A Measurement Study of a Commercial-grade Urban WiFi Mesh

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Introduction

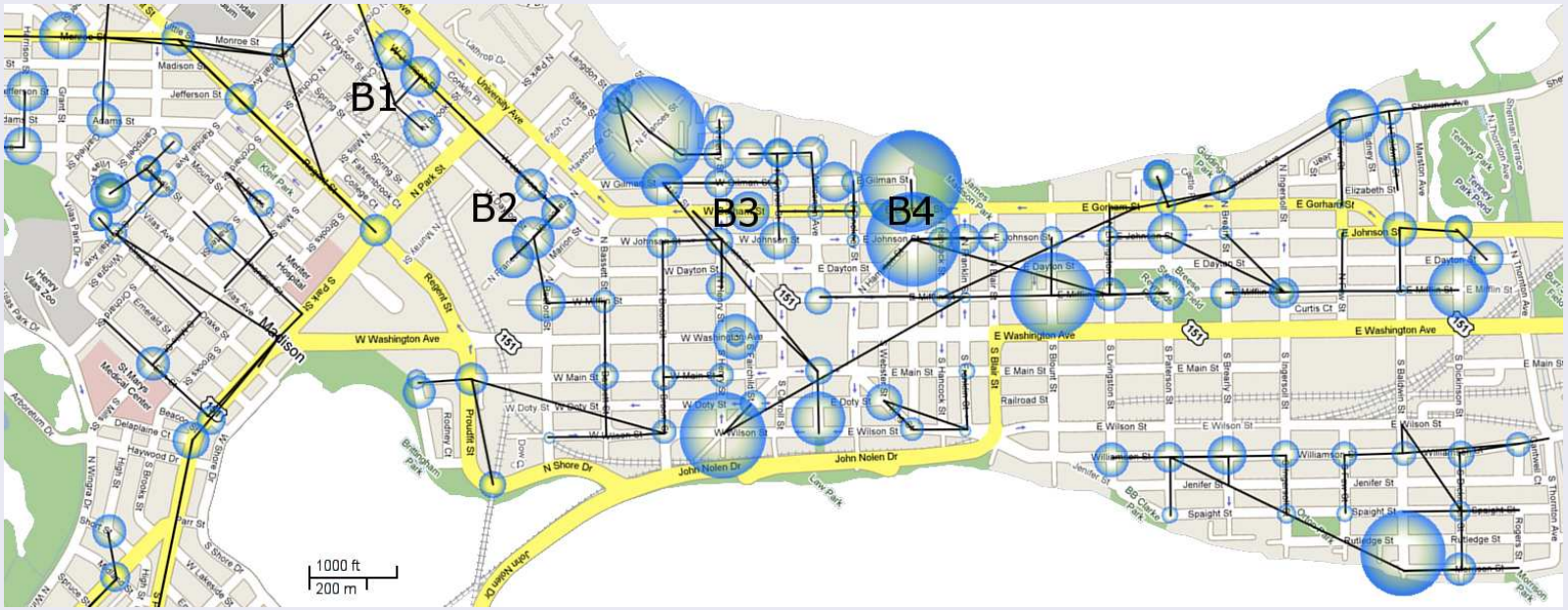
What?

- Measurement study of the **performance** and **usage** characteristics of an operational commercial urban wireless mesh network

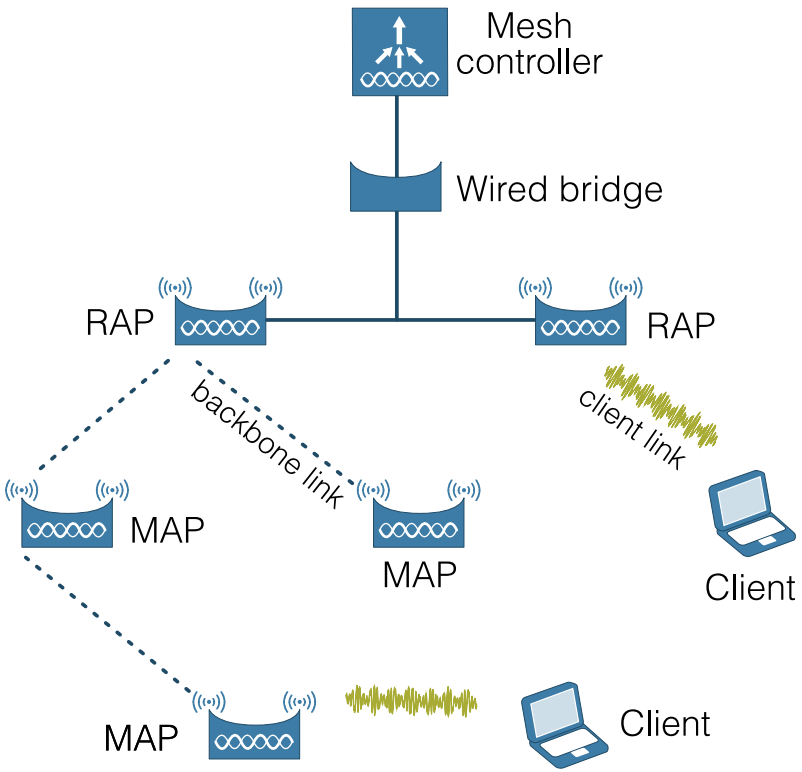
Why?

- Better understanding of these networks
- Previous measurement studies: Roofnet, TFA, DGP (all are custom testbeds built for experimentation)
- What is the state-of-the-art in the industry?
- How much of prior work is applicable?

MadMesh



- More than 250 MAPs covering 10 sq. miles
- Has been operational for about 2 years now
- Provides service to more than 1000 residential customers, small businesses, public safety organizations



Architecture

- Cisco 1510 MAPs, RAPs, Mesh controller
- Tree-based routing (vendor proprietary protocols)
- Backbone interface (802.11a, 5GHz)
- Access interface (802.11 b/g, 2.4 GHz)

Study Goals & Data Sets

Categories of study:

- Mesh planning and deployment
- Mesh routing
- User experience
- Usage characterization

Data collection:

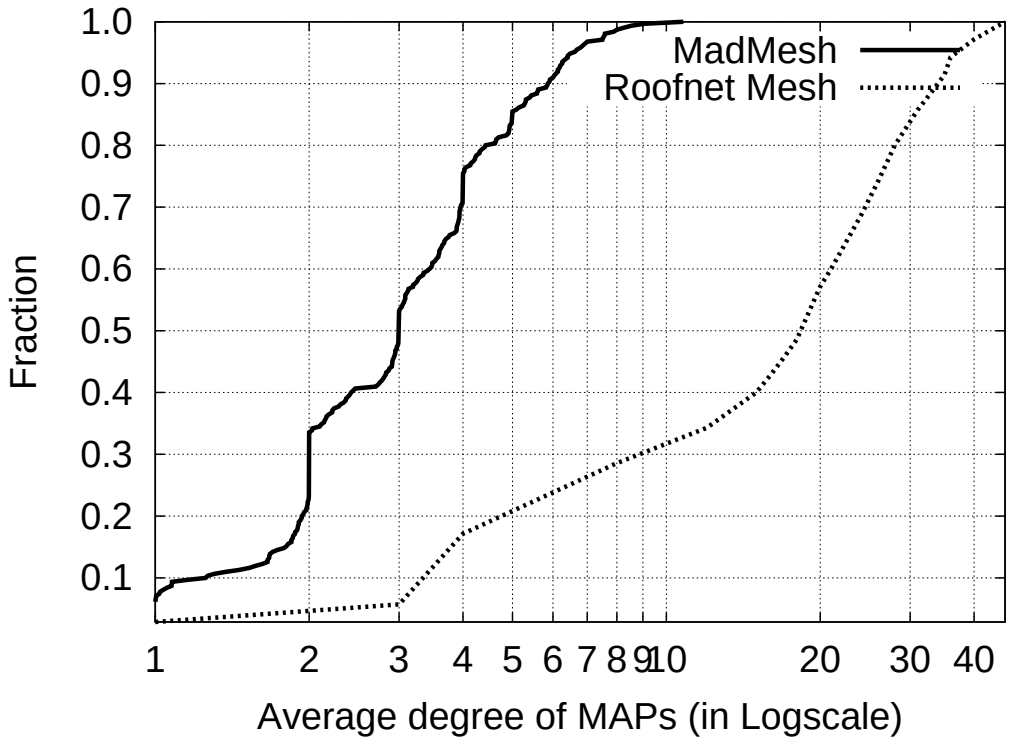
- Period infrastructure logs: SNMP (every 3 min), tools at the controller
- Passive measurements: Deployed indoor/outdoor nodes
- Active measurements: coverage, throughput experiments
- Two week period - 1.7 million SNMP records; 100 hrs of active measurements

Deployment Characteristics:

- What kind of connectivity does each MAP have? Is the network robust against failures?
- What are the link-level error rates and signal qualities on the backbone and access links?
- Does the network topology lend itself to new techniques like wireless network coding?

Q. What is the average MAP degree?

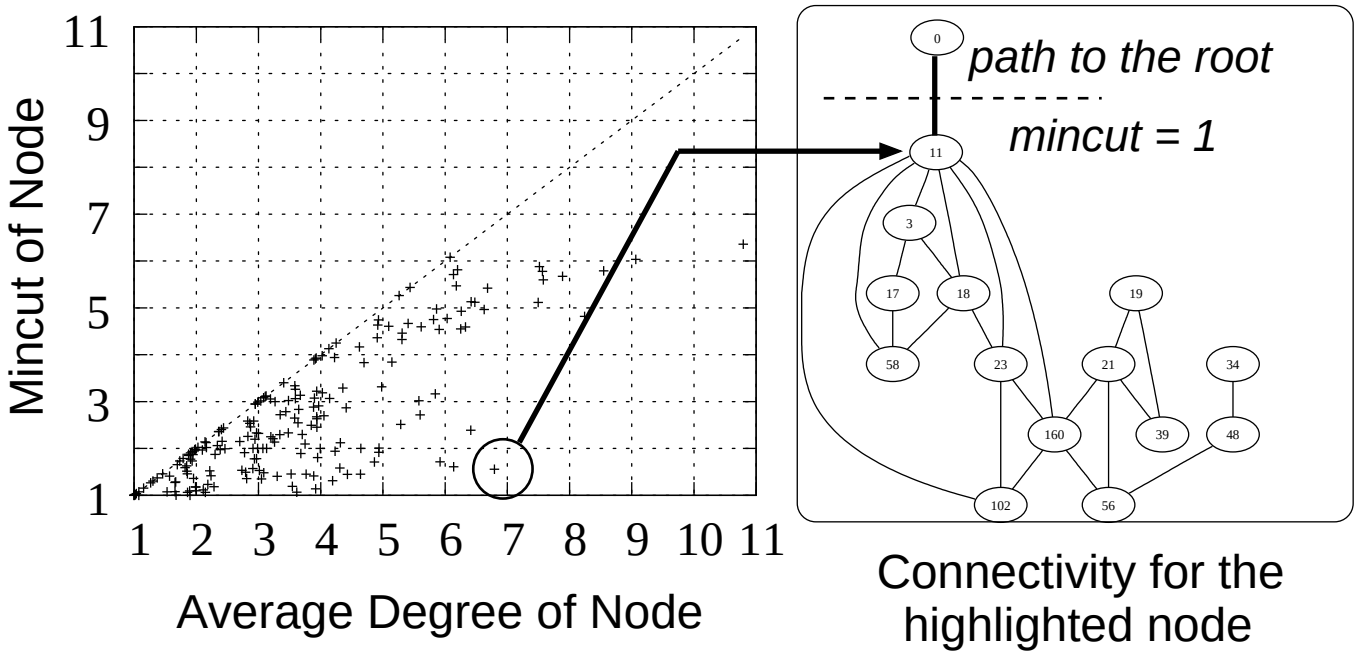
- Lower degree ⇒ less re-routing choices during losses
- Higher degree ⇒ over-provisioning, self-interference



- MAPs: 20% have degree ≤ 2 and 50% have degree > 3
- Much higher degree for Roofnet

Q. Is the deployment robust?

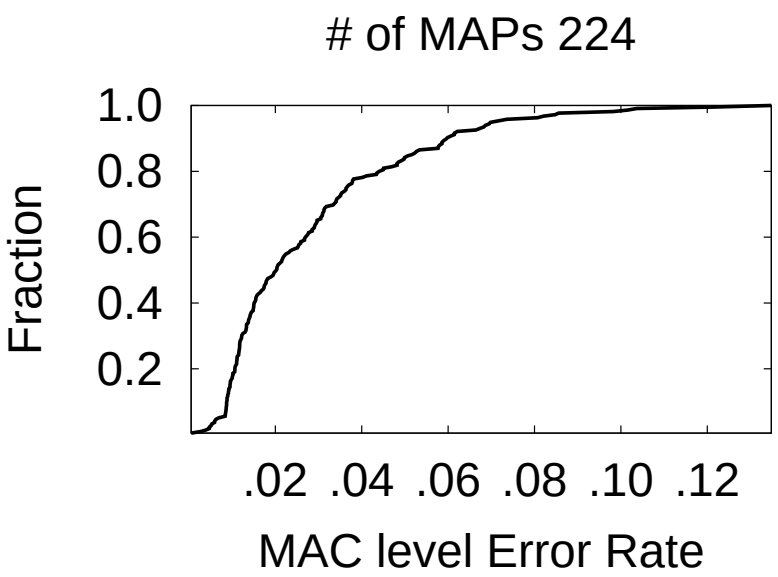
- **Min-cut**: the minimum number of edges, whose removal would disconnect the MAP from the graph



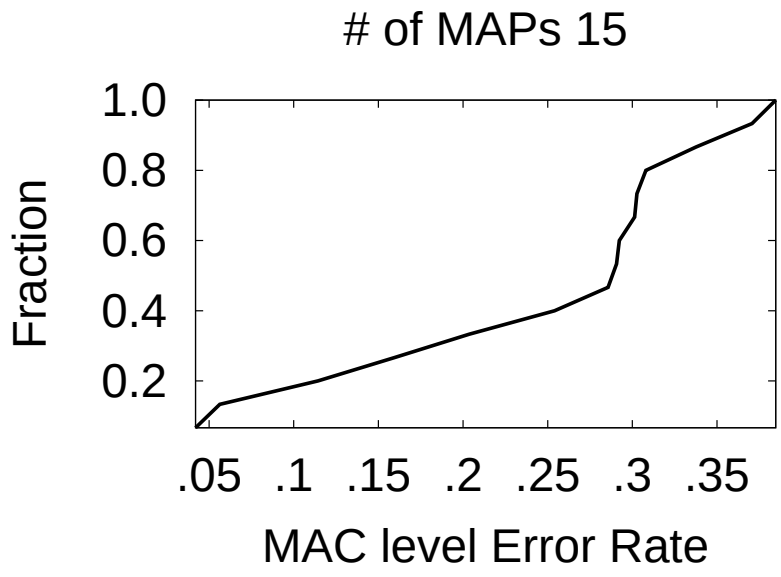
- 8% of the MAPs have min-cut ≤ 2
- Some MAPs with degree as high as 7 have min-cut ≤ 2

Q. How good are the access and backbone links?

Backbone

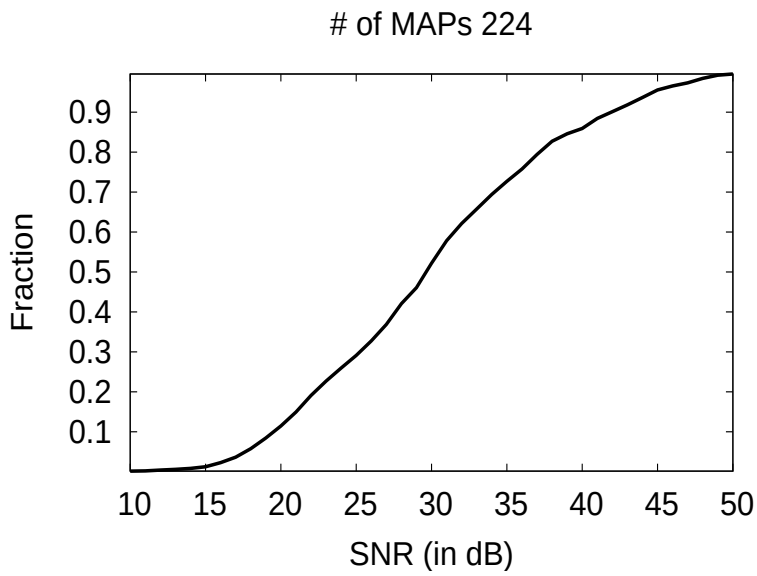


Access



- Much higher loss rates on access links
- Why is this the case?

Backbone



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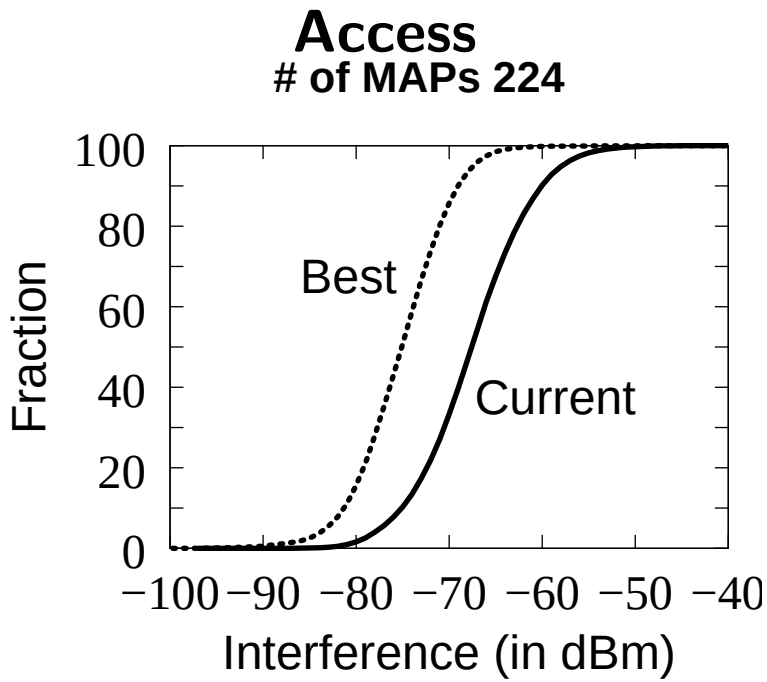

- Good quality backbone links
- PER on access: (1) low SNR (2) interference
- ≥ -70dB interference on 80% of the access links
- Channel selection can help

Q. Are techniques like network coding applicable?

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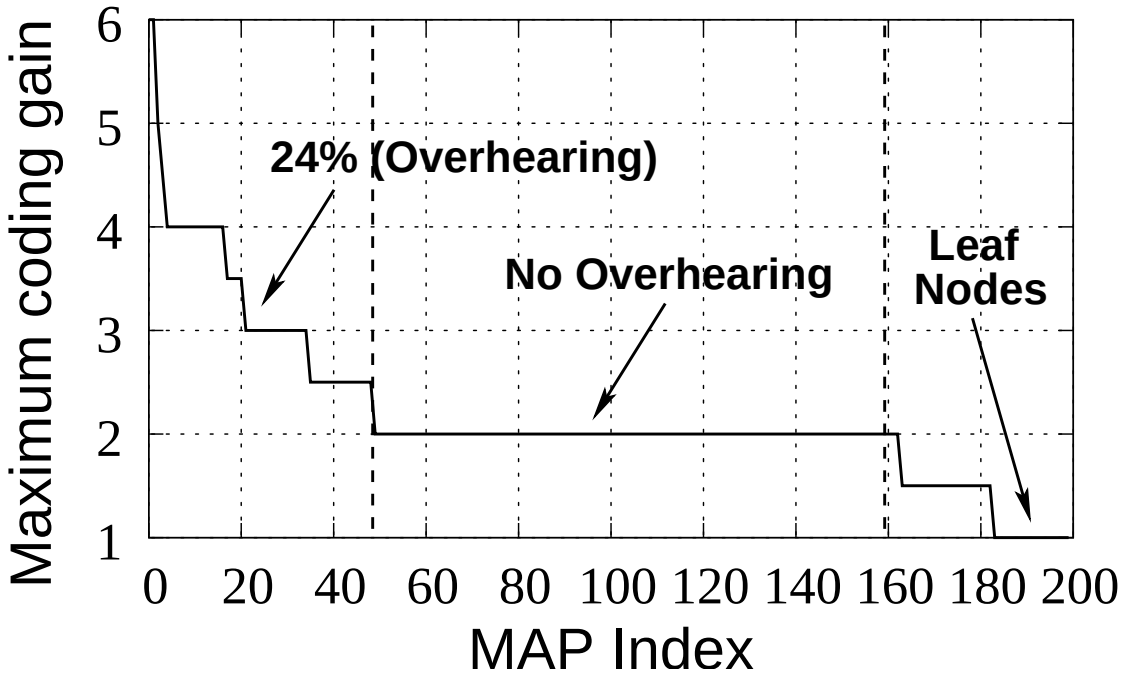
- COPE: XOR operations, opportunistic listening
- Coding rule:

  To transmit n packets, $p_1, ..., p_n$, to n nexthops, $r_1, ..., r_n$, a node can XOR the n packets together only if each next-hop r_i has all $n-1$ packets p_j for $j \neq i$.

- We calculate the **maximum coding gain** at each MAP
- Depends on a number of factors; Measure of overhearing supported by the deployment



- For 66% of the MAPs, coding gain was 2
- 24% of MAPs had coding gain > 2 (Max. coding gain was 6)
- Network coding can indeed improve the performance

User Experience

Characterizing the user experience:

- How good is the client connectivity? Are coverage holes prevalent?
- What are the observed client throughputs?

Q. How prevalent are coverage holes?

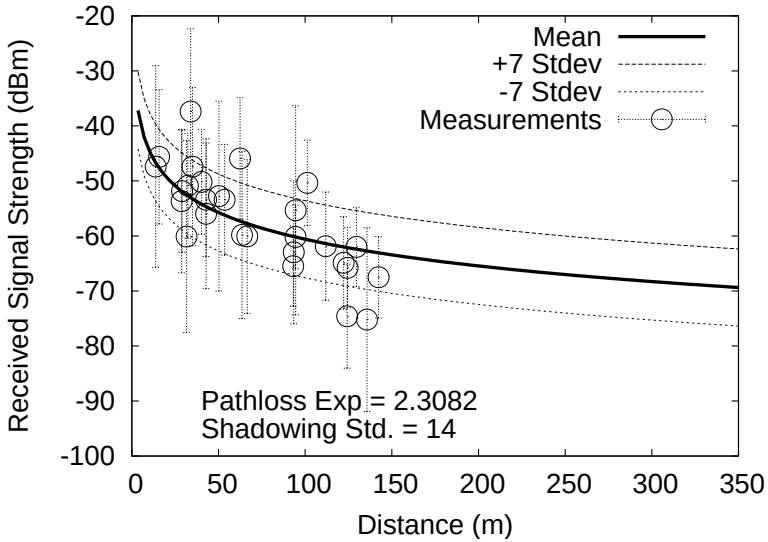
- Estimate using a path-loss model:

$$P_{dBm}(d) = P_{dBm}(d_0) - 10\alpha log_{10}(\frac{d}{d_0}) + \epsilon$$

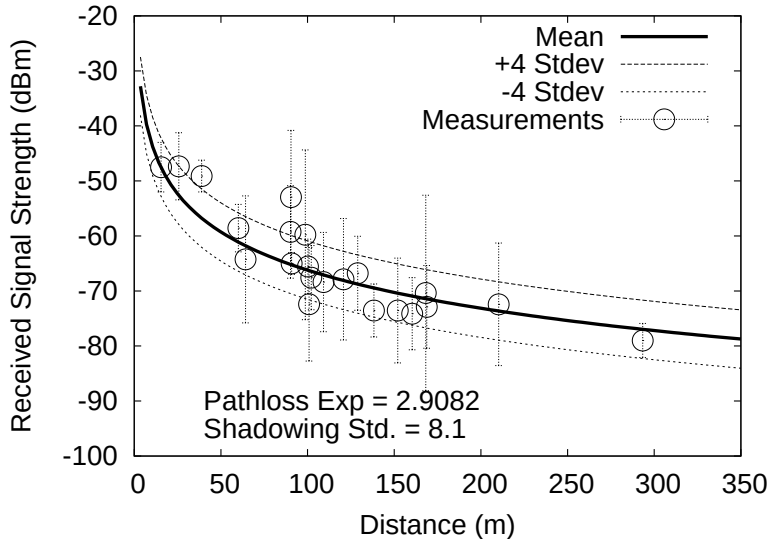
- Collected signal strength information at 25 locations for each MAP, and then estimated α, ϵ

- Path-loss modeling results:

$\alpha = 2.3$ (Campus)



$\alpha = 2.9$ (Downtown)



- Path-loss varies with each MAP (location)

User Experience
Client connectivity

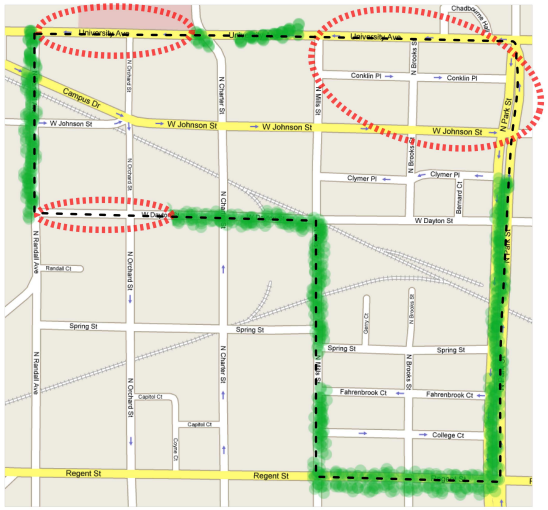
connected when walking

connected when driving at 25 mph

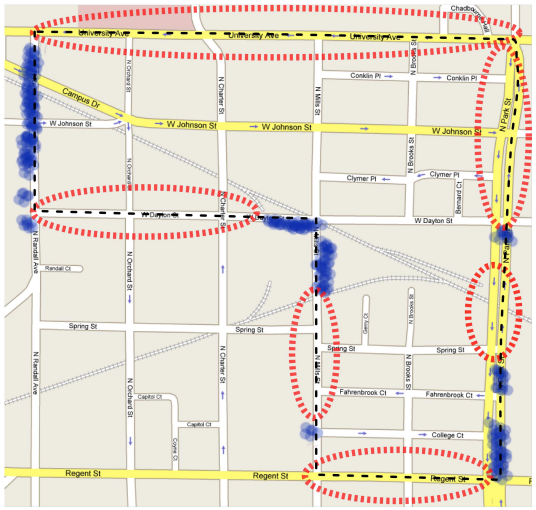
coverage hole

client trajectory

Walking test



Driving test



- Propagation model based radio map shows this area to be 'covered'
- Simple monitoring tool at the clients
- More holes prevalent at vehicular speeds
- Client feedback can really help

Q. What are the throughputs achieved at different locations?

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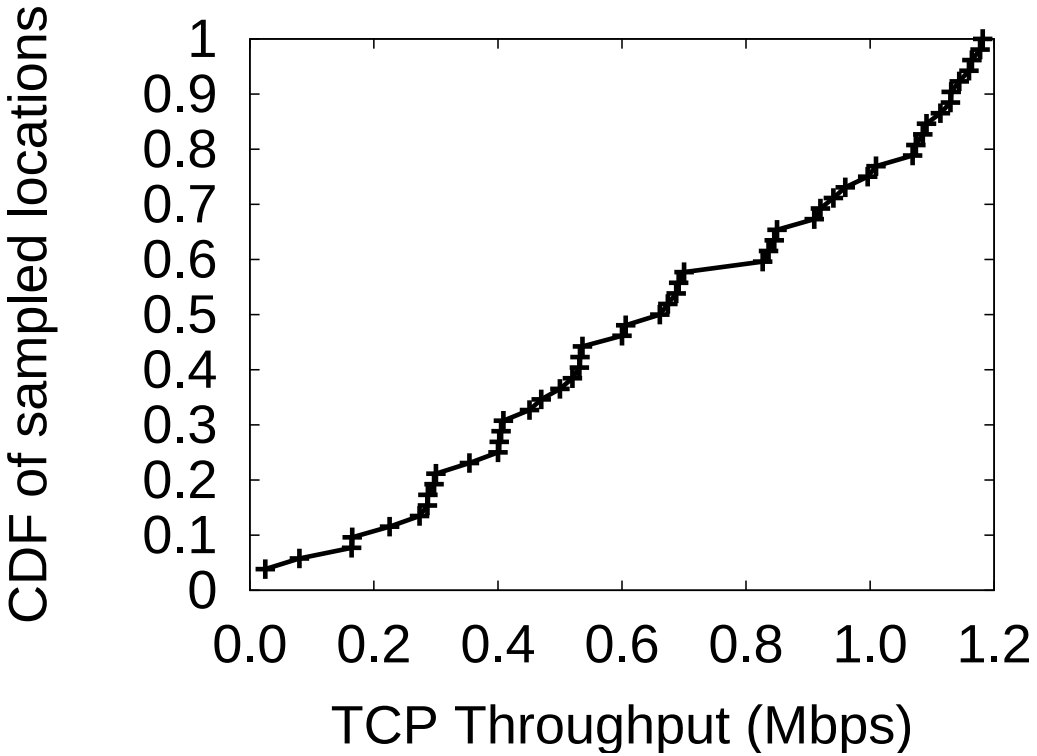
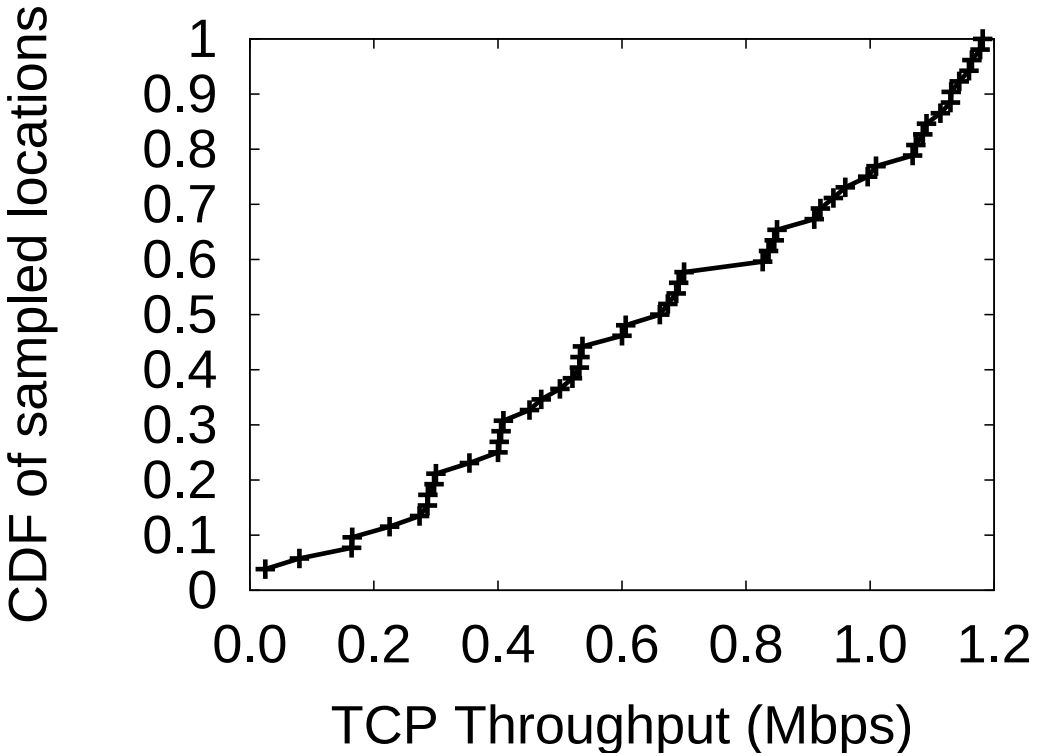
- Random sample of 100 locations
- 3 runs of TCP iperf tests, 100 seconds each

Results of throughput tests:



- 10% of the clients have less than 0.2 Mbps, while 80% have less than 1 Mbps

Results of throughput tests:



Factors:

- RSSI
- Hop-count
- Channel Congestion
- Shared Congestion

- 10% of the clients have less than 0.2 Mbps, while 80% have less than 1 Mbps

Usage Characterization

Characterizing mesh usage:

- How many clients are using the network? How does the usage vary with time?
- How does client distribution vary with MAPs, across different hops etc. ?

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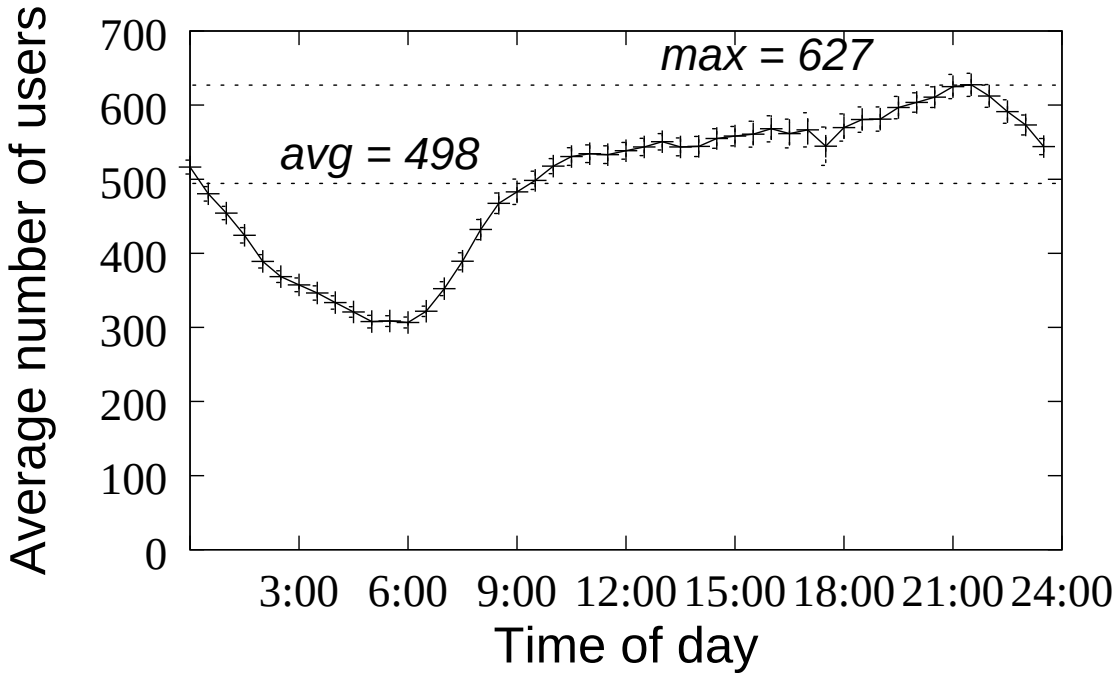

- Most number of clients were connected at around 10 PM

Q. How does the usage vary across MAPs?

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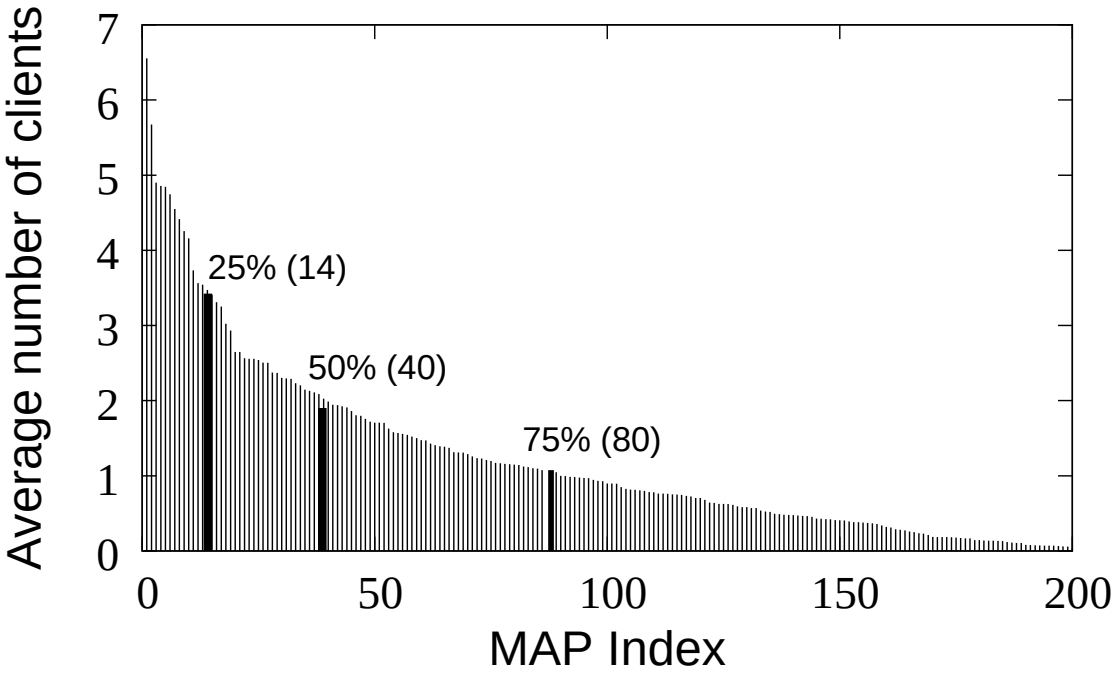


- Clearly, certain MAPs are more popular than others
- 50% of clients are connected to 40 MAPs (20%)

Summary

Main observations:

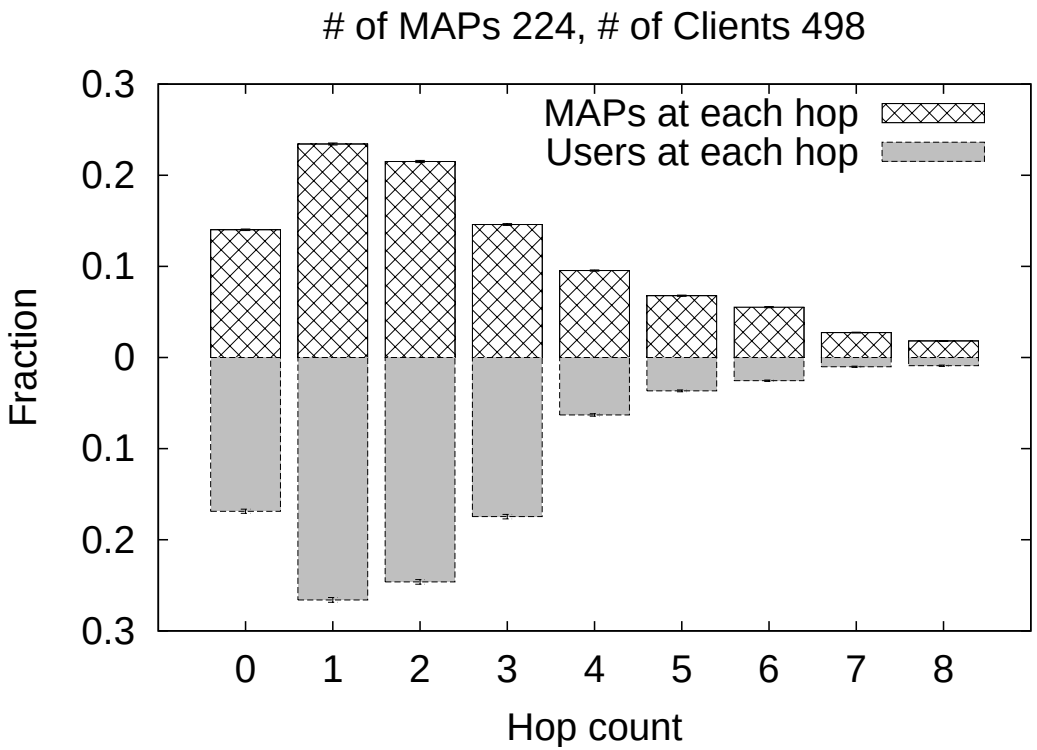
- Robustness – ensure path diversity
- Bottleneck – it is the access link; channel selection can help
- Management – client feedback can really help
- Techniques like network coding are applicable
- User characteristics – night time peaks and uneven usage

Questions?

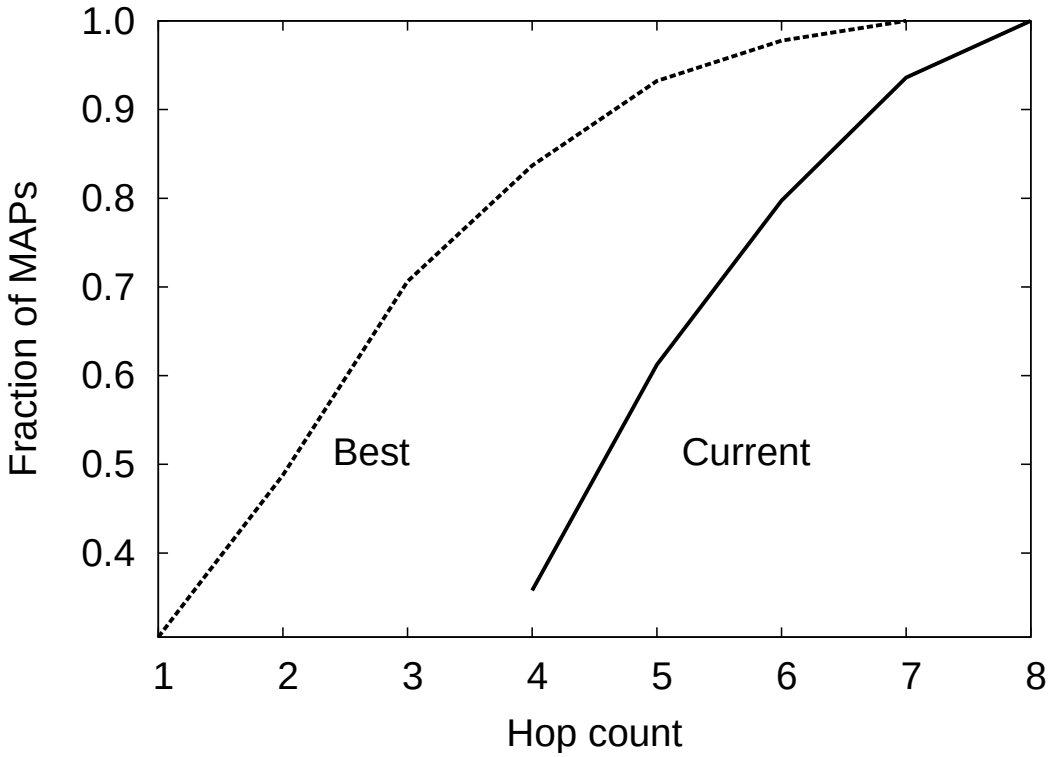
Other slides

Routing Strategy

- EASE metric (SNR, hop-count)
- How well does it perform?



- For 15% of the MAPs are RAPs
- 60% of MAPs have hop-count ≤ 2
- 8% of MAPs have hop-count ≥ 5



- Chose only neighbors with SNR ≥ 14dB
- Shorter paths were indeed available