Accessing WiFi Networks from Moving Vehicles

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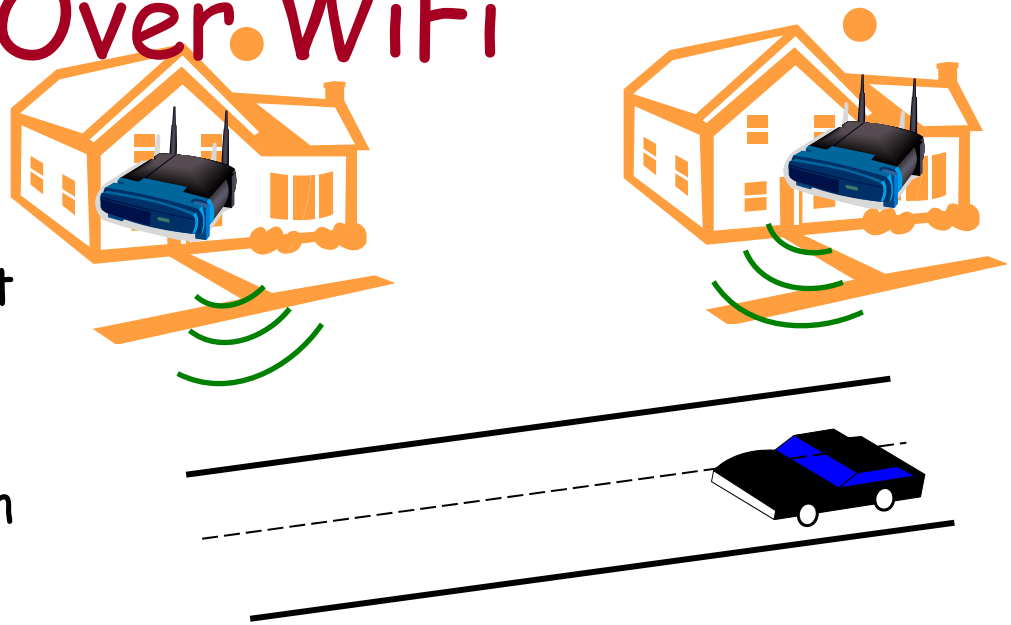
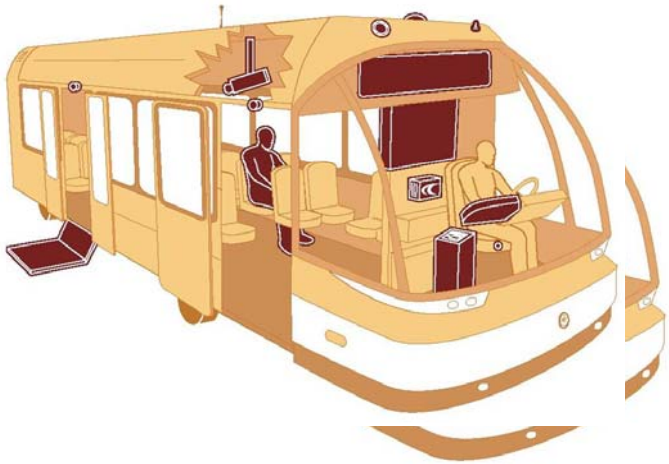
Vehicle to Infrastructure Communication Over WiFi

- Why WiFi?
  - Already dense deployment in urban areas.
  - High BW at short ranges.
  - Unlicensed band operation (free).
- Secure APs are not show-stoppers.
  - Community architectures such as FON.
  - Municipal WiFi.



- While realistic, performance, protocol issues need to be addressed.

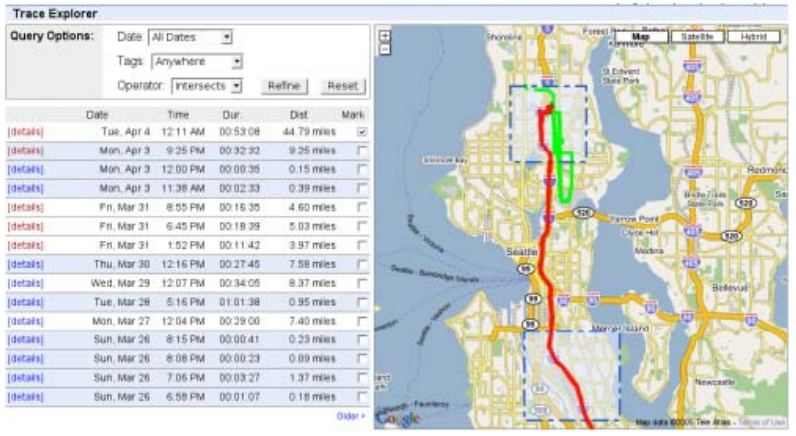
Applications



Internet Access

Rear-Seat Entertainment

Traffic and Weather Information



Vehicle as Mobile Sensor

Growing Body of Work

- University of Bremen and HUT
- MIT (CarTel, Cabernet)
- Microsoft Research (ViFi)
- University of Waterloo
- Rutgers University- Winlab

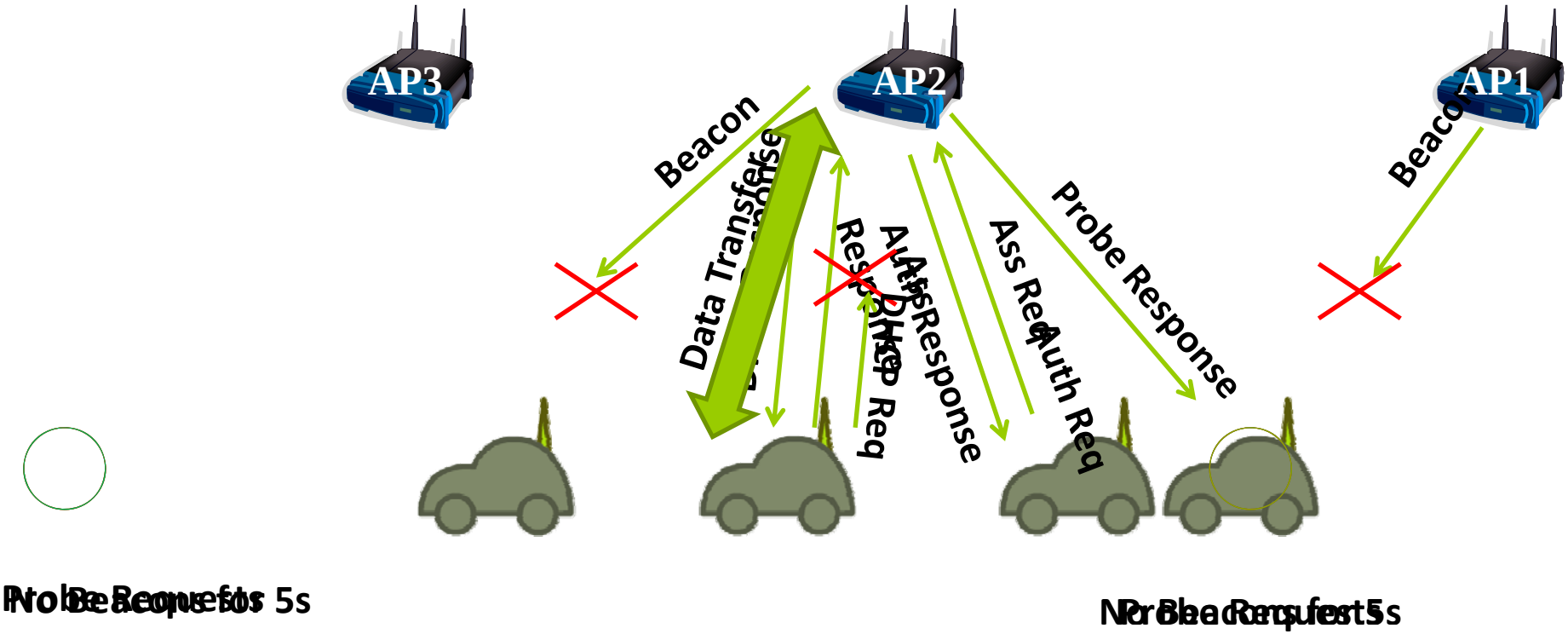
Performance Issues in Vehicular WiFi Access

- High handoff/association overhead: 1-2 sec average.
  - Short duration of connectivity: 13 sec average.
- Poor link quality: 80% link delivery ratio on average.

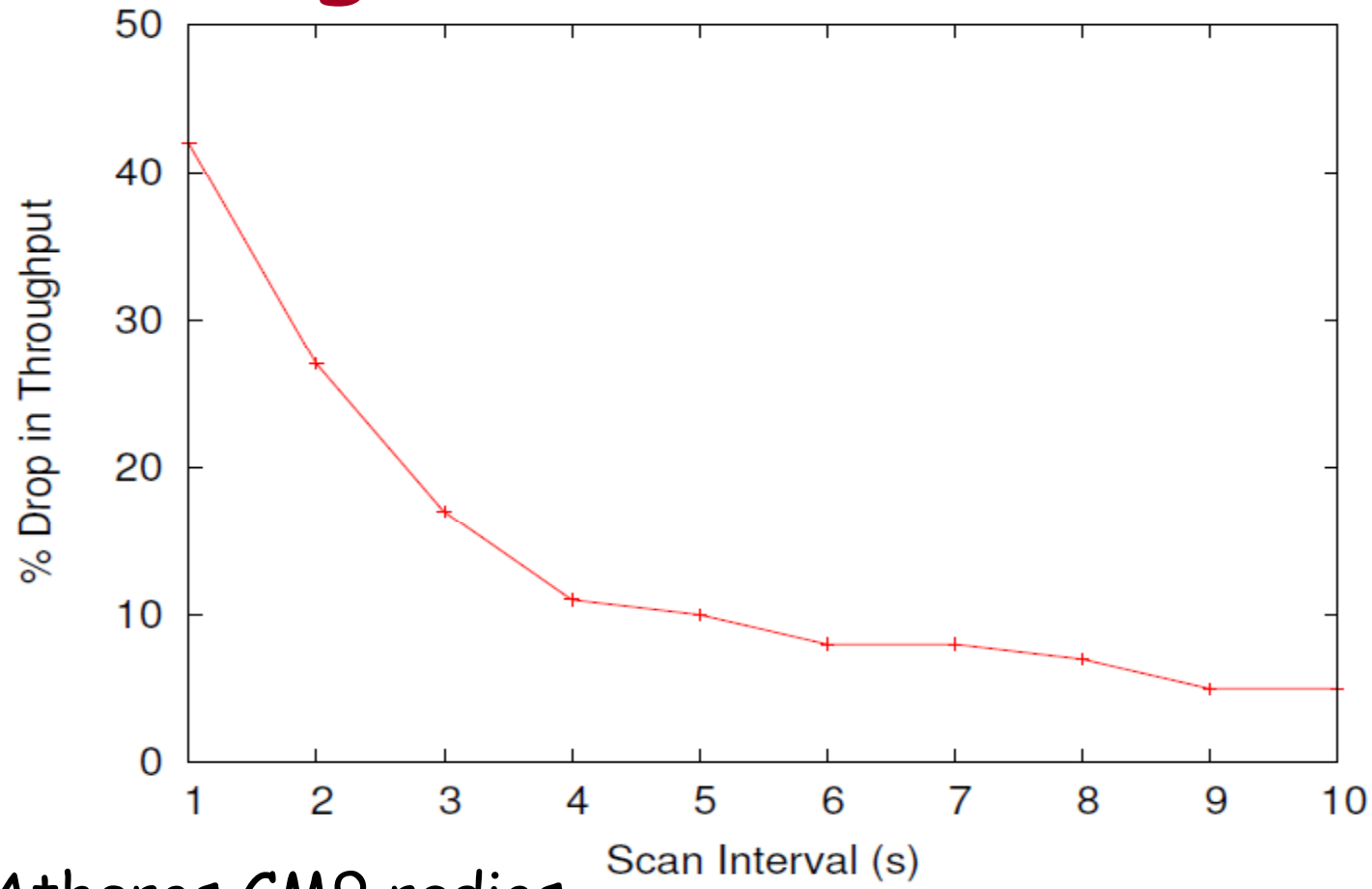
[MIT CarTel project]

- Can downloads be pre-fetched at APs?

Handoff Scheme for a Typical WiFi Client



Scanning While Connected



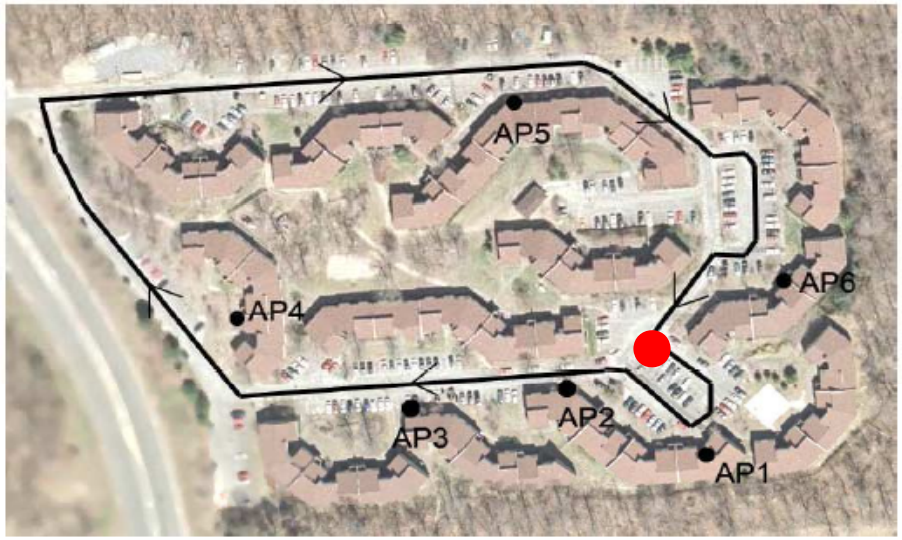
- Atheros CM9 radios
- UDP Iperf experiment – 11Mbps physical bit-rate
- Receiver scans once every scanning interval

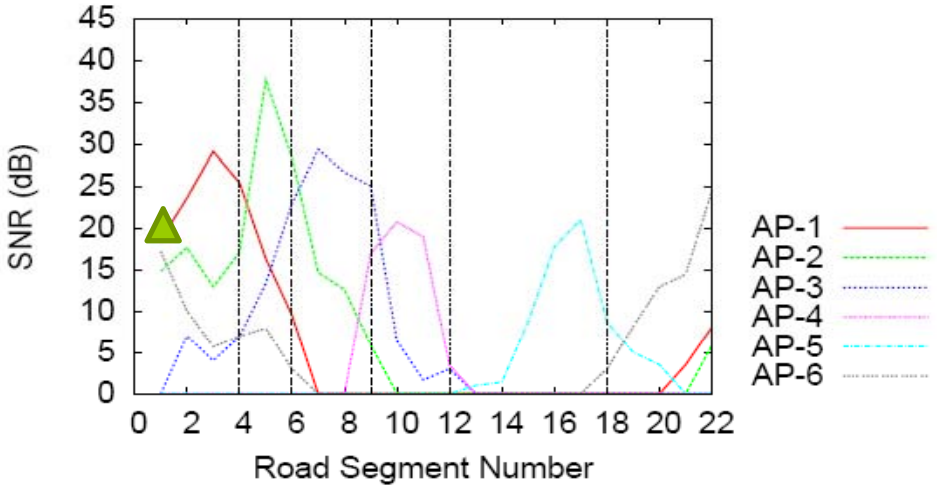
Fast Handoff

- Eliminate DHCP delay via use of zero-configuration.
  - Use randomly chosen IP address from a well-known pool with conflict resolution.
- Use scripted handoff.
  - People drive mostly on familiar routes.
  - Collect geo-tagged RF fingerprints for APs.
  - Use them to pre-compute handoff locations on following drives.

Scripted Handoff

Choose best AP to handoff at every location

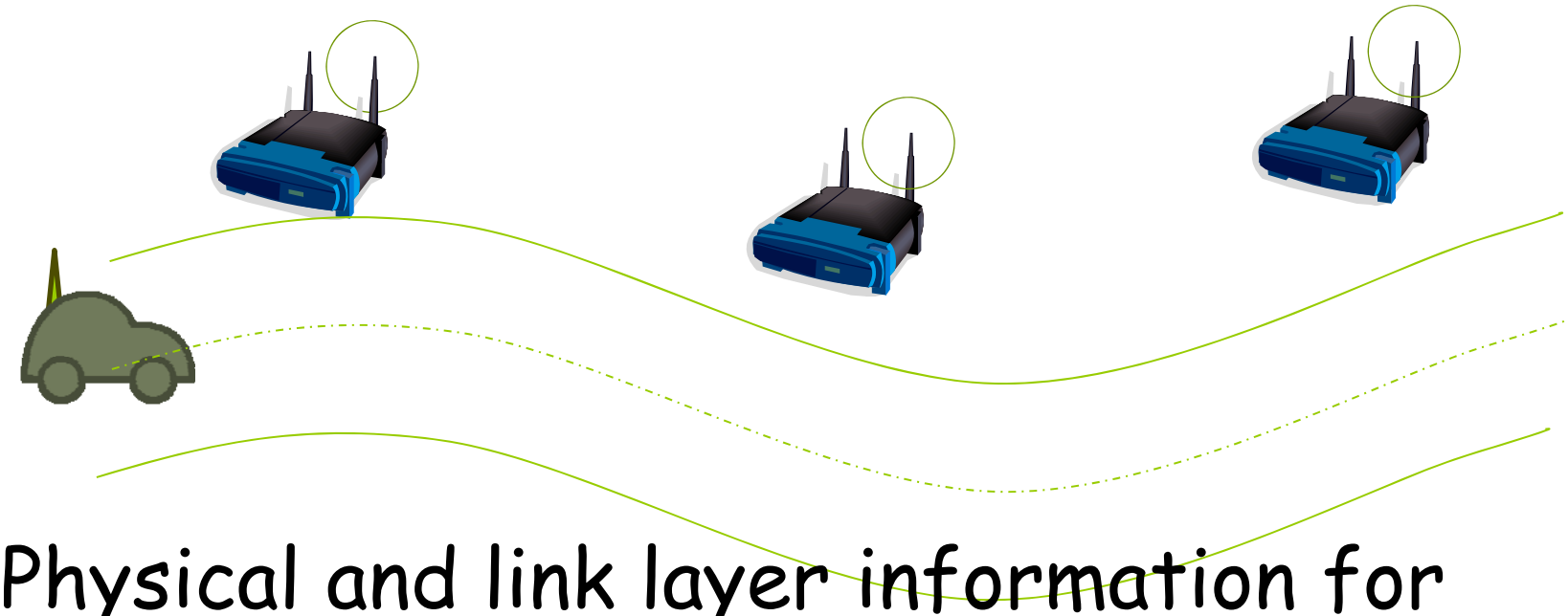




Works only if SNR is stable wrt location

Is SNR Stable?

Data Collection

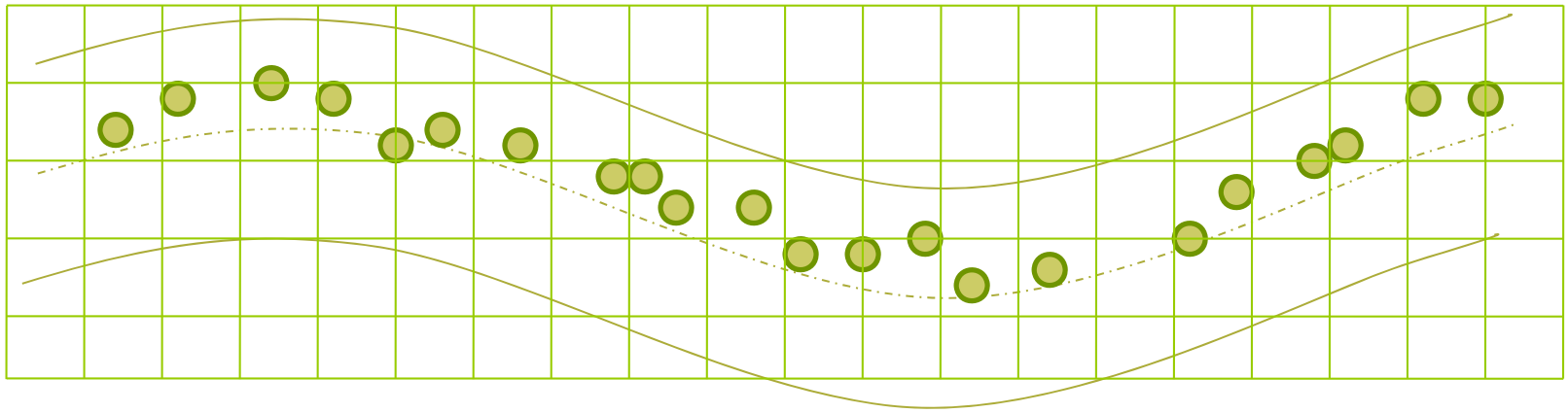


Physical and link layer information for every packet heard from APs logged along with GPS coordinates.

Data collected on two volunteers' cars for 3 and 6 months respectively.

Is SNR Stable?

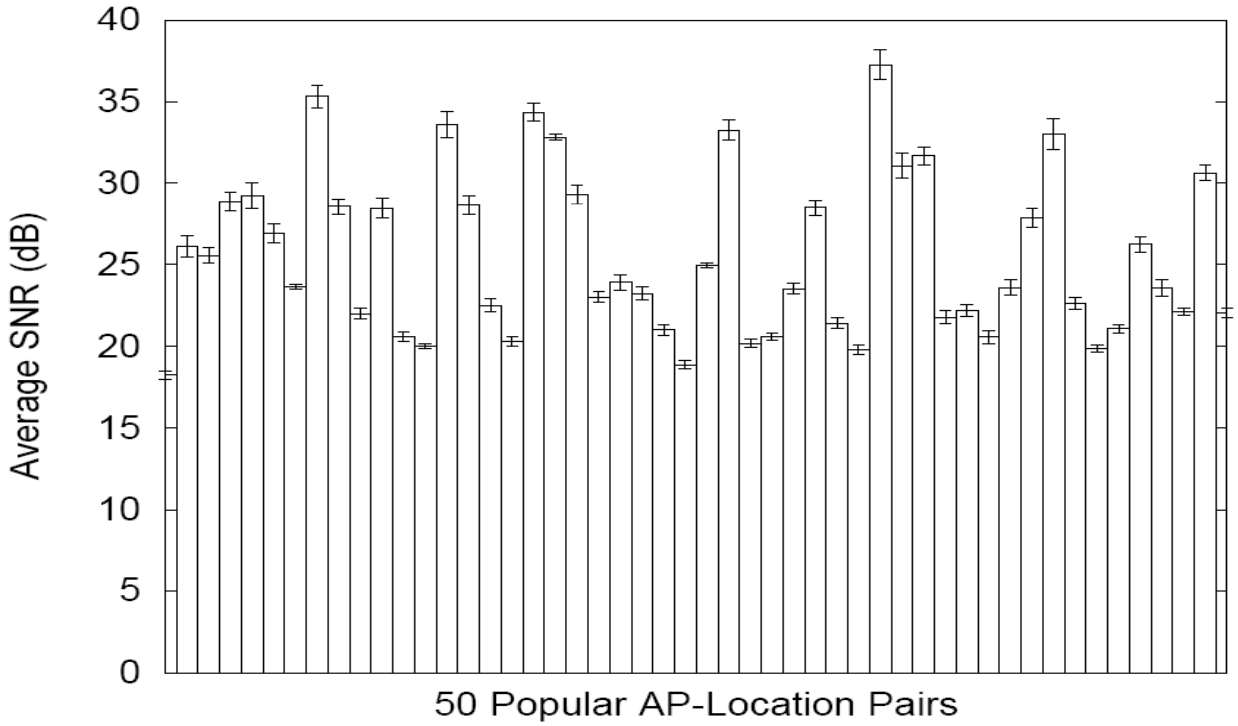
Analysis



- Overlay a 10m x 10m grid.
- All samples mapped to the respective grid square center.
- Compute Average, 90% CI of SNR for each AP-Location pair.

Is SNR Stable?

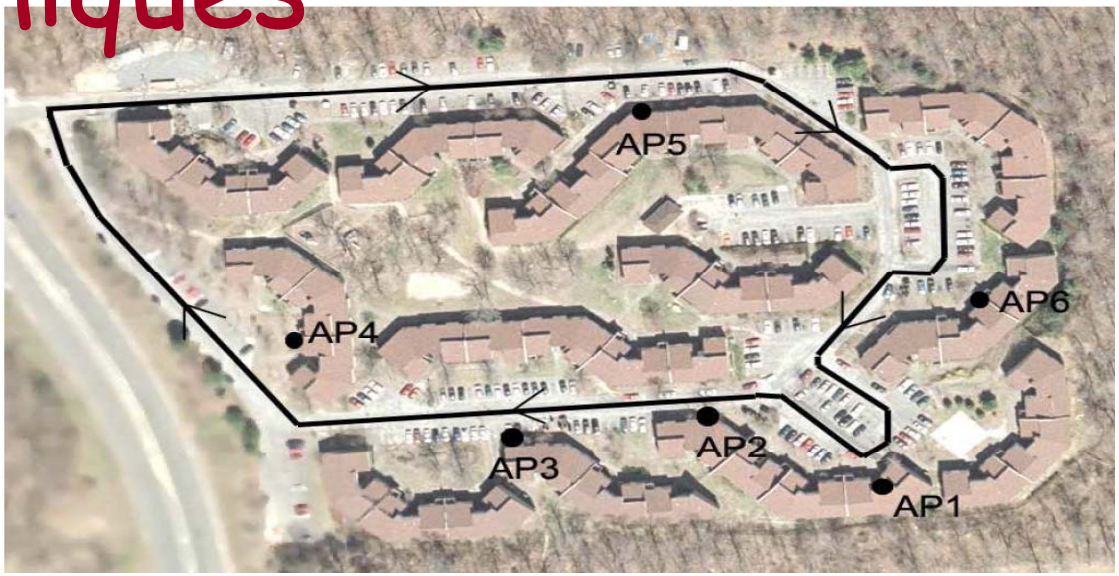
Results



Median overall SNR logged = 22dB

Median width of 90% CI = 2dB

Comparison of Handoff Techniques



Metric	Naive	Best Online	Best Offline (Scripted Handoff)
Avg Throughput (Kbps)	102.6	113.52	232.8
Avg Outage period per AP (s)	36.82	31.2	13.45
Percentage of successful connection establishments	24%	53%	90%

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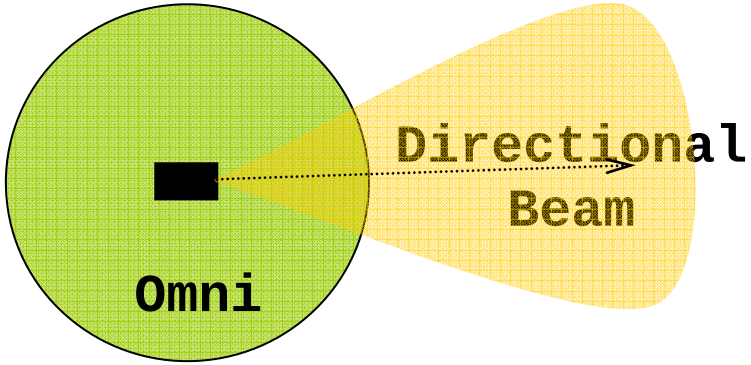
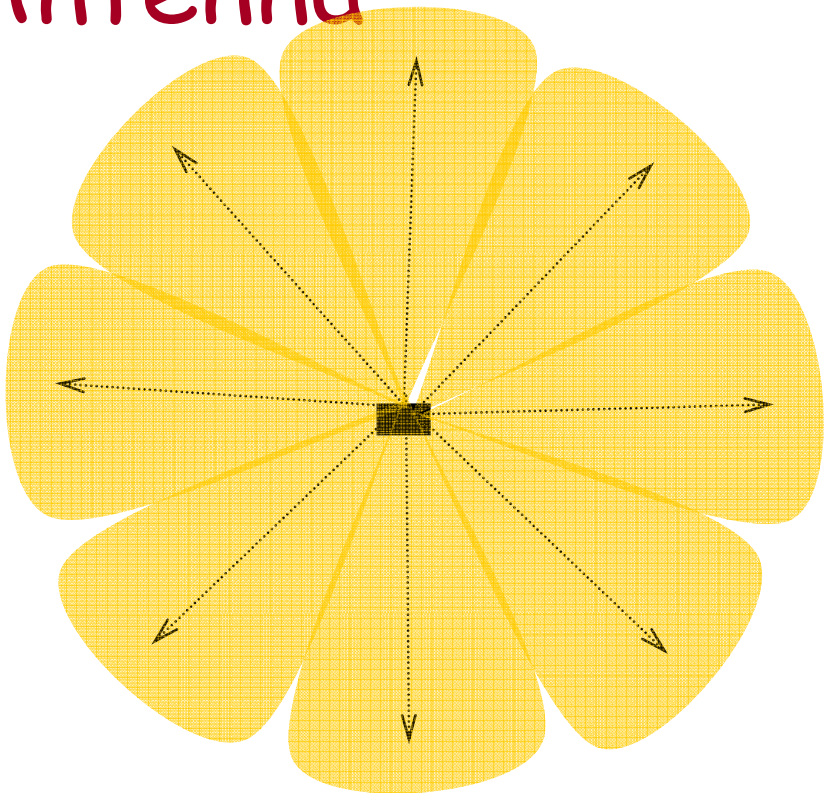
Improve SNR Using Steerable Beam Directional Antenna



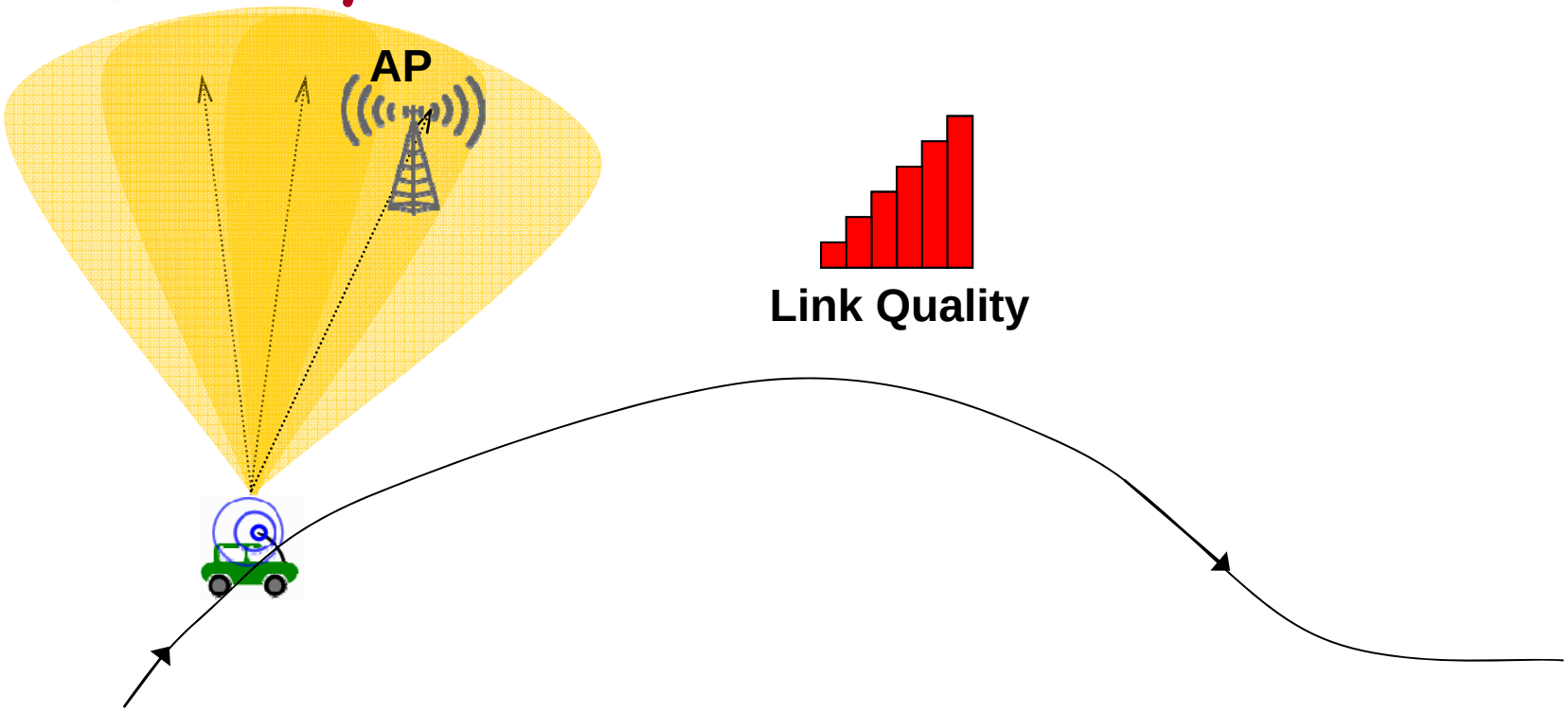
- Higher gain on transmit or receive.

-Translates to higher SNR (better link quality).

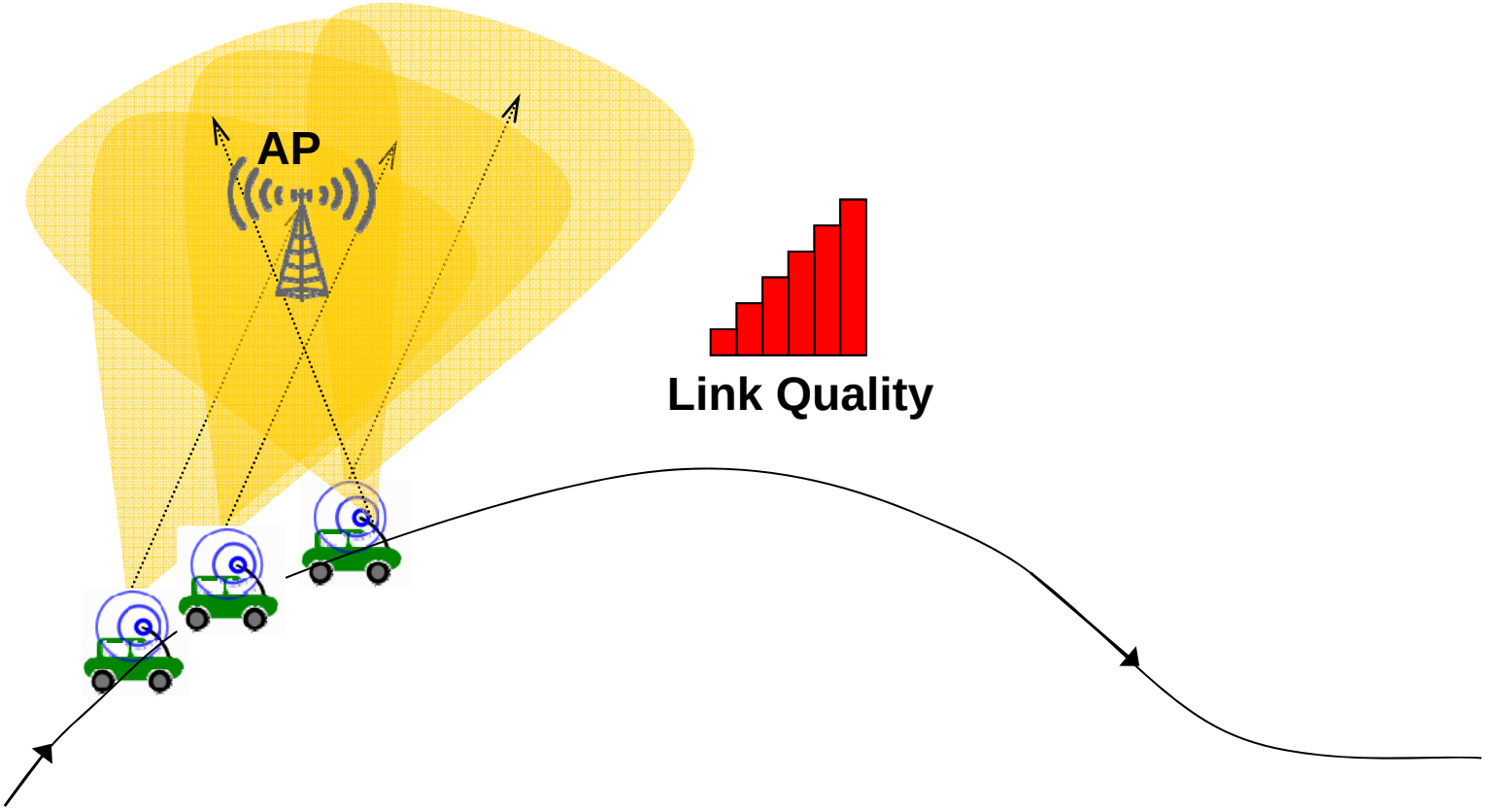


-Beam electronically steerable.

Effect of Beam Steering on Link Quality

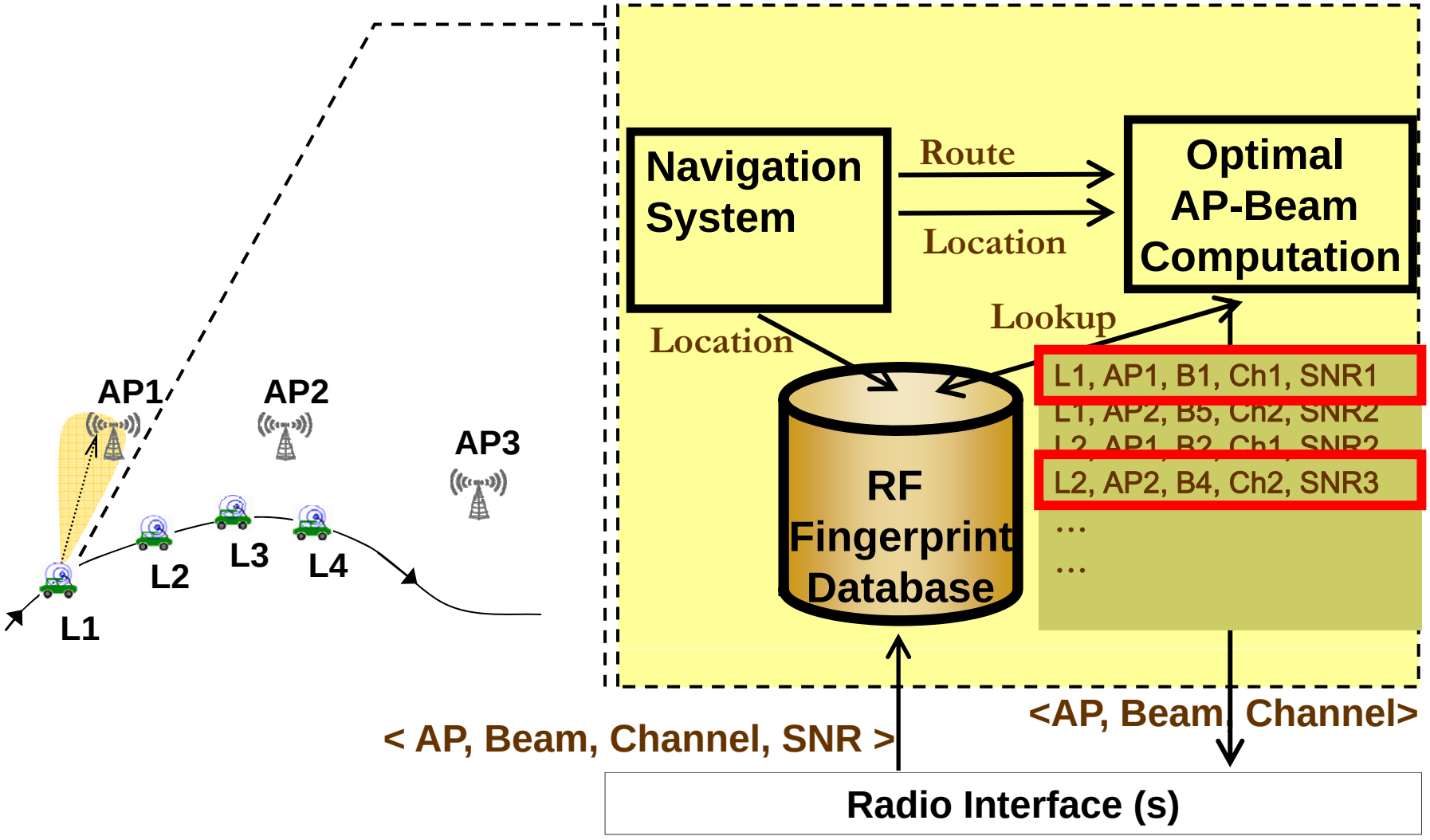


Problem – How to Beam Steer?



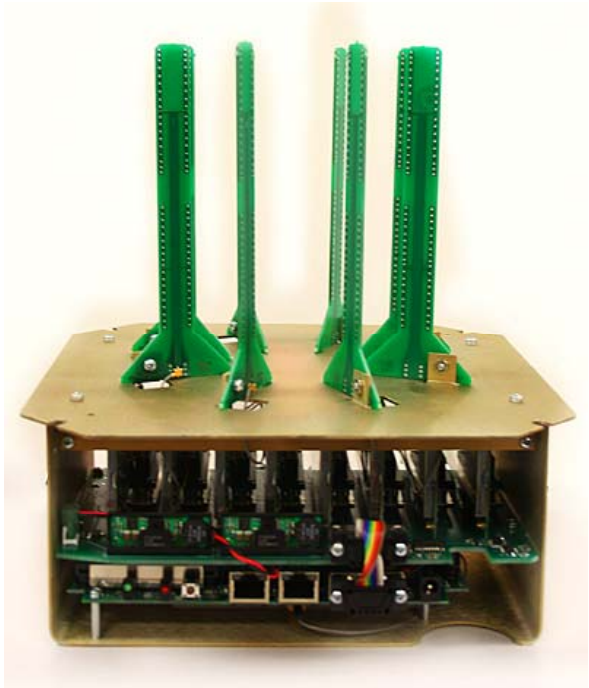
- Need to steer the beam effectively.
- Again can use prior RF fingerprints, but on a per-beam basis.

System Architecture

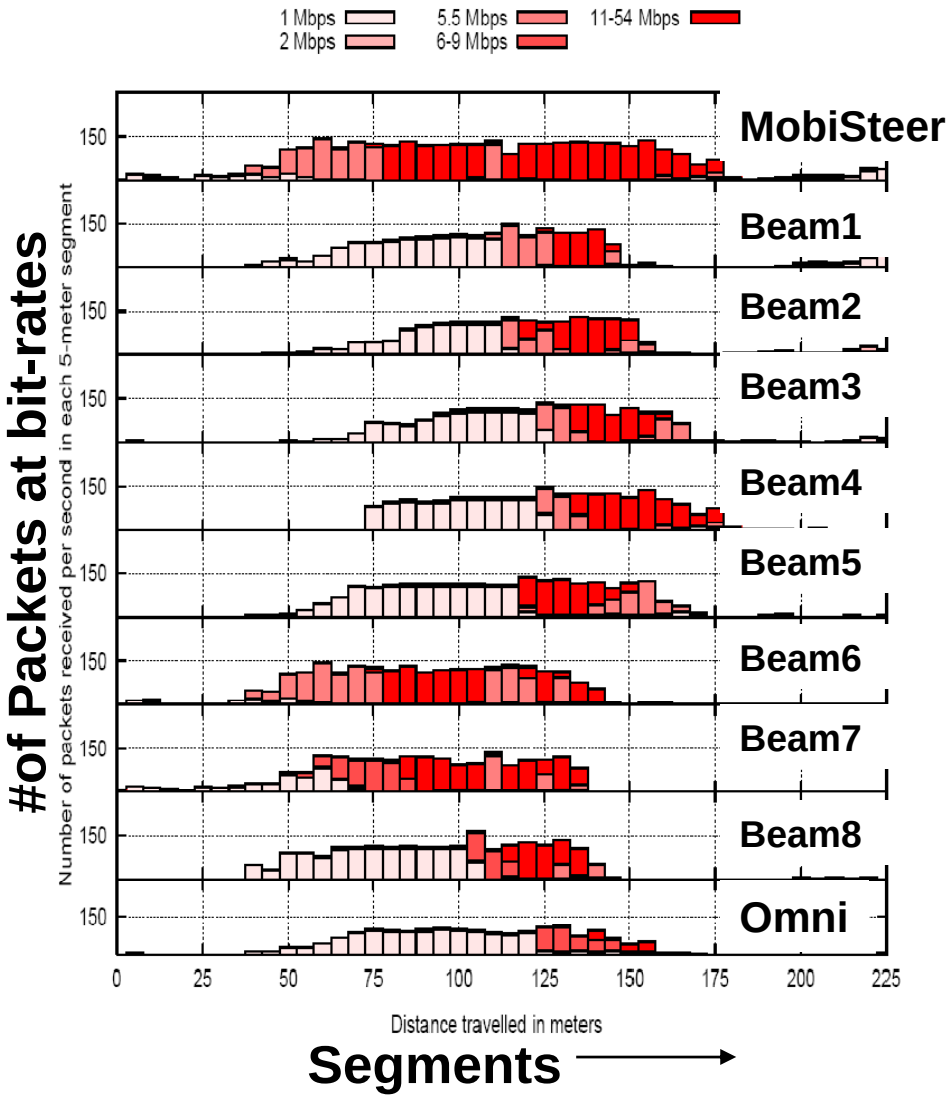


System Prototype

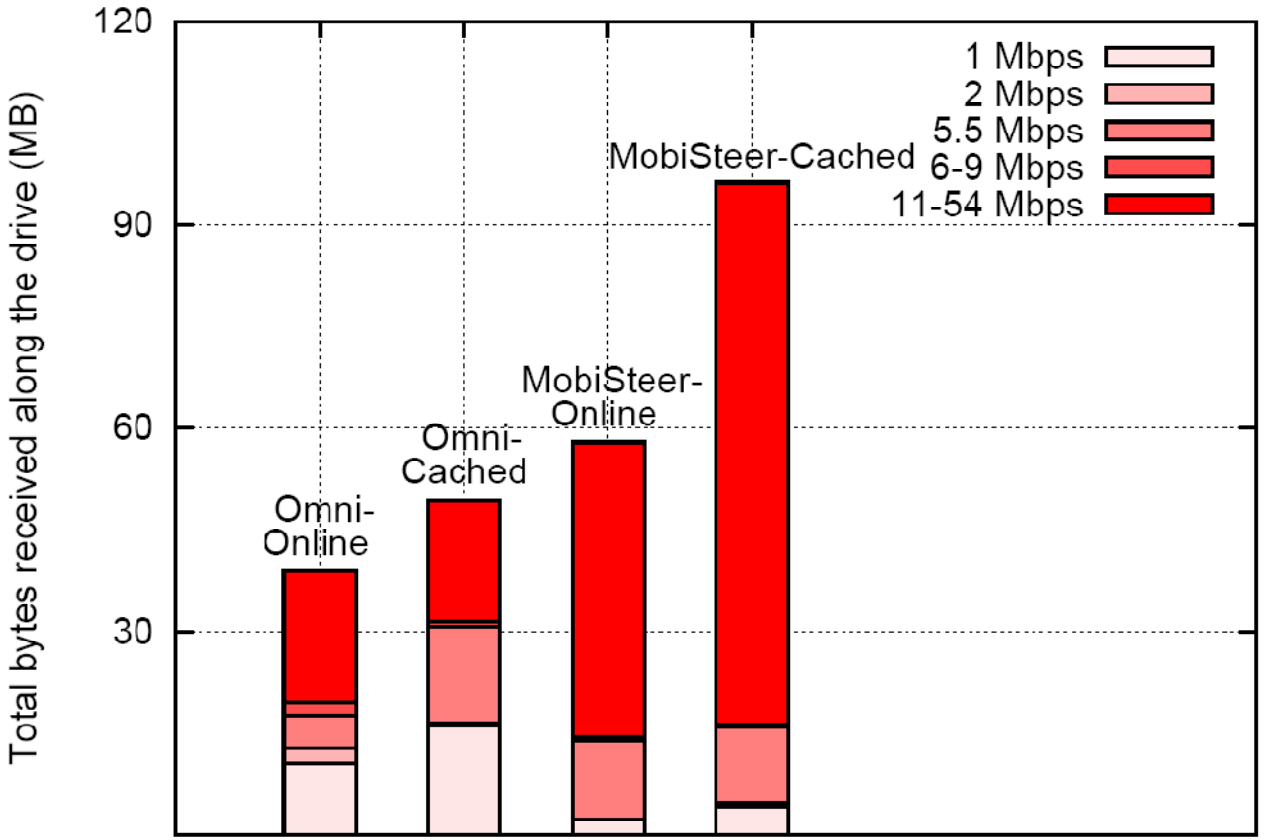
- Phocus Array Steerable Antenna system from Fidelity Comtech
  - 8 Beams - 45° beam width/ 15dBi gain
  - Atheros 802.11b/g radio
  - 250usec beam steering



Controlled Experiments



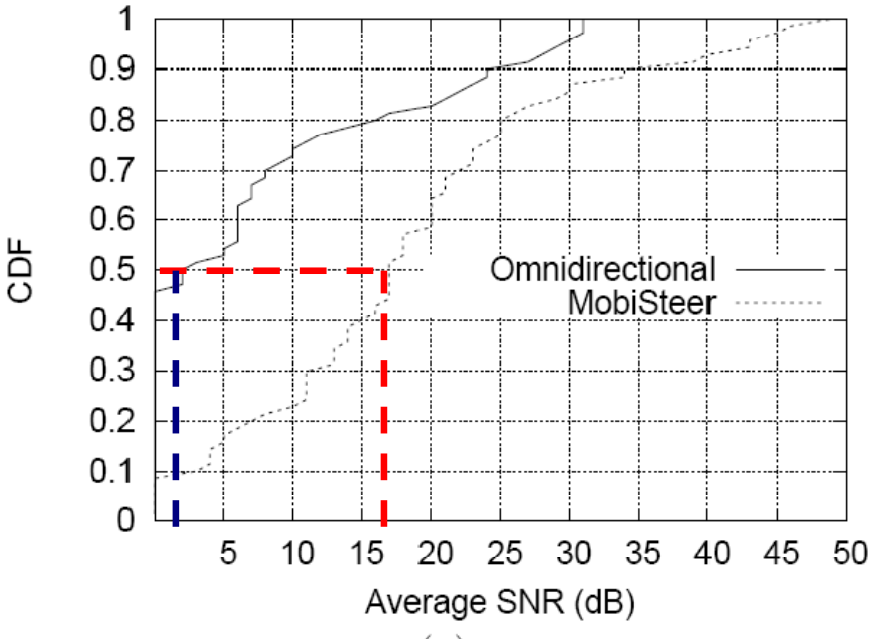
Online vs Cached



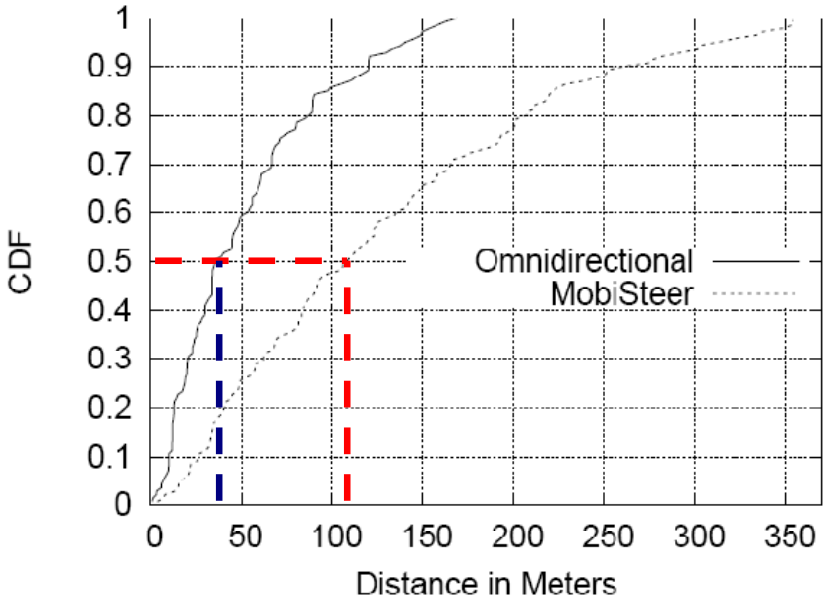
1. **MobiSteer Online lower than Cached by 39%**
2. **Online still better than Omni by 50%**
3. **Caching benefits Omni too**

In-Situ Experiment

Uses APs in the neighborhoods around campus.



Around 14dB gain in link quality (SNR)



2.5x improvement in range

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[MIT CarTel project]

- Can downloads be pre-fetched at APs?

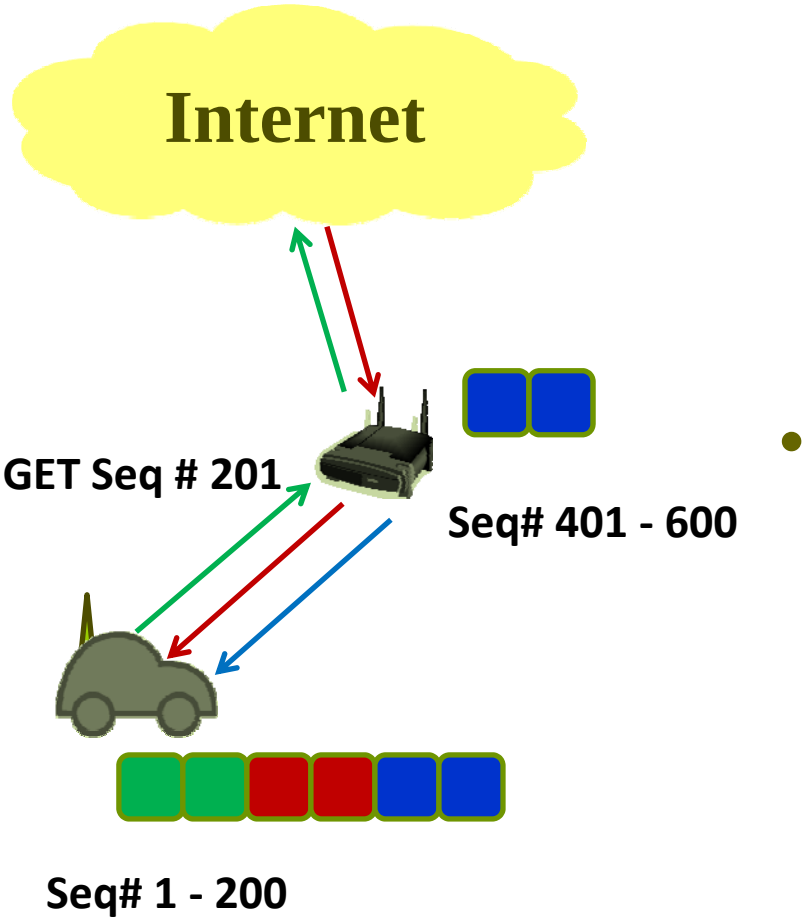
Prefetching Downloads

- Imagine large downloads.
- Predict mobility from historical data (which APs at what times).
- Predict amount of download possible from historical data (SNRs from RF fingerprints).
- Prefetch portions of the file at future APs according to the prediction.

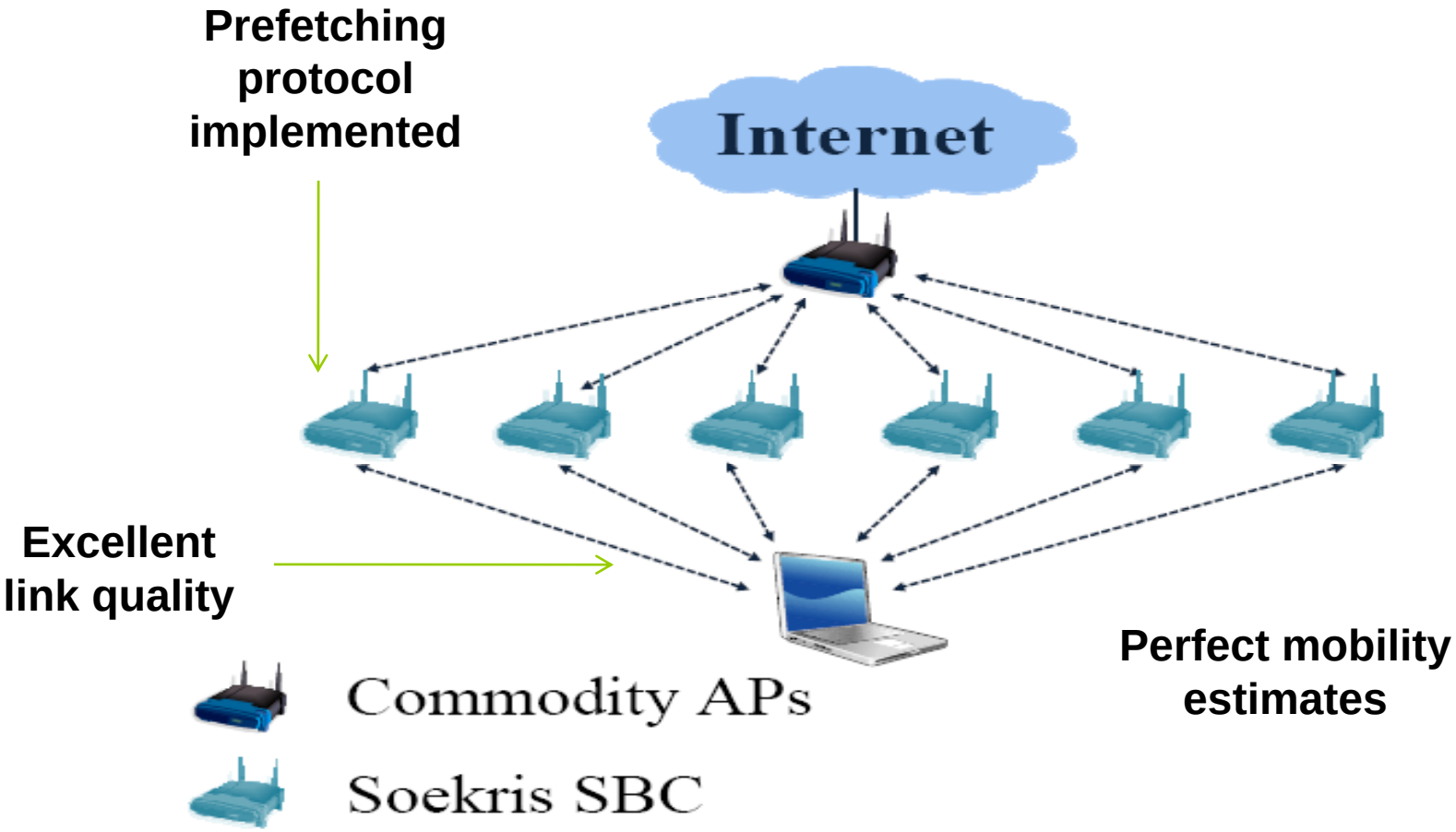
- PF_REQUEST(<AP_{k+1}, s_{k+1}, e_{k+1}>, …,
- <AP_{k+n}, s_{k+n}, e_{k+n}>)

Download Methods

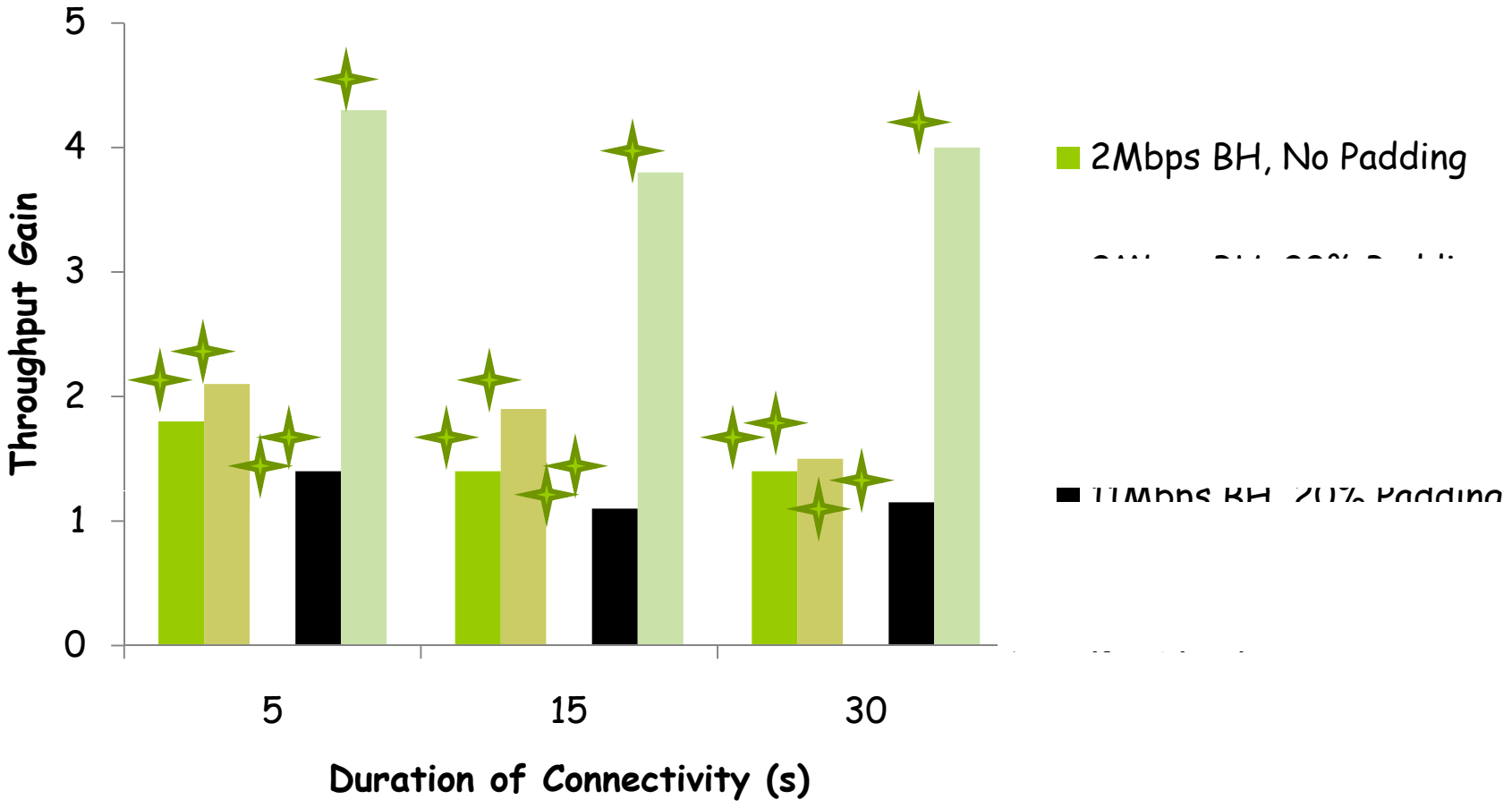
Sequential Download



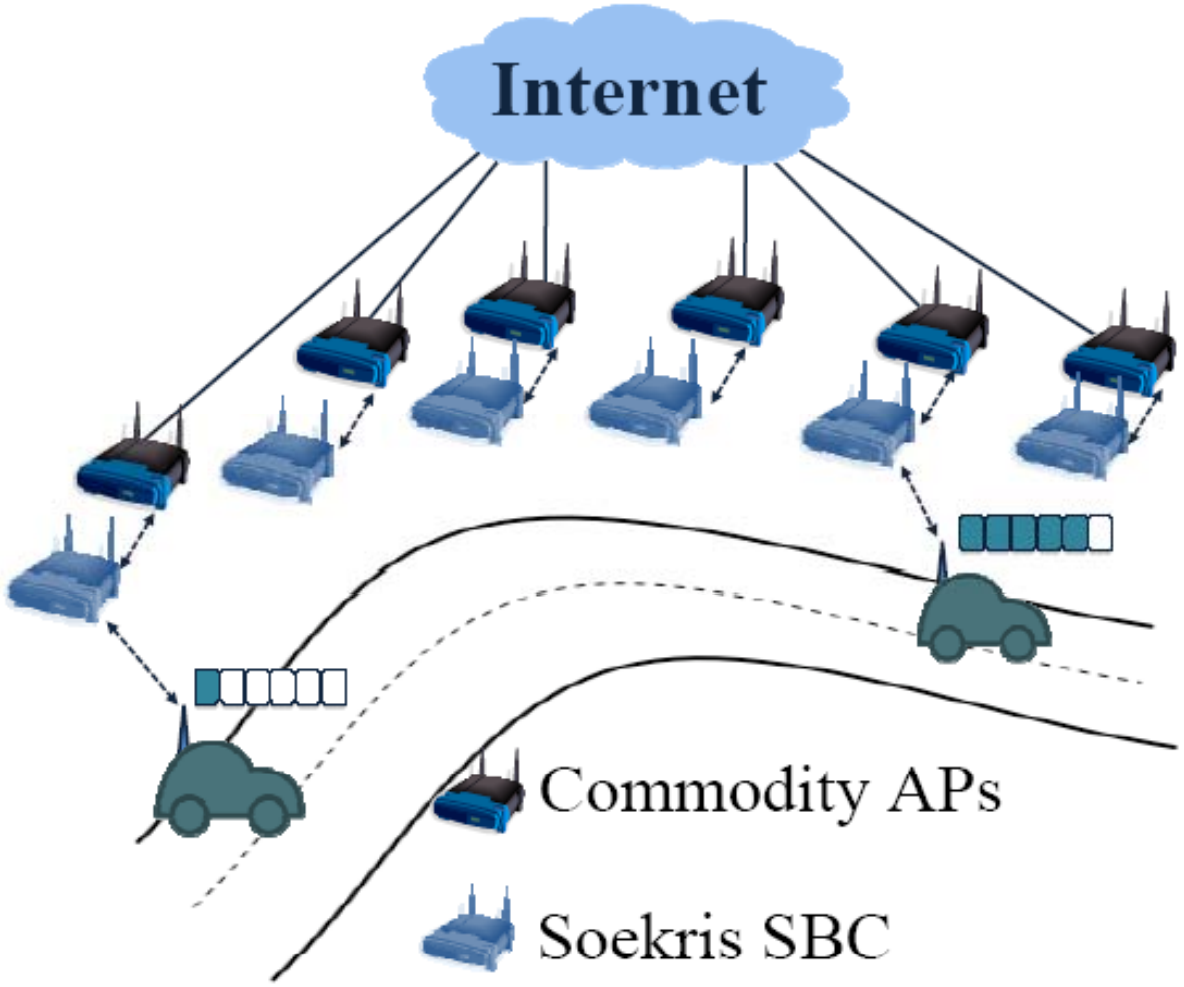
Simulated Driving Experiments



Simulated Driving Experiment Results

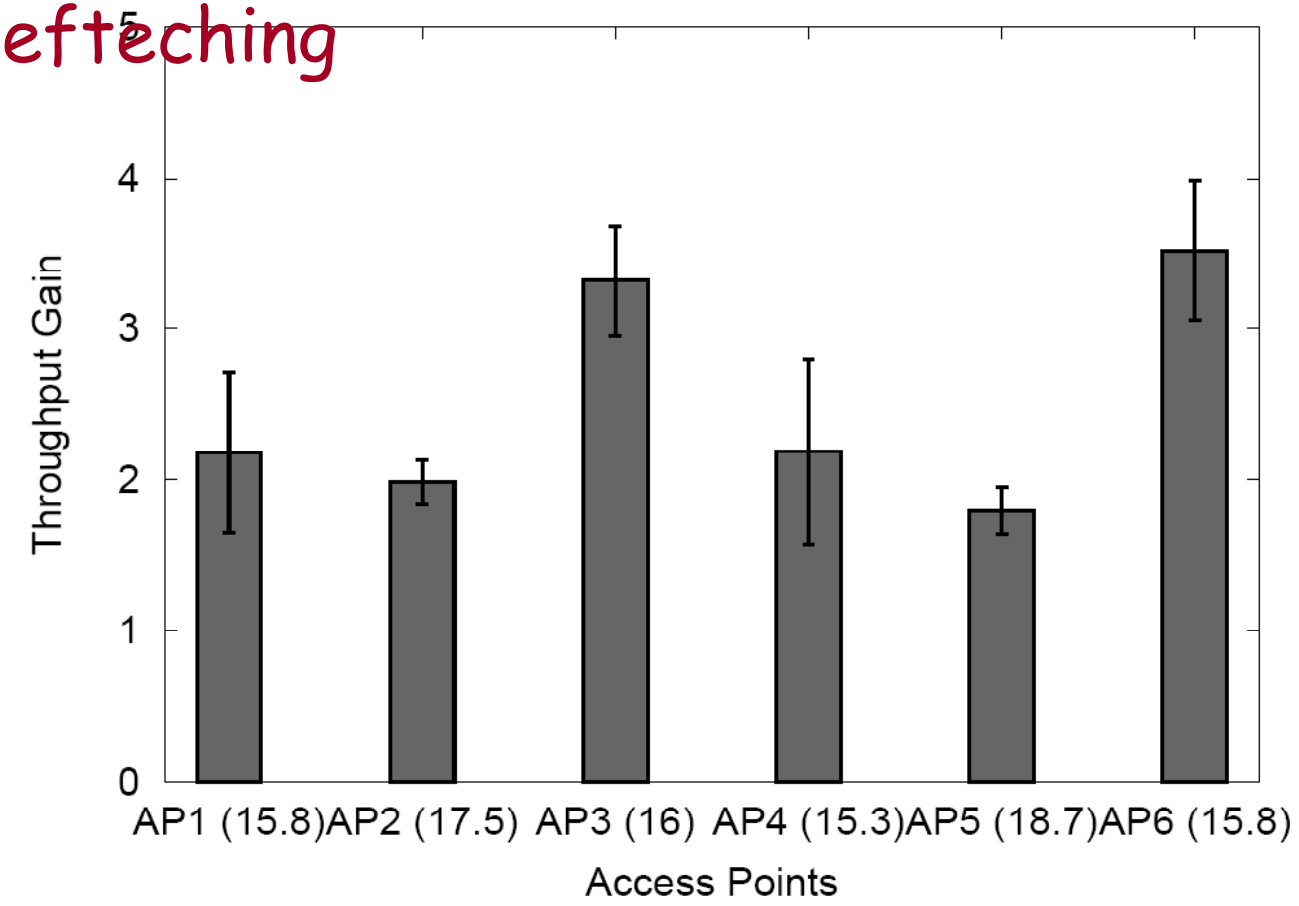


Driving Experiments
Non-Sequential Download



Driving Experiments

Non-Sequential Download – Improvements over no-prefteching



Aggregate performance improvement over no prefetching is 2.5

Summary

- Scripted handoffs and beam steering using prior RF fingerprints can offer significant improvement in WiFi link and handoff performance in vehicular environments.
- Prefetching and non-sequential downloads can further improve performance.

Thank You!

Papers (MobiSys07, Infocom08, VANET08, MobiSys09) and also some data traces available via http://wings.cs.sunysb.edu