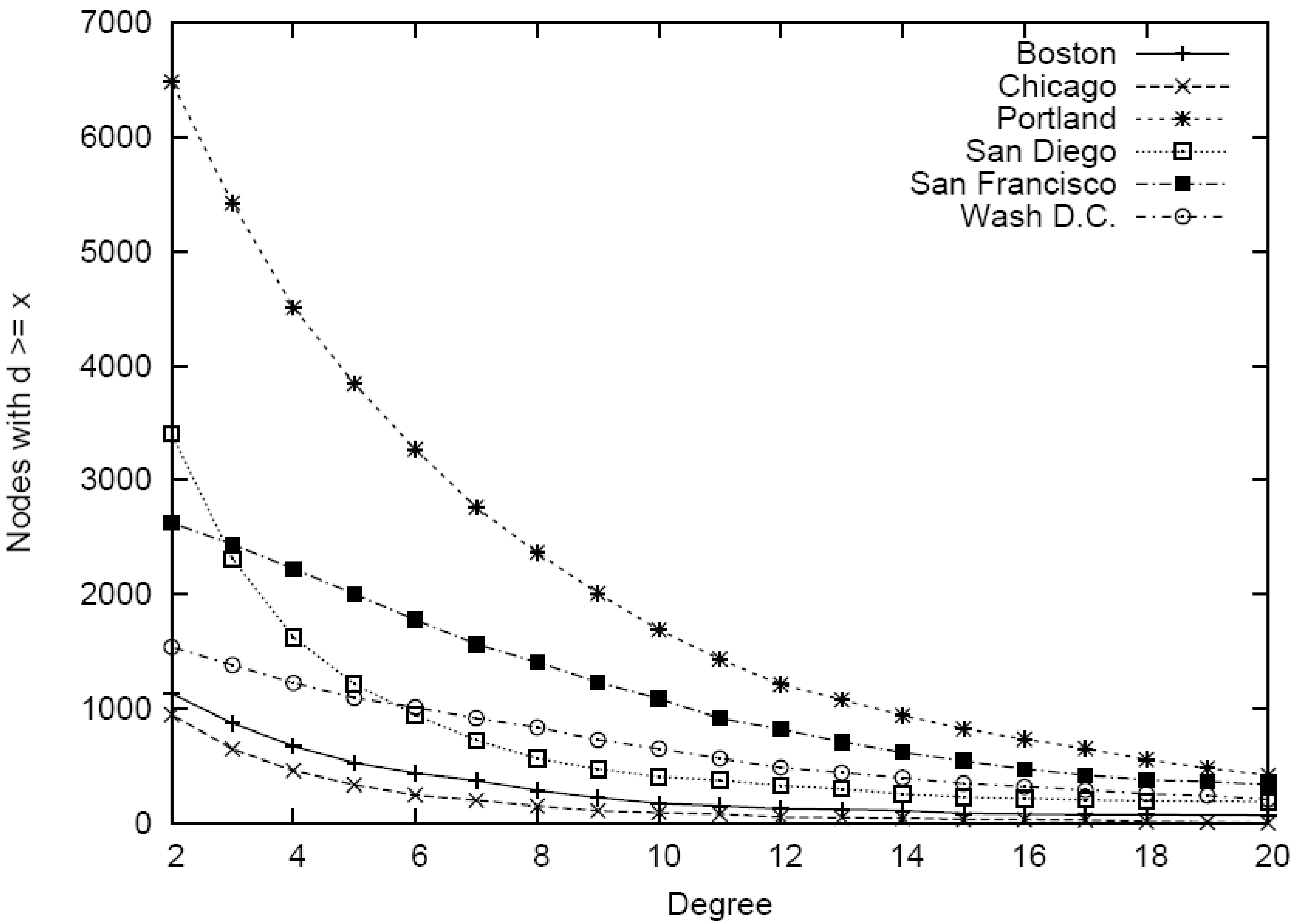
AP Stats, Degrees: Placelab

(Placelab: 28000 APs, MAC, ESSID, GPS)

	#APs	Max. degree
Portland	8683	54
San Diego	7934	76
San Francisco	3037	85
Boston	2551	39



Degree Distribution: Place Lab



Unmanaged Devices

WifiMaps.com
(300,000 APs, MAC, ESSID, Channel)

Channel	%age
6	41.2
2	12.3
11	11.5
3	3.6

- Most users don’t change default channel
- Channel selection must be automated

Opportunities for Change

Wardrive
(667 APs, MAC,
ESSID, Channel,
Rates, GPS)

Linksys (Cisco)	33.5
Aironet (Cisco)	12.2
Agere	9.6
D-Link	4.9
Apple	4.6
Netgear	4.4
ANI Communications	4.3
Delta Networks	3
Lucent	2.5
Acer	2.3
Others	16.7

- Major vendors dominate
- Incentive to reduce "vendor self interference"

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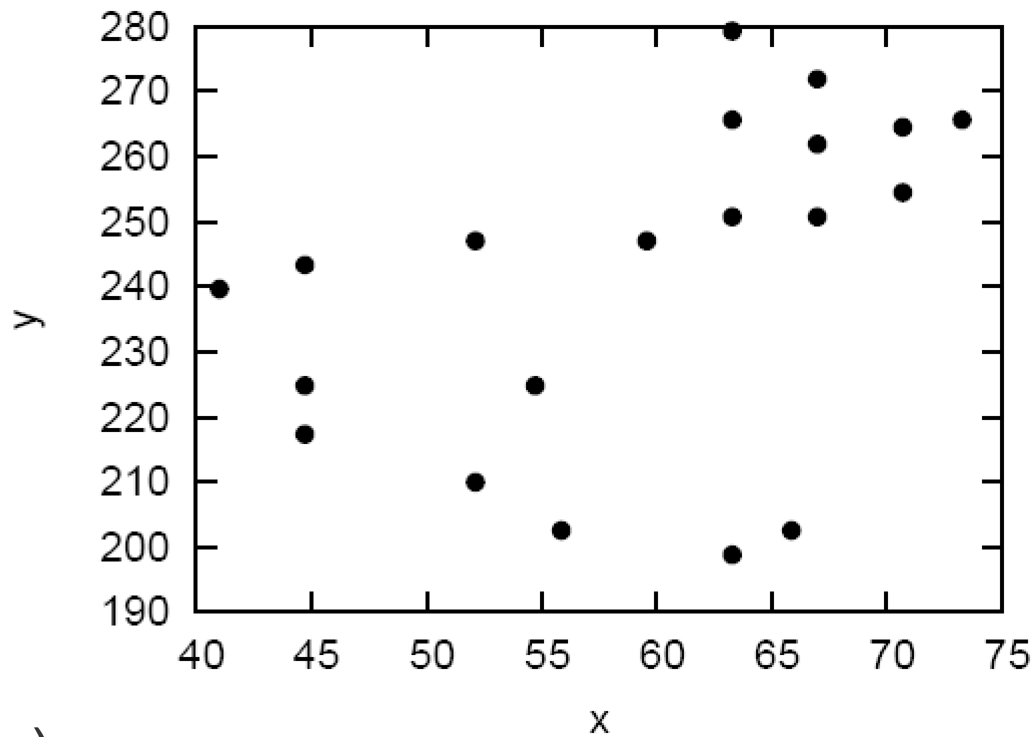
Impact on Performance

- Glomosim trace-driven simulations

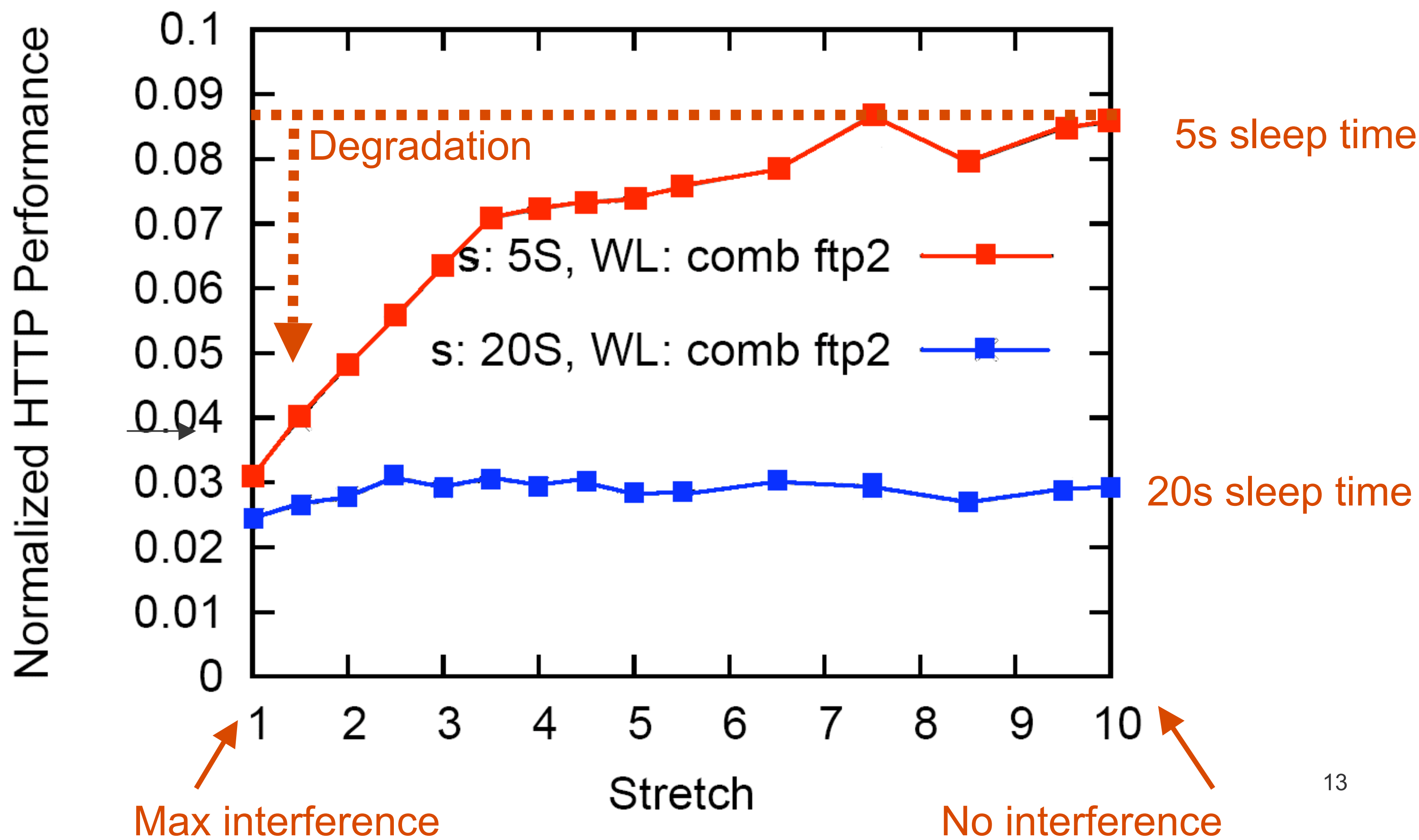
• “D” clients per AP
• Clients are located than 1m from their APs
• Transmit power=15dBm
• Trans. range = 31m
• Interference range = 65m
• Each client runs HTTP/FTP workloads
• HTTP transfers are separated by a sleep time drawn from Poisson(s)

Map Showing Portion of Pittsburgh Data



Impact on HTTP Performance

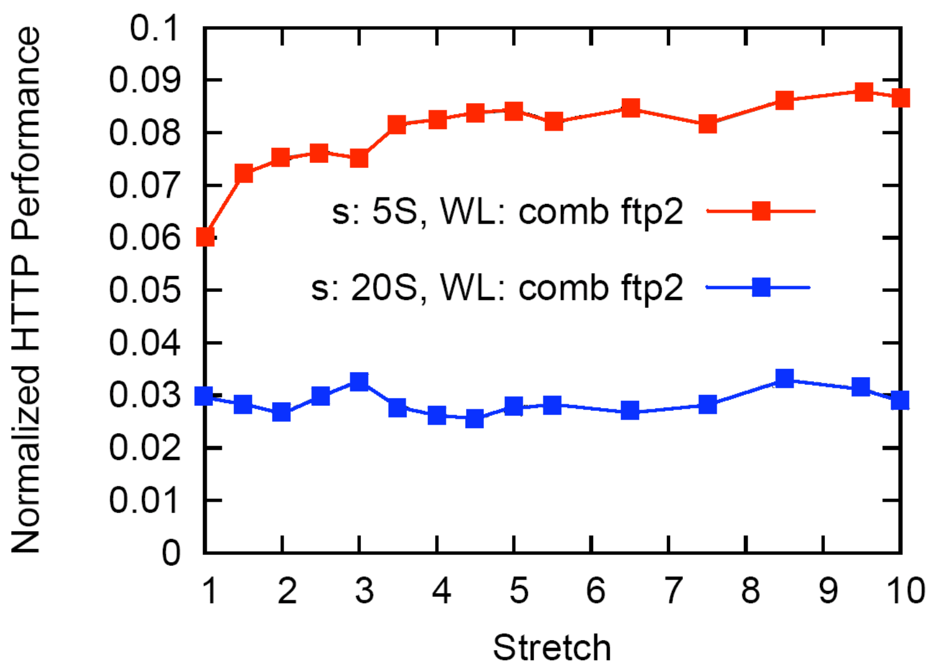
3 clients per AP. 2 clients run FTP sessions.
All others run HTTP.
300 seconds



Optimal Channel Allocation vs.
Optimal Channel Allocation + Tx Power Control

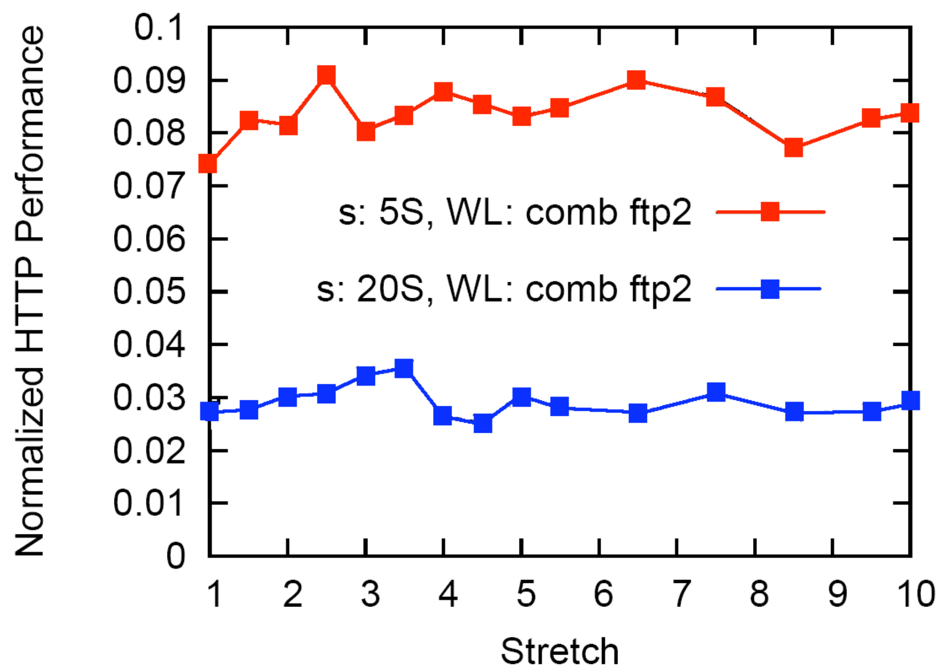
Channel Only

Each AP is statically assigned
1 of the 3 non-overlapping channels



Channel + Tx Power Control

Some of the APs use a power
level of 3dBm.



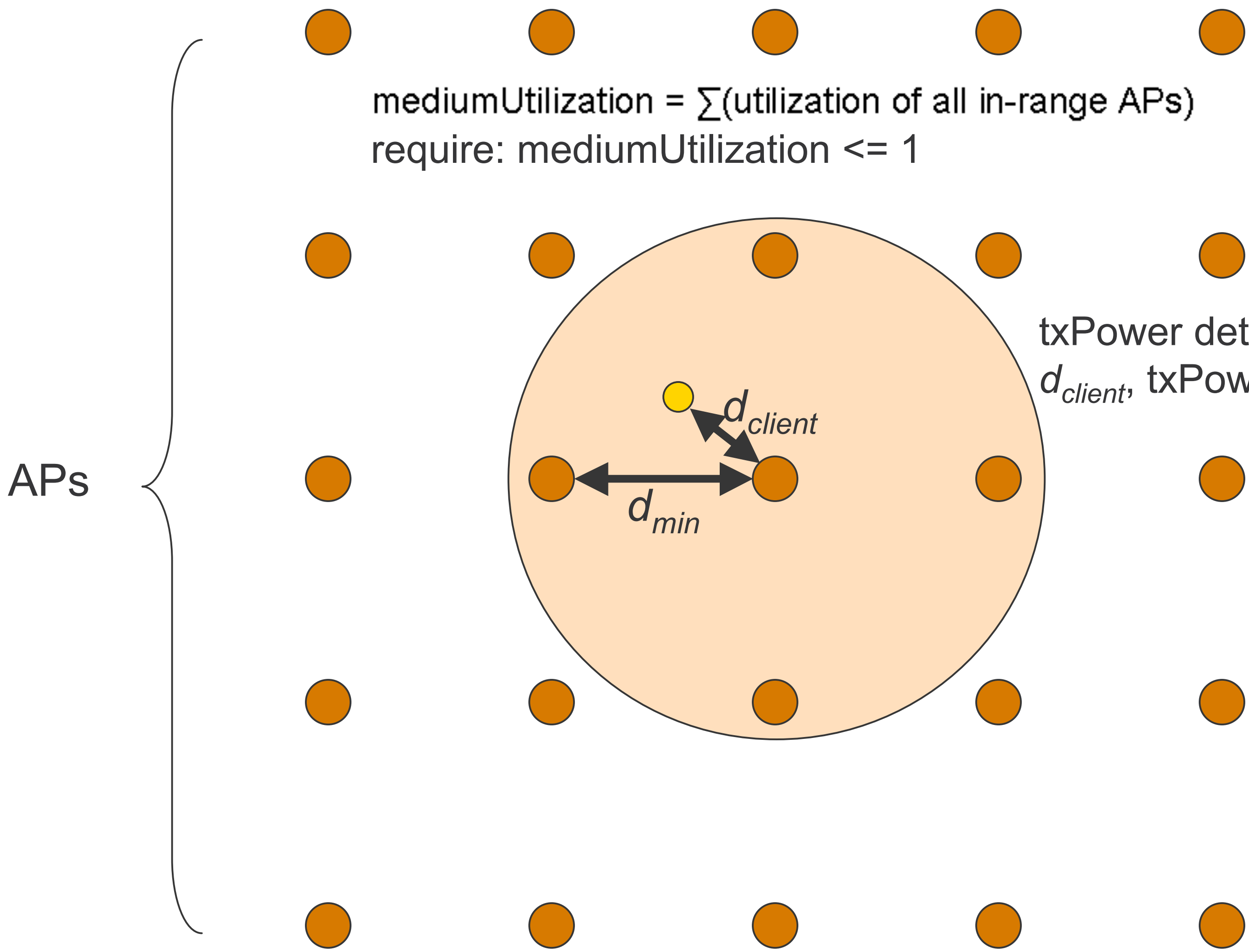
Incentives for Self-management

- Clear incentives for automatically selecting different channels
  - Disputes can arise when configured manually
- Selfish users have no incentive to reduce transmit power
- Power control implemented by vendors
  - Vendors want dense deployments to work
- Regulatory mandate could provide further incentive
  - e.g. higher power limits for devices that implement intelligent power control

Impact of Joint Transmit Power and Rate Control

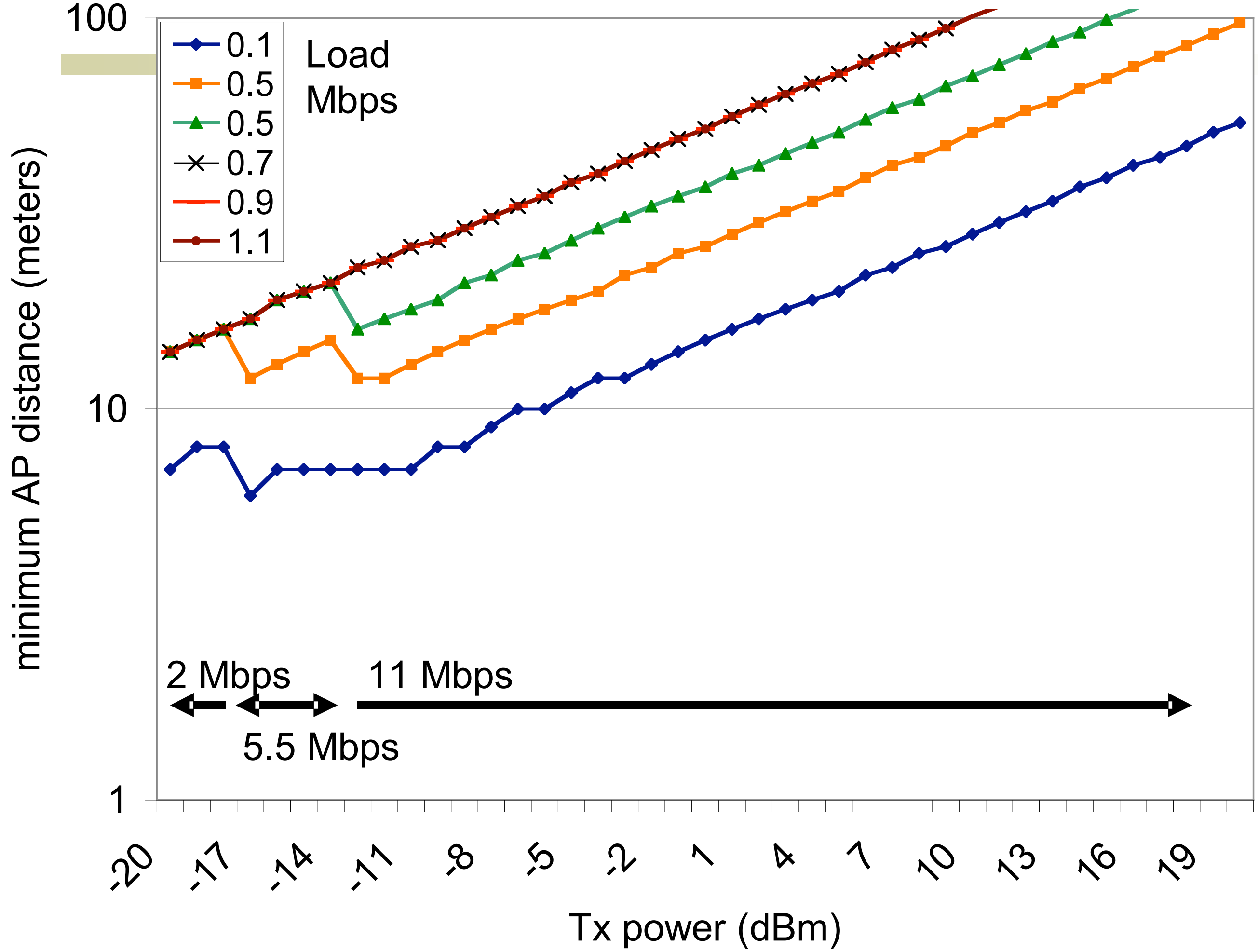
Objective: given <load, txPower, d_{client}> determine d_{min}

mediumUtilization = ∑(utilization of all in-range APs)
require: mediumUtilization <= 1



txPower determines range
d_{client}, txPower determines rate

Impact of Transmit Power Control



- Minimum distance decreases dramatically with transmit power
- High AP densities and loads requires transmit power < 0 dBm
- Highest densities require very low power → can't use 11Mbps!

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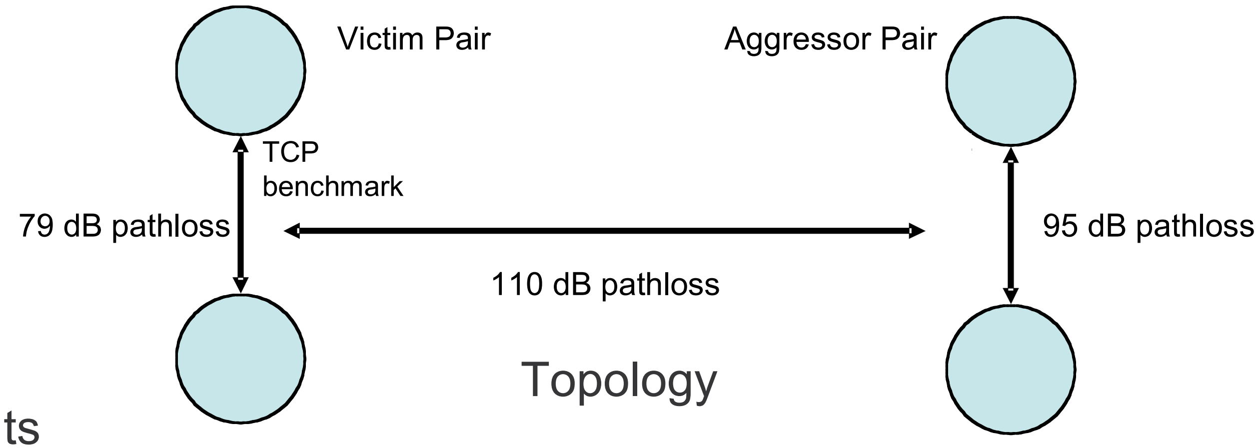
Power Selection Algorithms

- Rate Selection
  - Auto Rate Fallback (ARF)
    - 6 consecutive packet transmissions→ selects the next higher transmission rate
    - 4 consecutive packet trans. failures→ selects the next lower transmission rate
    - No packet is sent in 10 seconds→ uses the highest possible rate for the next transmission.
  - Estimated Rate Fallback: ERF
    - Each packet contains its transmit power level and the path loss and noise estimate of the last packet received.
    - This allows the sender to estimate the SNR at the receiver.
    - ERF then determines the highest transmission rate supported for this SNR.

Power and Rate Selection Algorithms

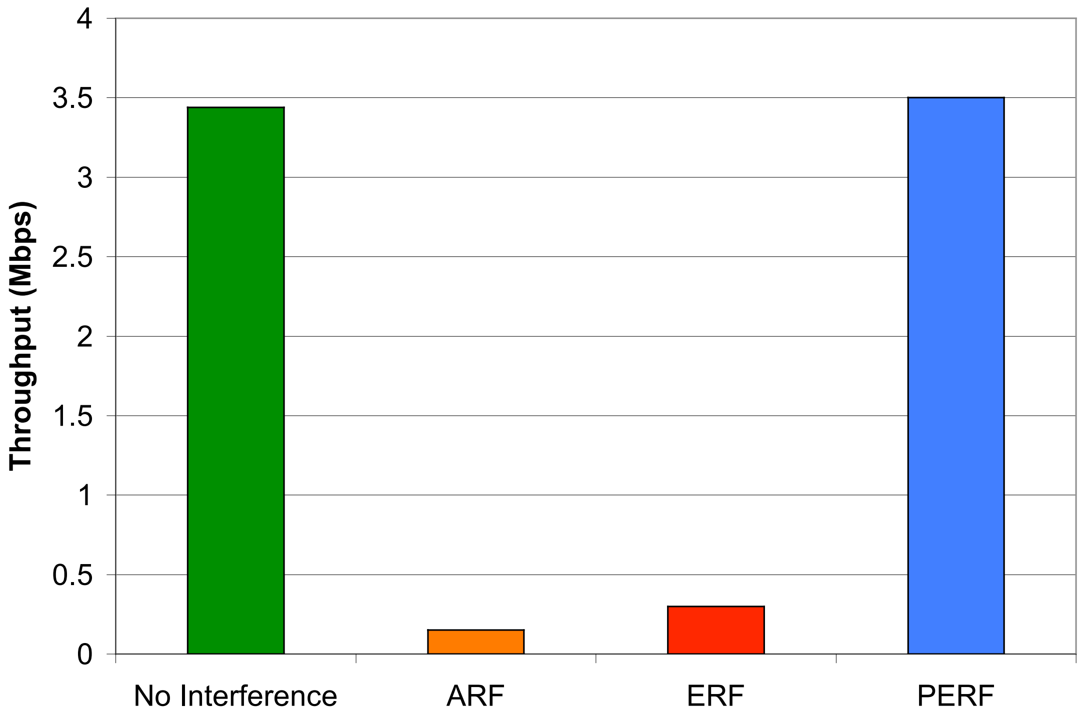
- Joint Power and Rate Selection
  - Power Auto Rate Fallback (PARF)
    - At the highest rate, after a given number of successful transmissions → reduce the transmit power
    - At the lowest rate, after a given number of failures → increase the transmit power
  - Power Estimated Rate Fallback: PERF
    - The sender estimates the SNR at the receiver.
    - If SNR > the decision threshold for the highest transmit rate → lower the transmit power

Lab Interference Test



Topology

Results



Conclusion

- Significant densities of APs in many metro areas
- Many APs not managed
- High densities could seriously affect performance
- Static channel allocation alone does not solve the problem
- Transmit power control effective at reducing impact

Ongoing Work

- Joint power and multi-rate adaptation algorithms
  - Extend to the case where TxRate could be traded off for higher system throughput
- Automatic channel selection
- Field tests of these algorithms