Infrastructure Mobility: A What-If Analysis

Mahanth Gowda
Nirupam Roy
Romit Roy Choudhury
Wireless Network Capacity

Revolutionary work in the last 30 years
  Beamforming, MIMO, power-control, channel assignment, coding ...
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Capacity is reaching Shannon's limit, but the demand is still increasing
Growing agreement in the community that we have reached saturation at the PHY Layer ...
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Next jump perhaps from new networking architectures.
Static Infrastructure, Mobile Clients
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What if Infrastructure is Mobile
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What if Infrastructure is Mobile
Regimes of Infrastructure Mobility

Mobility Range
Regimes of Infrastructure Mobility

Tethered Mobility (feet)

Mobility Range
Regimes of Infrastructure Mobility

Tethered Mobility (feet)

Ceiling Track Mobility (meter)

Mobility Range
Regimes of Infrastructure Mobility

Mobility Range

- Tethered Mobility (feet)
- Ceiling Track Mobility (meter)
- Cell Tower Relays (km)
Regimes of Infrastructure Mobility

Three main sources of gains
Indoor Multipath
Multipath can Add up Destructively
Multipath can Add up Destructively
Multipath can Add up Destructively
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Out of phase components
Multipath can Add up Destructively

Out of phase components

Destructive multipath – nullified signal
Small Mobility Facilitates Constructive Multipath
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In Phase alignment with small AP motion
Small Mobility Facilitates Constructive Multipath

- In Phase alignment with small AP motion
- Constructive multipath – amplified signal
Shadowing
LoS Path blocked by wall

Shadowing
Shadowing

LoS opportunity by evading shadow
Regimes of Infrastructure Mobility

- Tethered Mobility (feet)
- Ceiling Track Mobility (meter)
- Cell Tower Relays (km)

Mobility Range
Timescales

Channel Variation  Traffic Changes  User Location  Topology  Faults

Time
1. What’s the Killer App?

Opportunities are many:
- Better capacity
- Localization
- Improved energy
- Security
- Fault management
- QoS, reliability, prioritization,
- Software defined mobility … scalable

Not entirely sure about killer app
- Treating this as a bottom-up research
Robots permeating life … design, cost, reliability, safety not major issues

2. Is this Really Practical?
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Smart homes!
3. How Compelling are the Gains?
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**Single-AP Mobility**

- Mobility can be only in small spatial scale (< 1 sq ft)
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  - Constructive multipath - To increase signal strength of clients
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- Upper bounds on throughput gain $\sim 2x$
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- Exploit multipath opportunities
  - Constructive multipath - To increase signal strength of clients
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- Upper bounds on throughput gain \( \sim 2x \)

- Long Range Macro-mobility can offer upto \( 3x \) gains
3. How Compelling are the Gains?

Multiple-AP Coordinated Mobility

Software Defined Infrastructure Mobility
3. How Compelling are the Gains?

Multiple-AP Coordinated Mobility

Software Defined Infrastructure Mobility

Joint Mobility Control over Cloud
3. How Compelling are the Gains?

Multiple-AP Coordinated Mobility

Software Defined Infrastructure Mobility

Upto 1.8x gains (based on measurement driven simulations)
4. Why not Overprovision?

Robotic WiFi APs can be plug and play → backward compatible

Moreover, multiple APs can together be mobile → additional gains

Yes, that’s possible.

However,
- re-wiring + Ethernet costly
- new protocols, eco-system
- backward compatibility
Measurements

Platform: USRPs and off-the-shelf laptops
Methodology

AP Mobility Area

Client

Client

Client

Client
Methodology

AP Mobility Area

Client

Client

Client
Methodology

AP Mobility Area

1 foot

Spot

Client
Methodology

AP Mobility Area

1 foot

Spot

Pixels

Client
Methodology

AP Mobility Area

Three Regimes of Mobility

Pixels

Spot

Client
Methodology

1) MicroMobility

Three Regimes of Mobility
Methodology

1) MicroMobility
2) MiniMobility

Three Regimes of Mobility
Methodology

1) MicroMobility

2) MiniMobility

3) MacroMobility

Three Regimes of Mobility
MicroMobility

Client

Your AP
MicroMobility

Client

Your AP

Good SNR
MicroMobility

Client

Your AP

Interfering (Neighbor) AP

Good SNR
MicroMobility

Client

Your AP

Weak Interference

Interfering (Neighbor) AP

Good SNR
SNR Variation within a Spot
SNR Variation within a Spot

CDF of (max – median) SNR.
SNR Variation within a Spot

CDF of (max – median) SNR.

CDF of (median - min) SNR.
MicroMobility: Upper bound on Throughput Gain with Interference

![Bar chart showing throughput gain for different scenarios: Lab, Home, Office, Apartment. The bars represent different client counts: 1 Client, 3 Clients, 5 Clients.](chart.png)
MiniMobility: SNR Variation over 6 Spots

Spot 1

Spot 2

Spot 3

Spot 4

Spot 5

Spot 6
MiniMobility: Upper bound on Throughput Gain

**Without interference**

**With interference**
MacroMobility: Upper bound on Throughput Gain

CDF

0.5

0

Gain Factor

0

5

10

15

Lab

Home

Apartment

Office
Coordinated Mobility

Cloud Controlled Mobility
Coordinated Mobility
Coordinated Mobility

Cloud Controlled Mobility
Coordinated Mobility Gains

30 Node, 6 AP testbed with measurement based simulation
Need not Move too much
Need not Move too much
Need not Move too much

Close by AP

Client
Need not Move too much
Need not Move too much
Need not Move too much
Need not Move too much
Need not Move too much
Need not Move too much
Need not Move too much

Pixels of comparable SNRs connected with a line. Far away pixels, chosen carefully, offer strong SNRs.
Many More Opportunities

• Energy savings
  • Due to greater data rates, fewer re-transmissions

• Range finding possible via careful antenna motion
  • Averages out multi-path

• More bits of secret keys from the channel
  • Through frequent antenna mobility

• Quadcopter based cell tower extension
  • Possible to avoid shadow regions
  • Channel quality at heights different from ground
Many Challenges too

• How to relocate to the right pixel for improved SNR?
• When to relocate?
• Joint mobility and power control, channel management
• Optimizing for multiple clients. New scheduling schemes
• Mobility planning in between protocol idle periods
• Leverage overheard transmissions for mobility decisions
• Improved multi-AP coordination
• Many others ...
Take Away

- Power Control
- Channel Selection
- Scheduling
- Coding
- Beamforming
- MIMO
Take Away

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- Channel Selection
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Infrastructure Mobility
Thank You!
Questions?

Mahanth Gowda
gowda2@illinois.edu

Systems and Networking Research Group (SyNRG)
http://www.synrg.csl.illinois.edu