Microsoft Research

Mobility & Networking Research

To invent technologies that make Microsoft's mobile devices, services & networks indispensable to the world

February 19, 2013

Today's focus

VEHICULAR NETWORKING
(1998, 2006-12)

Sharad Agarwal * Aruna Balasubramanian * Ranveer Chandra * Ratul Mahajan * Jitu Padhye

Victor Bahl

Vehicle to Internet connectivity

Increasingly common, provided by many public transit agencies and corporations

Riders love the facility

- Boosts ridership
- Enhances productivity
- Provides entertainment

…but performance can be poor

Routinely heard from service operators:

- *"there can be lapses in the backhaul coverage or system congestion"*
- *"cancel a failed download and re-try in approximately 5 minutes"*

Presentation outline

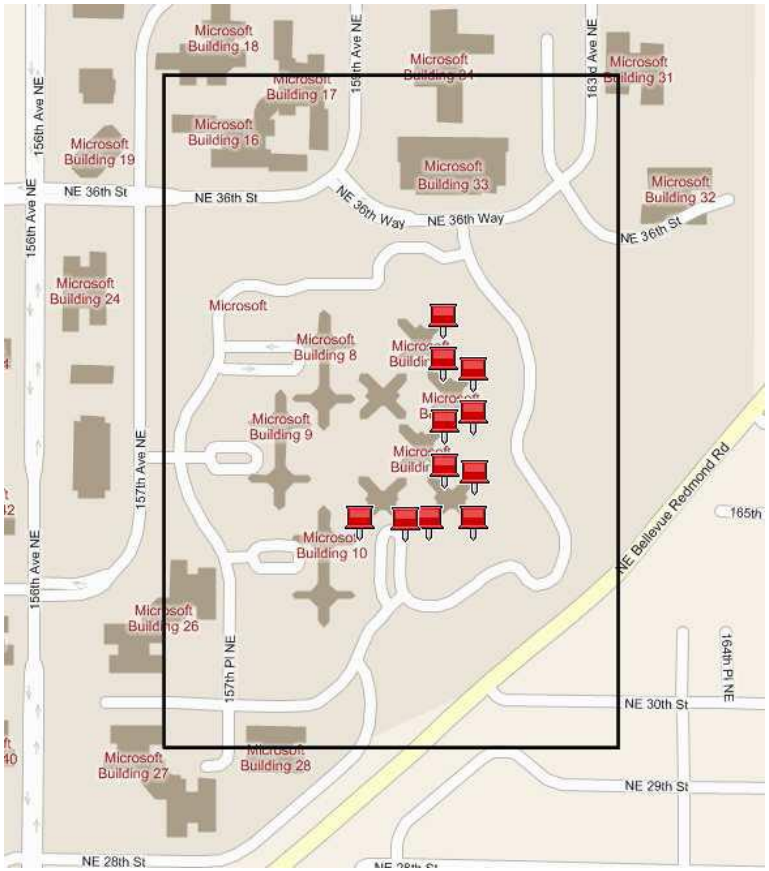
- Wi-Fi Internet connectivity for moving vehicles (2006-07)
- Offloading to Wi-Fi Access Points (2007-08)
- Smart Handoffs (2008-09)
- Connectivity via White Spaces (2007- present)
- Improving WWAN connectivity via OEC (2008-10)
- Cloud services for mobile (2009- present)

Connectivity

GOAL: BUILD THE MOST SPECTRUM EFFICIENT AND WELL-CONNECTED MOBILE DEVICES IN THE WORLD

Understanding Wi-Fi connectivity from moving vehicles (2006-07)

MSR's VanLAN Campus Tetbed

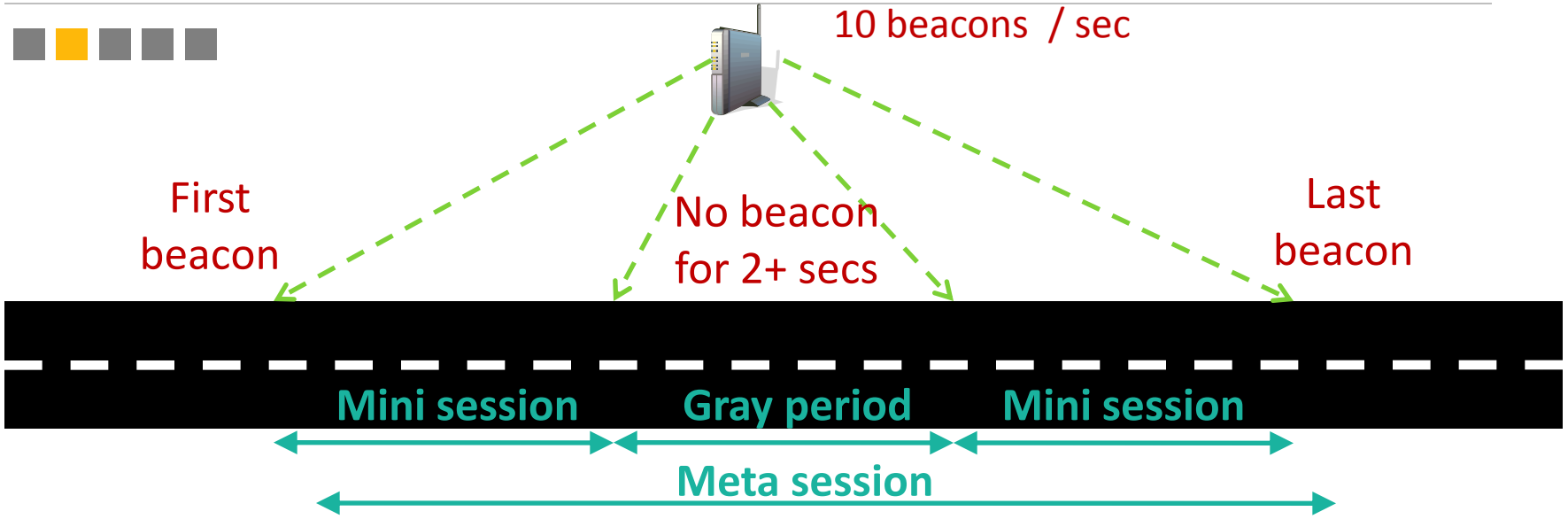


Uses MS campus vans

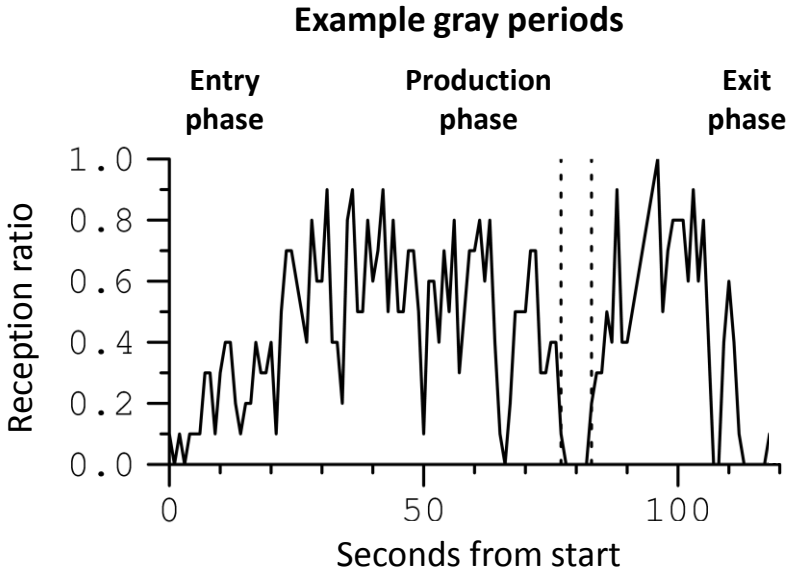
Base stations are deployed on roadside buildings

2 Vans, 11 Access Points / Base stations

Characterizing Vehicle-to-AP connectivity

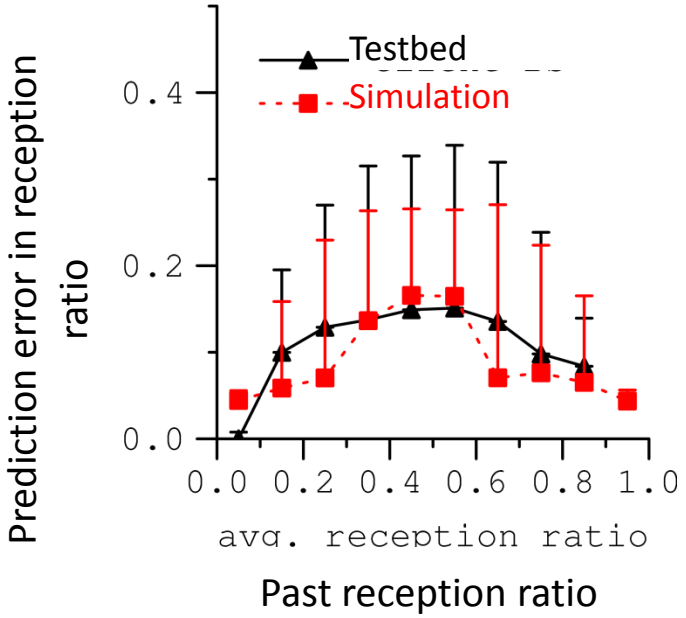


Observed behavior does not match earlier observations in controlled environments

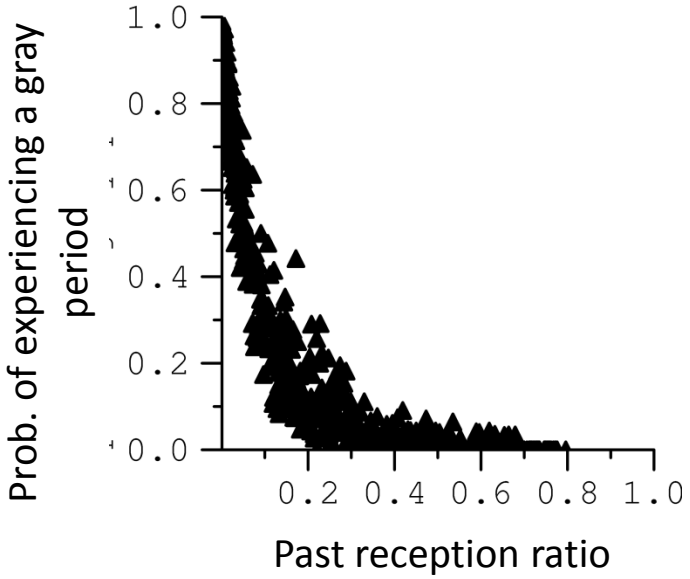


Learning: Historical information helps

Predicting performance at a location



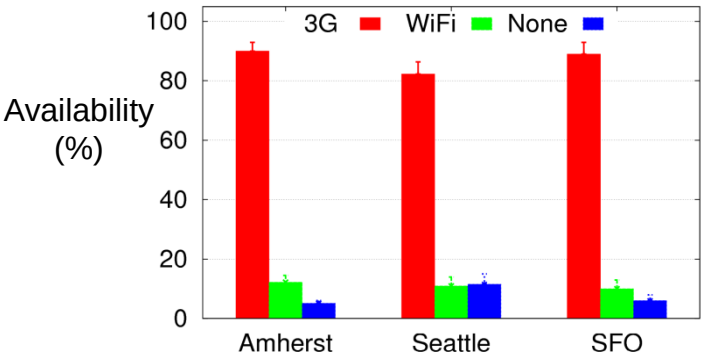
Identifying regions prone to gray periods



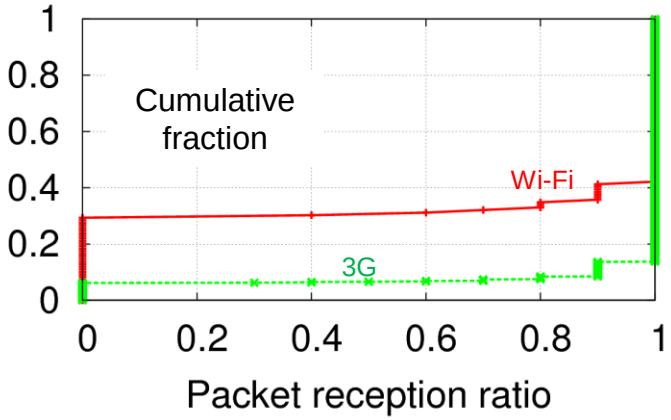
Can Wi-Fi augment 3G?

- Amherst (20 busses), Seattle (2 Vans, 1 car), San Francisco (1 car)

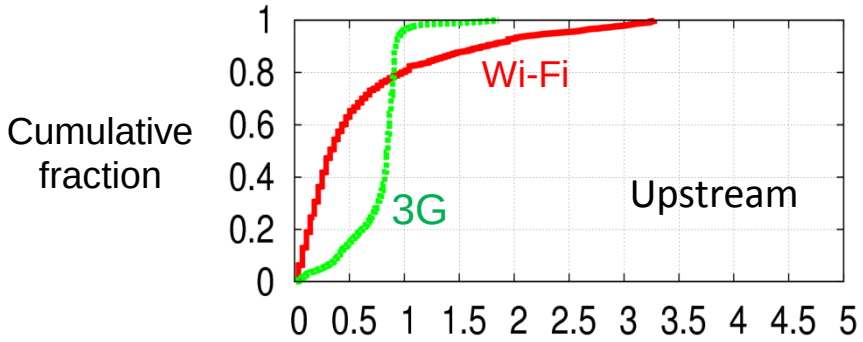
Wi-Fi availability is low

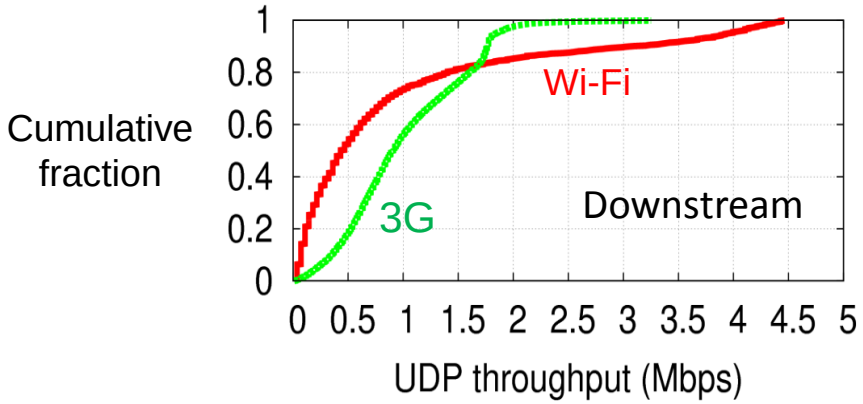


Wi-Fi loss rate is higher



Wi-Fi (802.11b) throughput is lower





Implications : normal offload strategies lead to poor application performance

Adding smarts to offloading

1. Prediction-based offloading

Increase data offloaded to Wi-Fi

Delay data transfers only if that reduces 3G usage

Transfer requirements: S bytes by D secs.

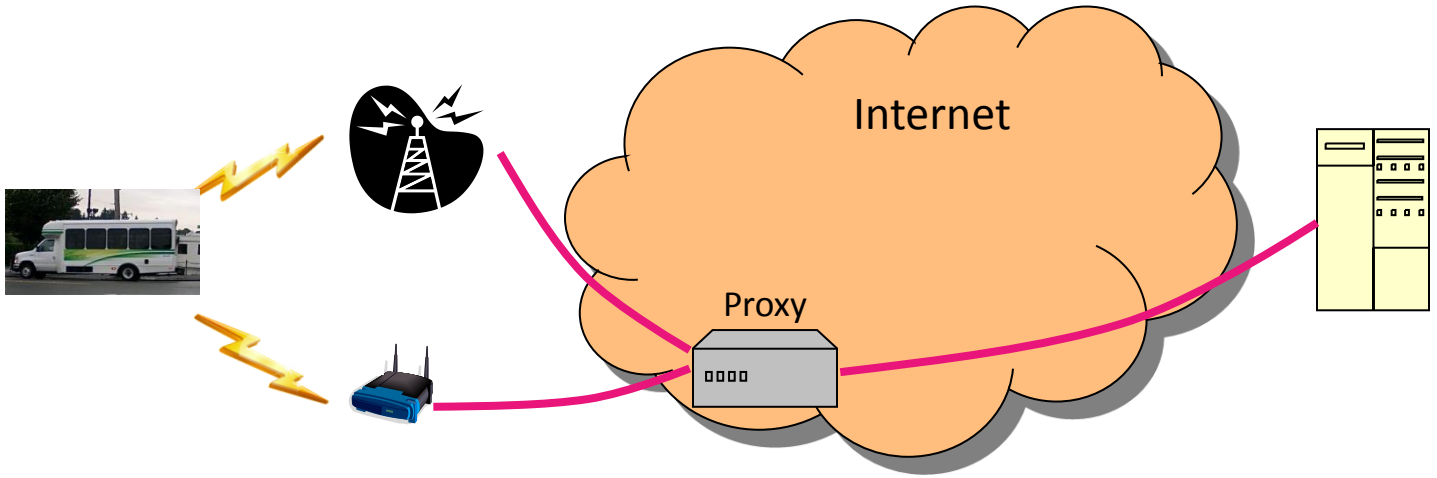
- W = Predicted Wi-Fi capacity over future D secs.
- Send data on 3G only when ($W < S \cdot c$)
- Send data on Wi-Fi whenever available

2. Fast Switching

Combat poor Wi-Fi connectivity

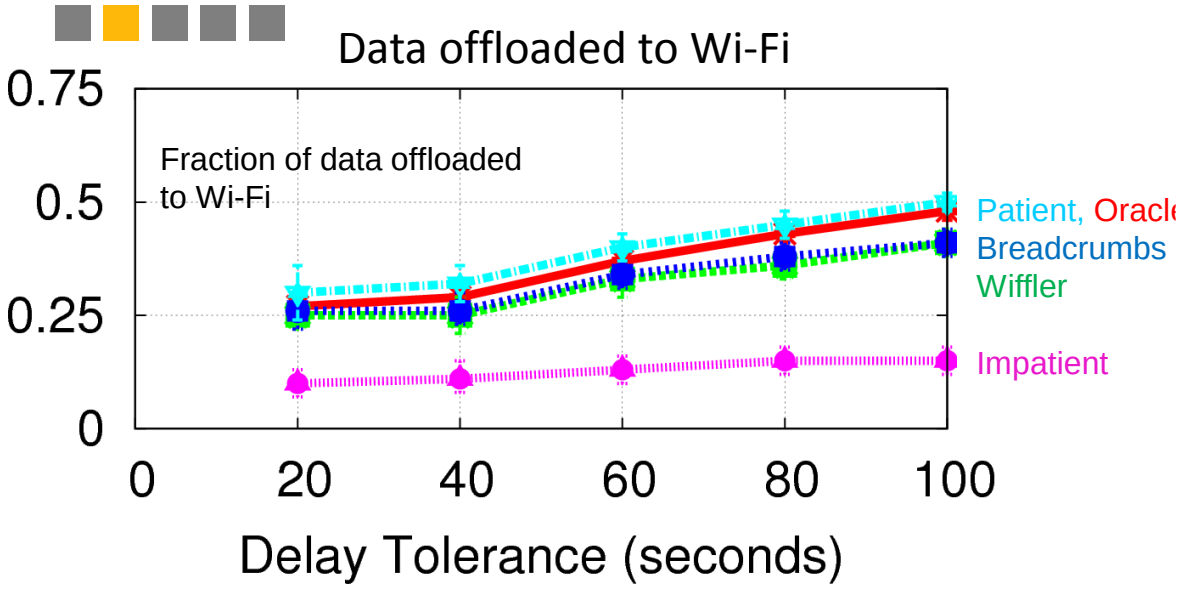
Send the packet on 3G if Wi-Fi does not succeed within a threshold

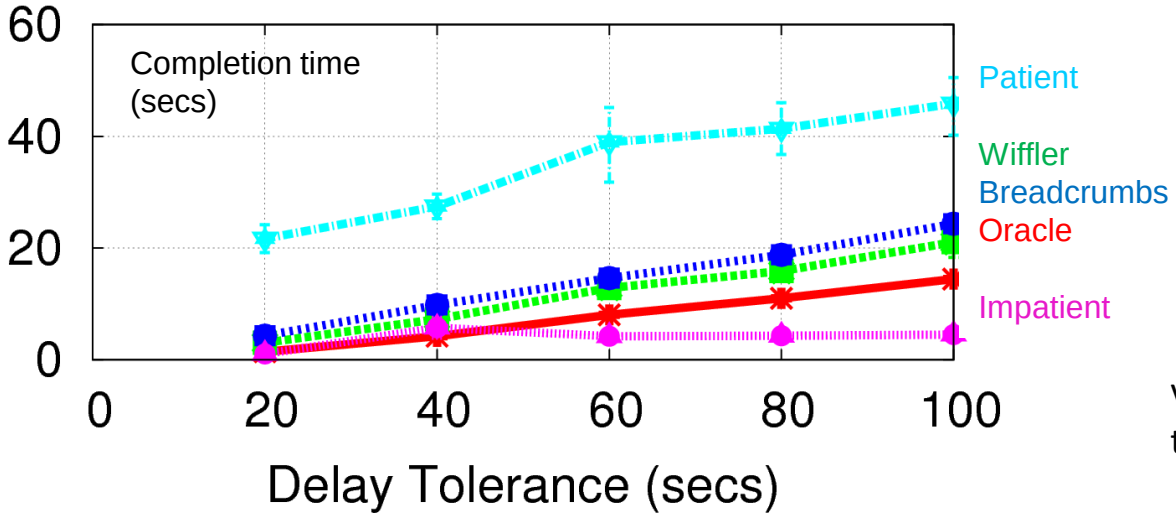
- Link-layer retransmissions take time
- Losses are bursty



Prediction-based offloading

with fast switching



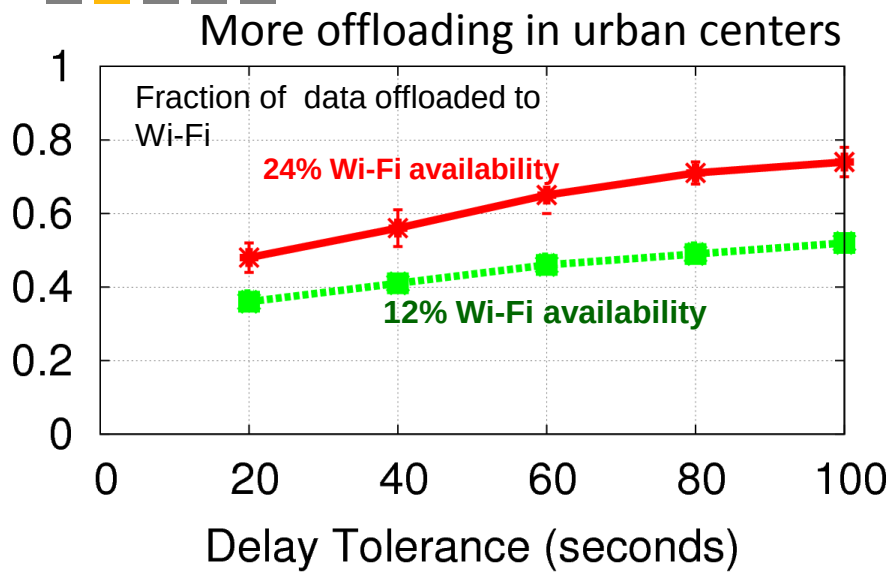


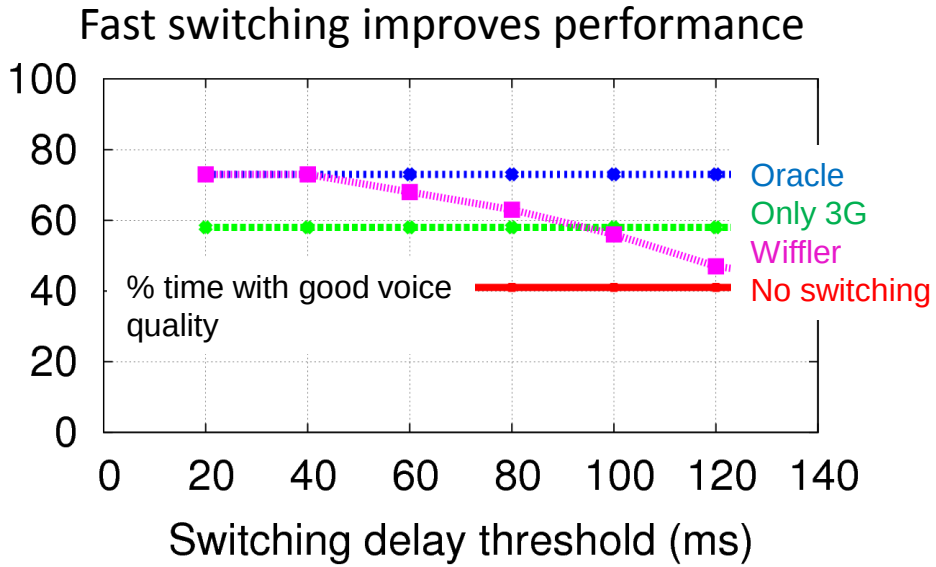
Comparing Strategies

- Impatient: use Wi-Fi when available
- Patient: waits until the delay threshold
- Breadcrumbs: prediction + location history
- Oracle: perfect future knowledge

Vary workload, AP density, delay tolerance, switching threshold

More results

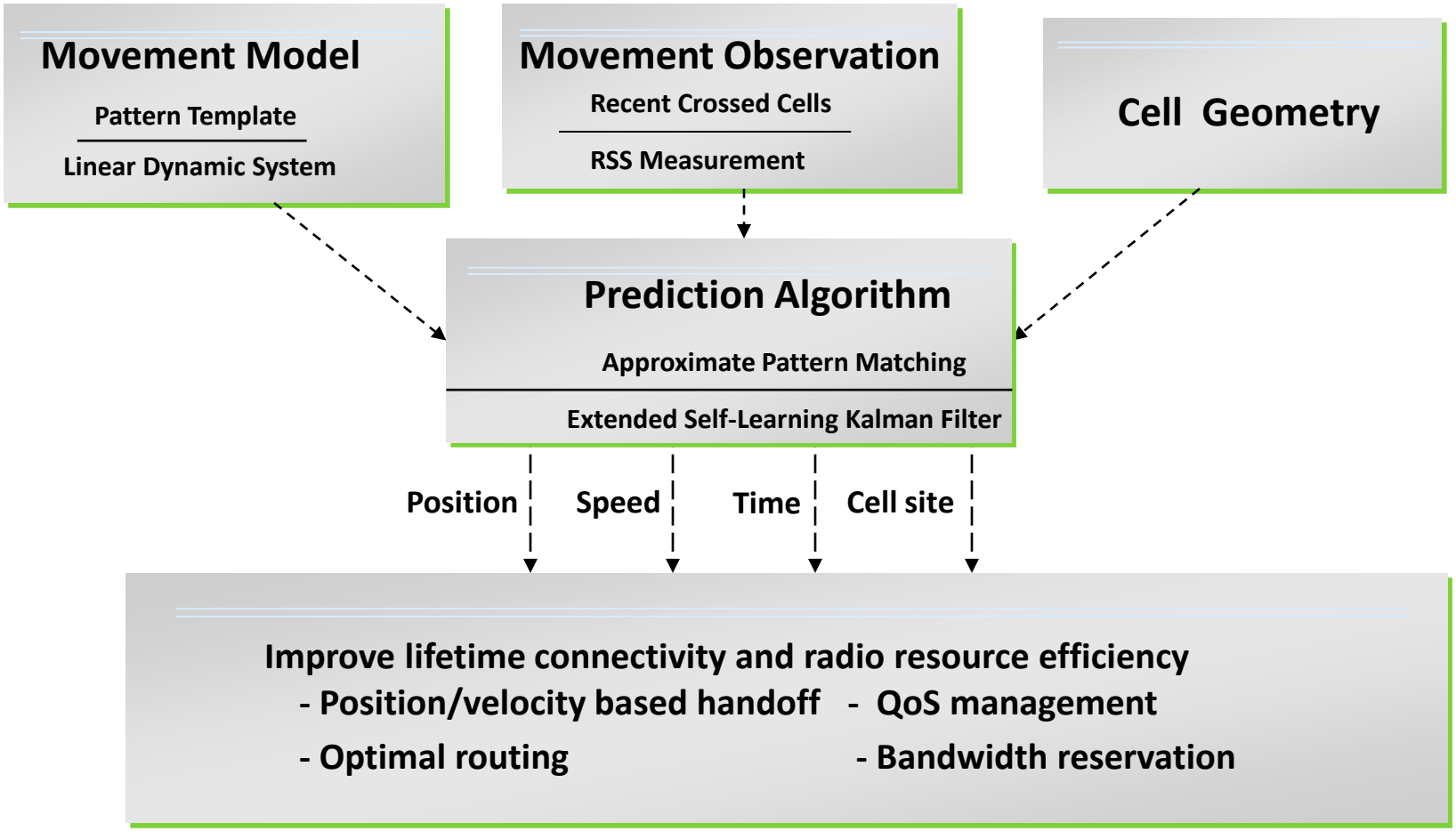




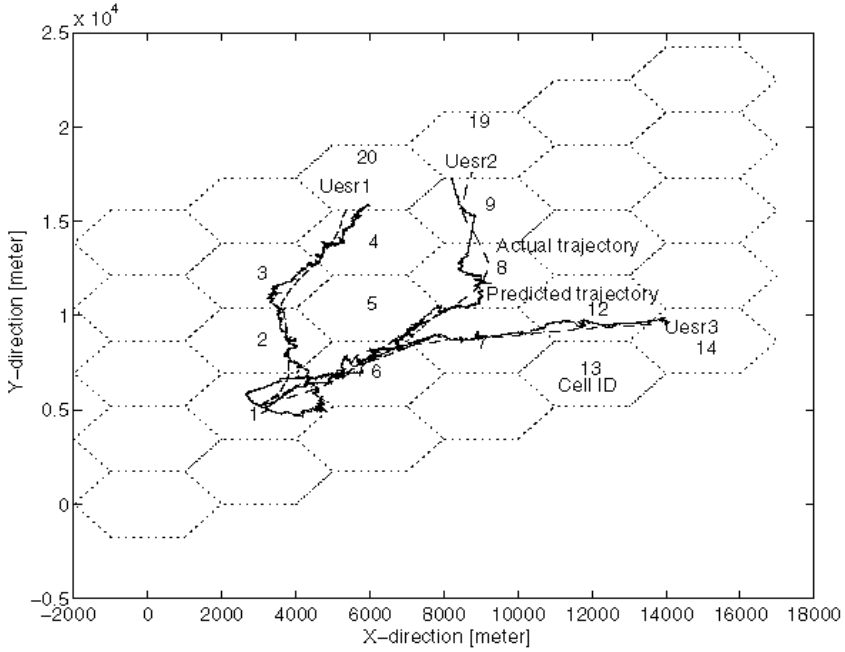
Conclusions

- Offloading to Wi-Fi can augment mobile data transfer capacity and reduce pressure on cellular spectrum
- Prediction-based offloading and fast switching can tackle low-density challenges

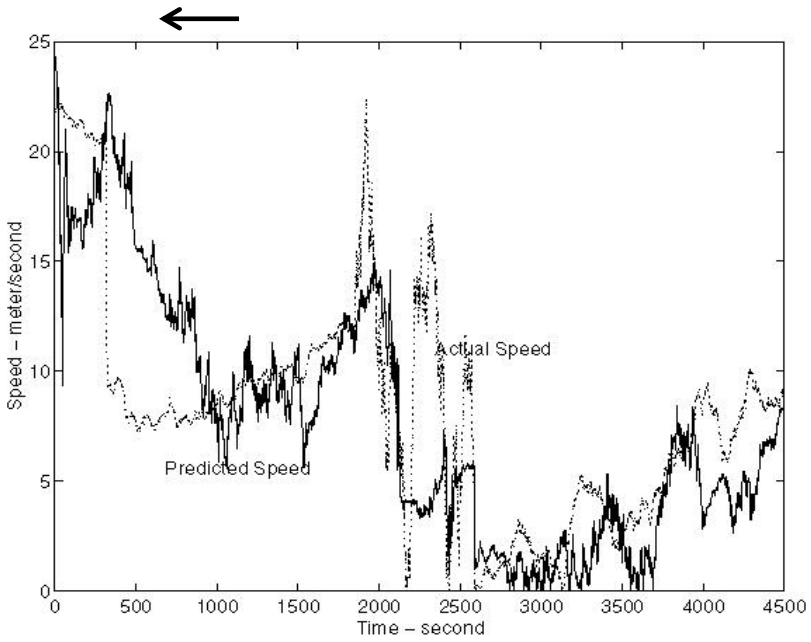
Trajectory prediction



prediction performance



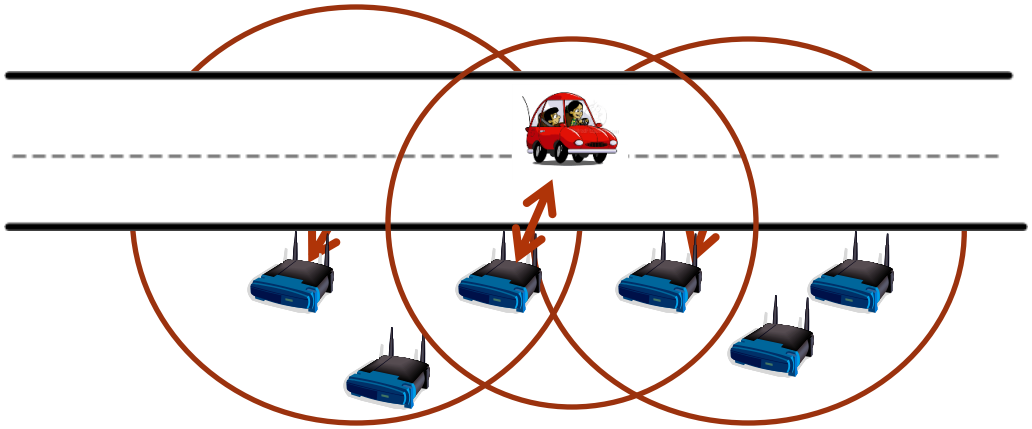
Trajectory Prediction



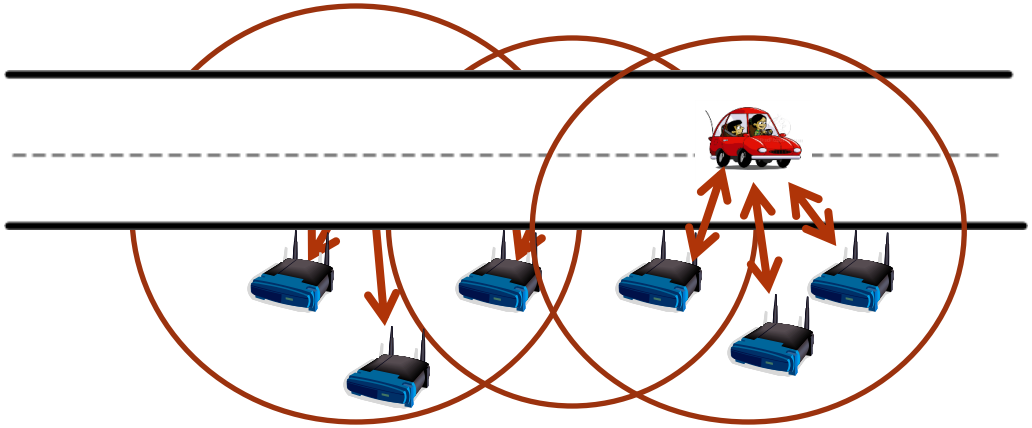
Speed Prediction

Handling handoffs in Wi-Fi nets.

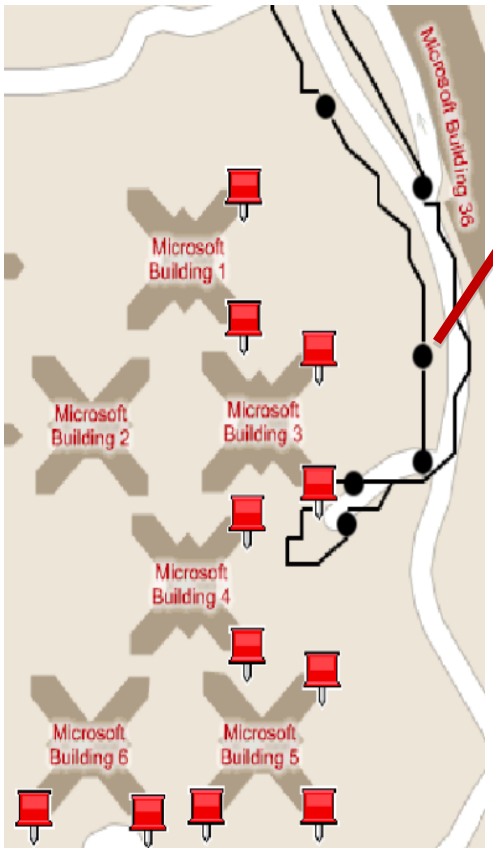
- Hard handoff
  - Clients talk to exactly one BS
  - Current 802.11



- Soft handoff
  - Clients talk to multiple BSes

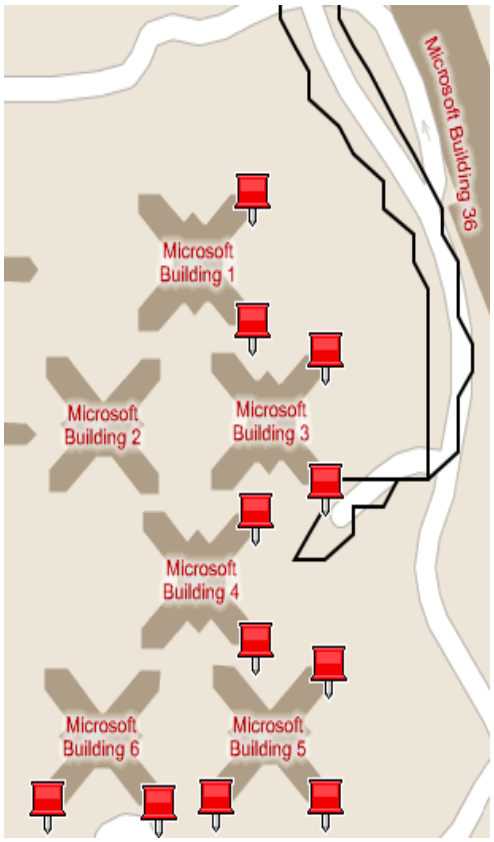


Comparing the two handoff policies



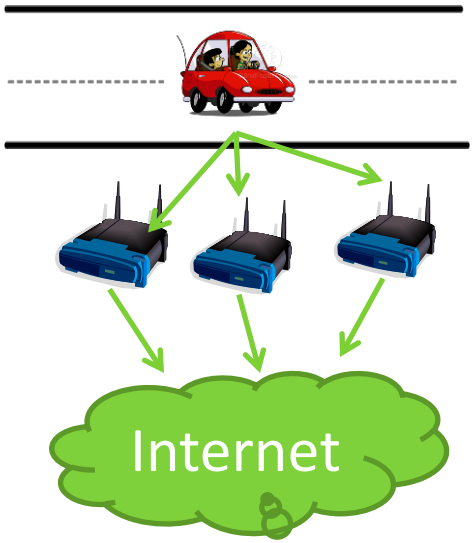
Disruption

Hard handoff



Soft handoff (ideal)

Designing a practical soft handoff policy



- Goal: Leverage multiple BSes in range

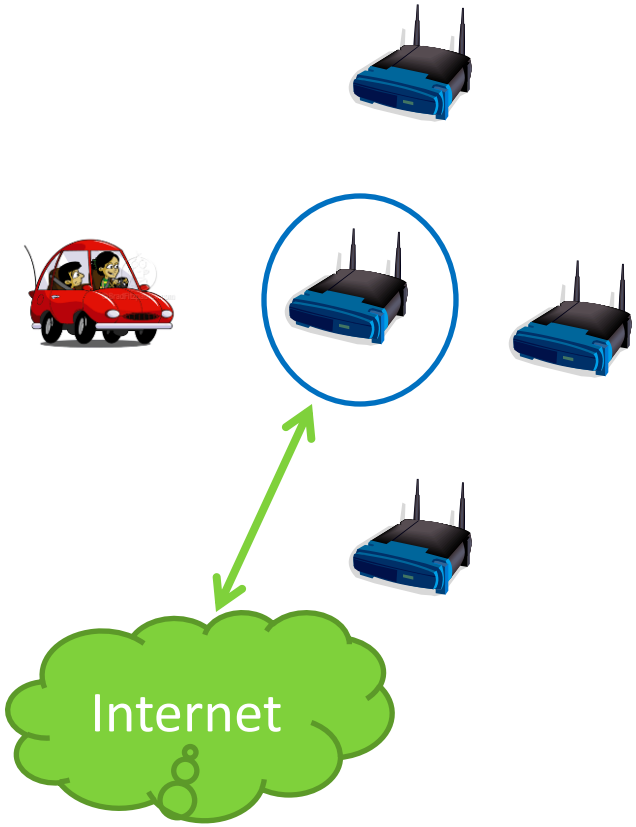
  Inter-BS backplane is bandwidth-constrained

  Ensure timely delivery of packets

  Cannot do fine-grained scheduling of packets

These constraints rule out known diversity solutions

ViFi overview



Vehicle chooses *anchor* AP/BS

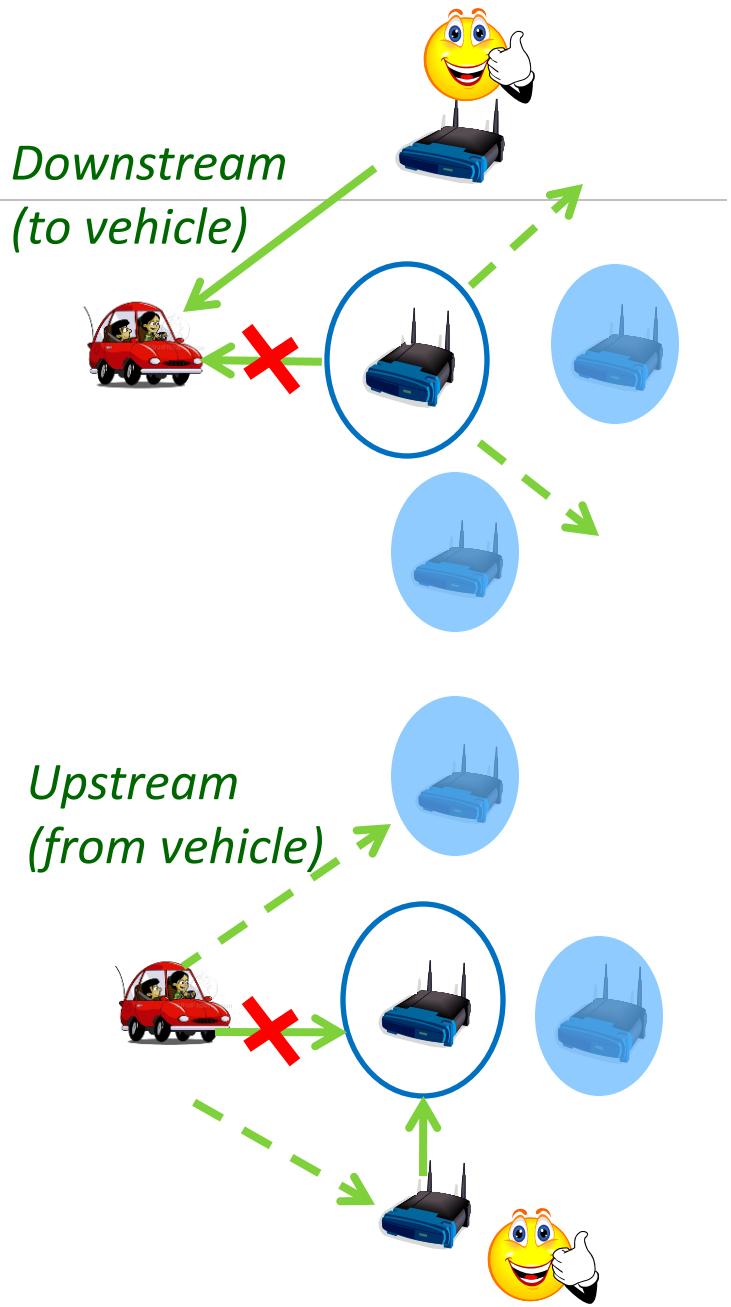
- Anchor responsible for vehicle's packets

Vehicle chooses a set of APs/BSs in range to be *auxiliaries*

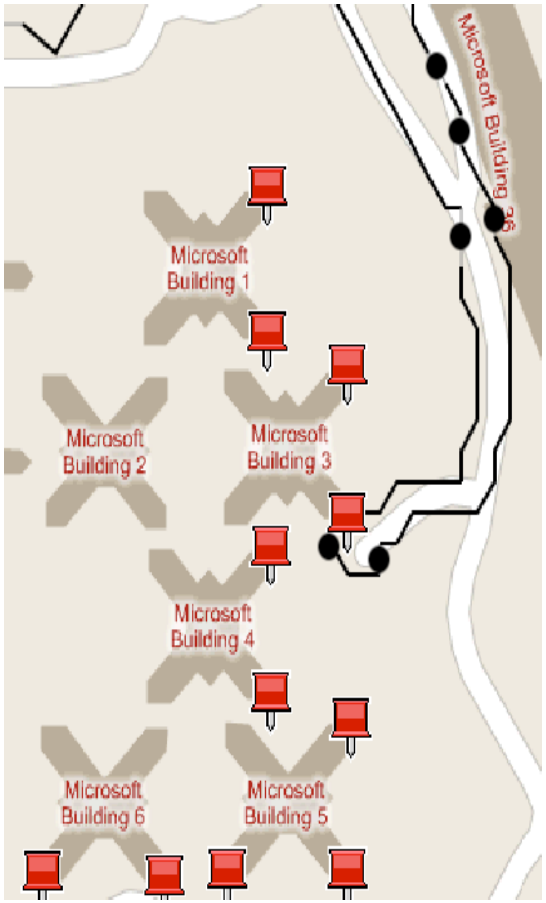
- Leverage packets overheard by auxiliaries

ViFi protocol

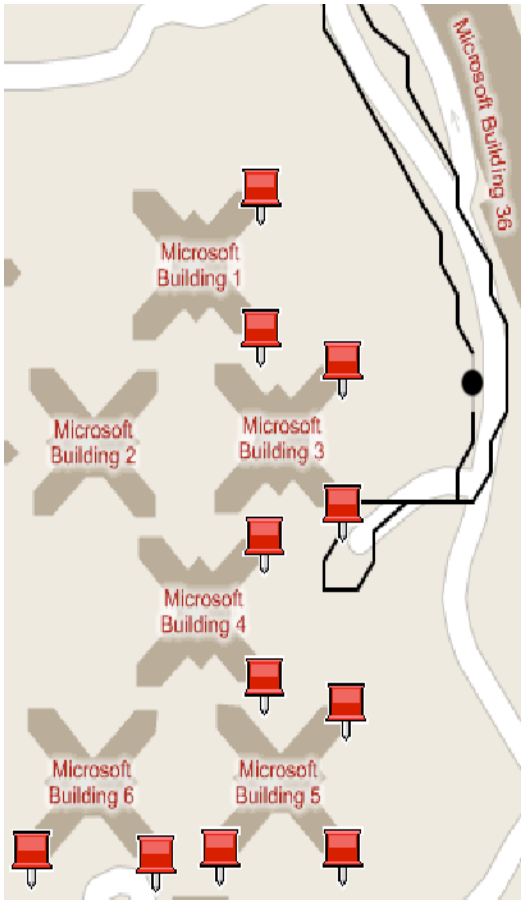
1. Source transmits a packet
2. If destination receives, it transmits an ack
3. If auxiliary overhears packet but not ack, it *probabilistically* relays to destination
4. If destination received relay, it transmits an ack
5. If no ack within retransmission interval, source retransmits



Disruptions reduced!

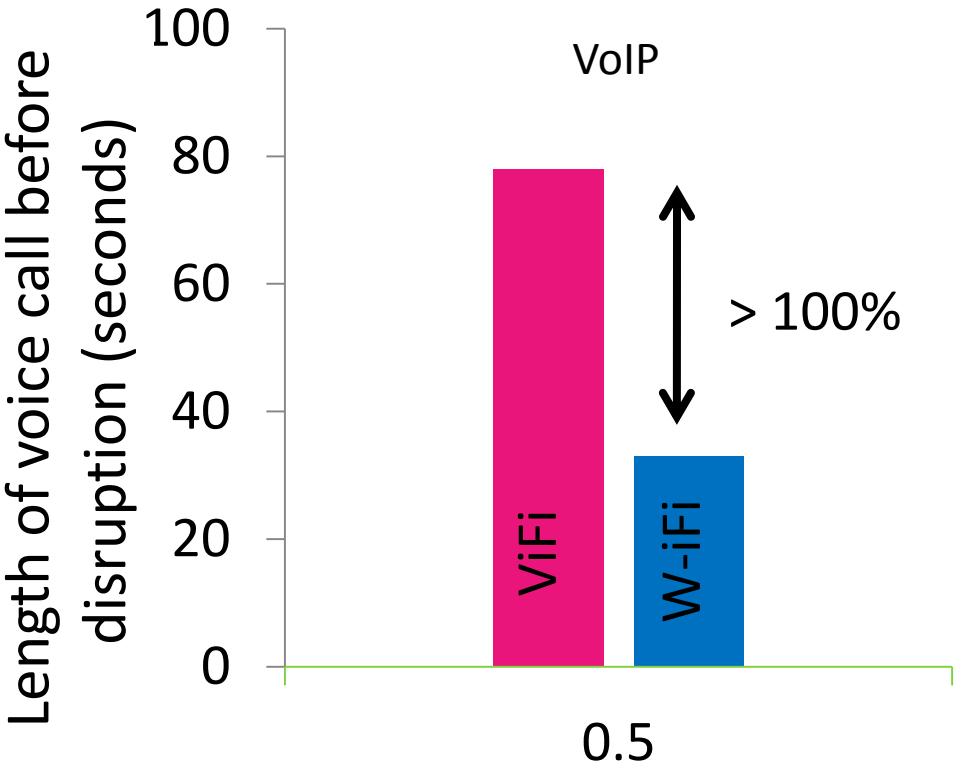


Wi-Fi

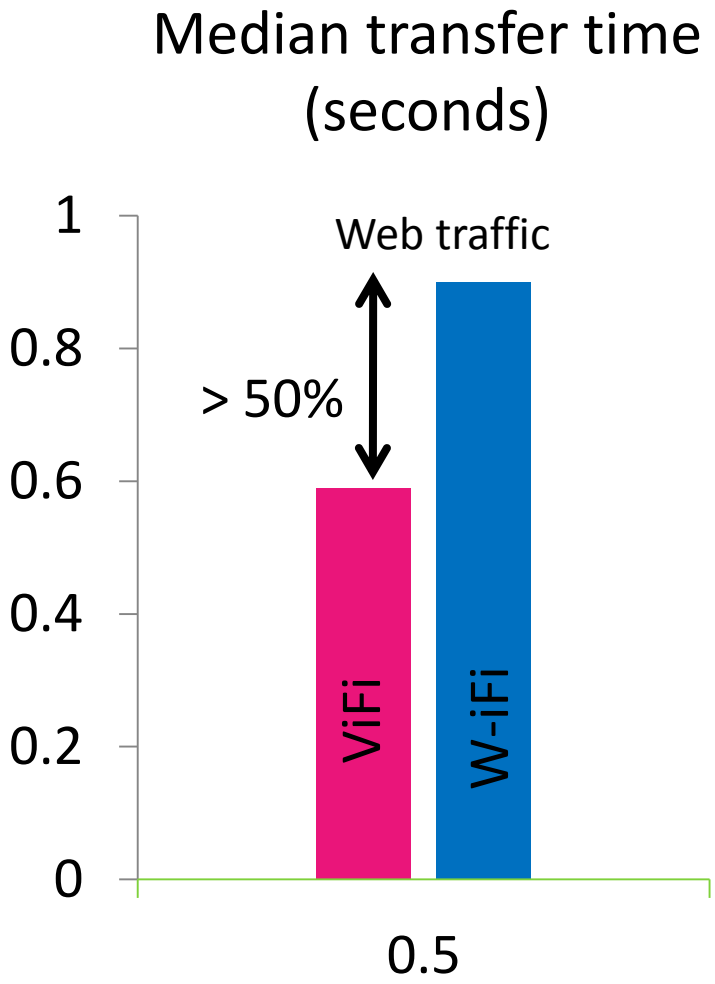


ViFi

Performance



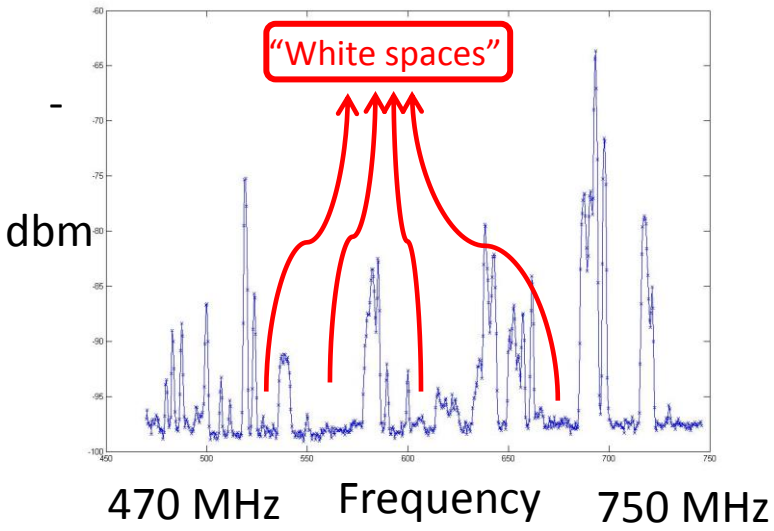
Traffic generated per G.729 codec
Disruption: when MoS < 2



Workload: Repeated downloads of a 10 KB file

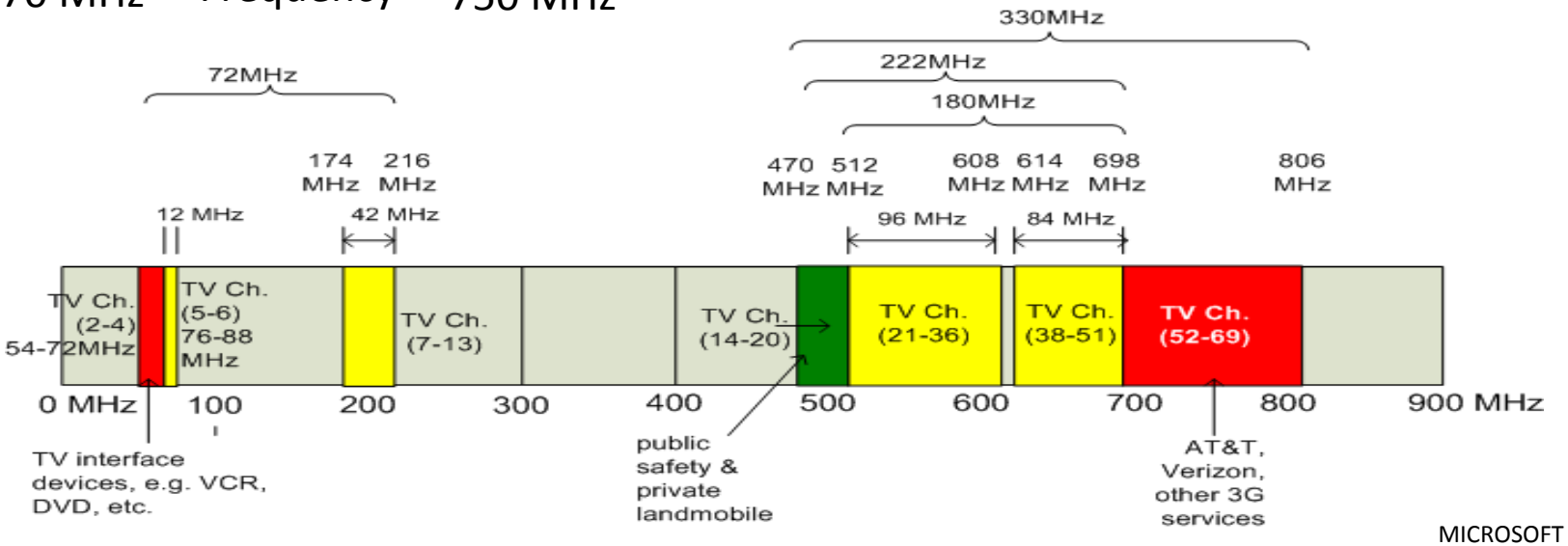
What about using White Spaces?

Harvesting Unused Spectrum



Properties

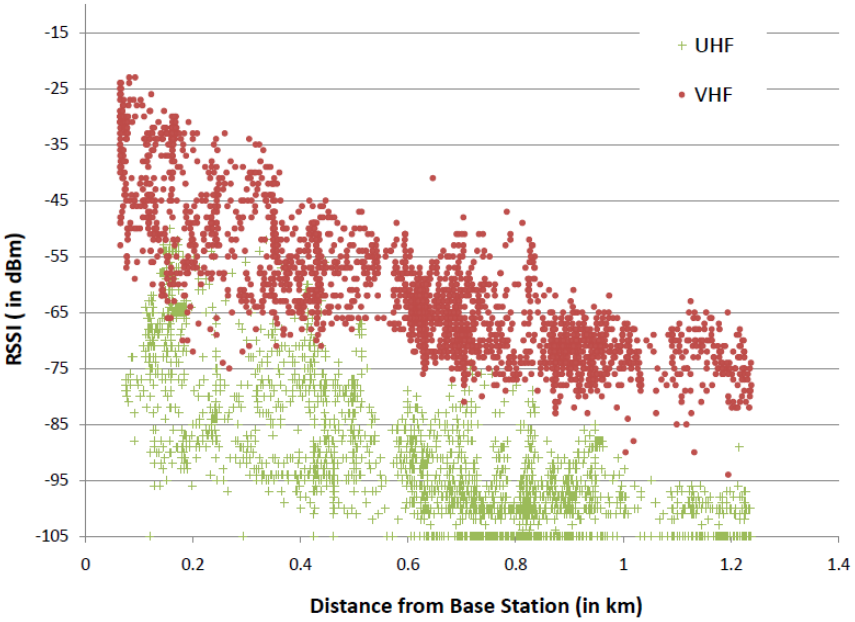
- Unlicensed
- Long range
- Deep penetration
- Bandwidth



What range can we expect?

Microsoft Redmond Campus

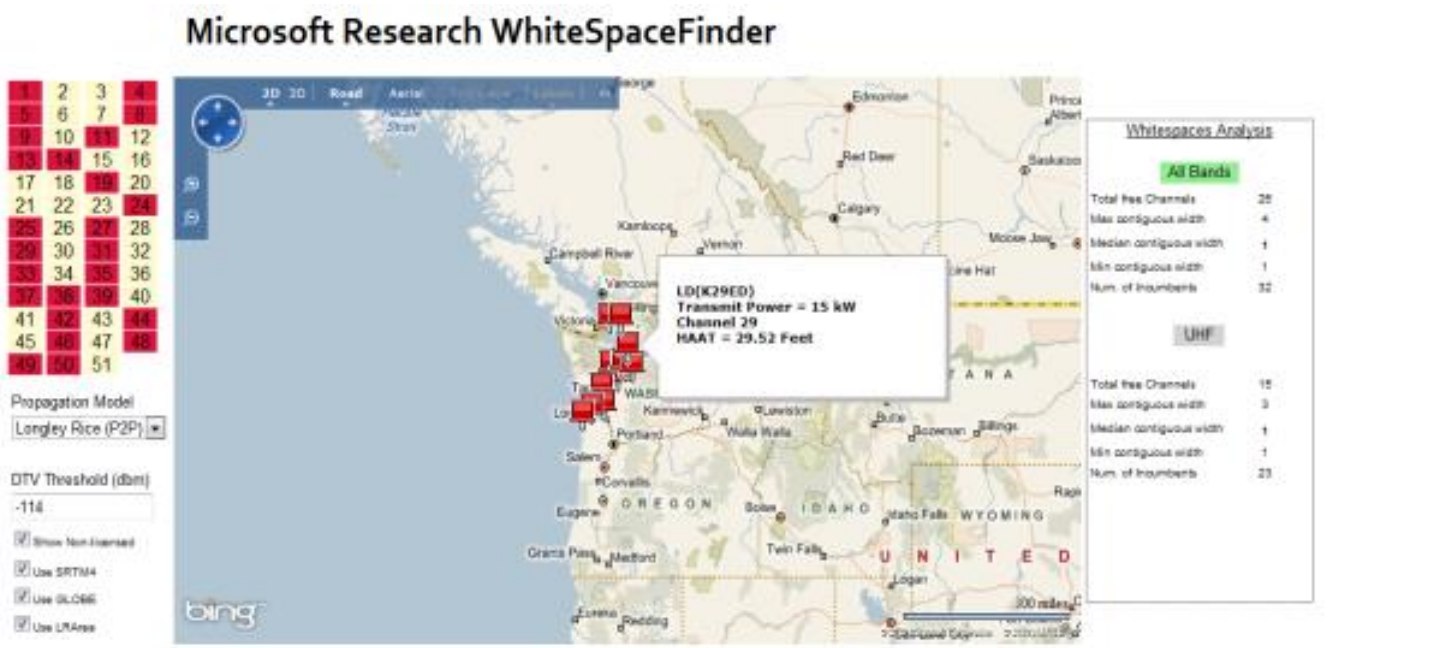
Route taken by the shuttle (0.95 miles x 0.75 miles)



Raw received power at different Distances from the transmitter

4-5 white space base stations can cover the entire Redmond campus

Database of spectrum availability

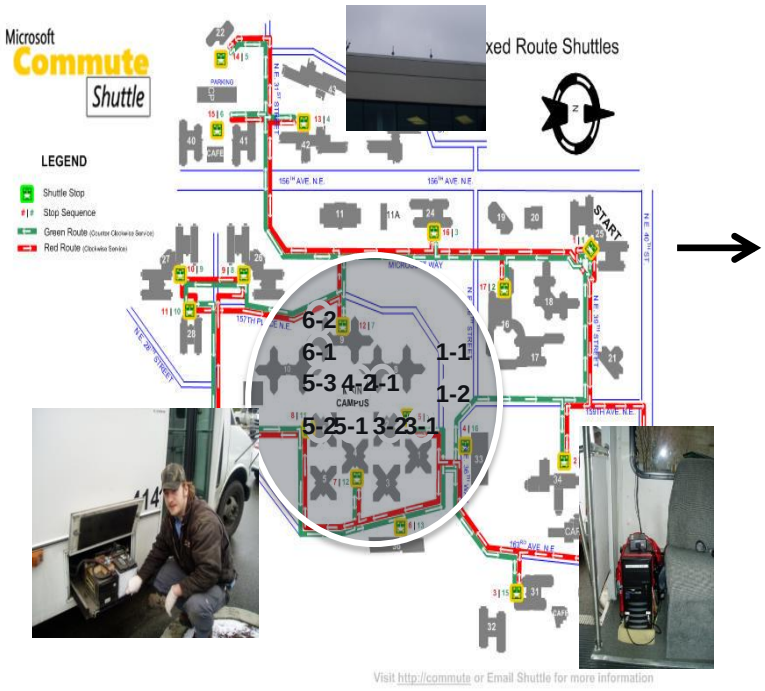


	Type	CallSign	Channel	Signal Strength (dBm)	TX Power (kW)	HAAT (Ft)	Distance (miles)	Elevation Data Source	Propagation Mode	Comments
Select	DTV	KMYQ	25	-19.2	1000	951.2	7.854	SRTM41	Line-Of-Sight Mode	
Select	DTV	KOMO-TV	38	-22.9	870.9	848.5	8.781	SRTM41	Line-Of-Sight Mode	
Select	DTV	KCTS-TV	9	-26.7	21.87	816.7	7.875	SRTM41	Line-Of-Sight Mode	
Select	DTV	KSTW	11	-27.1	100	904.2	7.896	SRTM41	Line-Of-Sight Mode	
Select	DTV	KWDK	42	-33.1	144.3	2279	12.46	SRTM41	Line-Of-Sight Mode	
Select	DTV	KWPX-TV	33	-36.8	398.1	2348	12.46	SRTM41	Line-Of-Sight Mode	
Select	DTV	KCPQ	13	-38.9	30.19	2000	31.57	SRTM41	Line-Of-Sight Mode	
Select	DTV	KUNS-TV	50	-40.3	239.8	2358	12.48	SRTM41	Line-Of-Sight Mode	
Select	DTV	KBTC-TV	27	-42.3	100	770.8	30.4	SRTM41	Line-Of-Sight Mode	
Select	DTV	KPST	44	-43.5	239.8	2328	12.46	SRTM41	Line-Of-Sight Mode	

The world's first urban White Space network

MS Shuttle Network

A giant white space hot-spot network on Microsoft campus

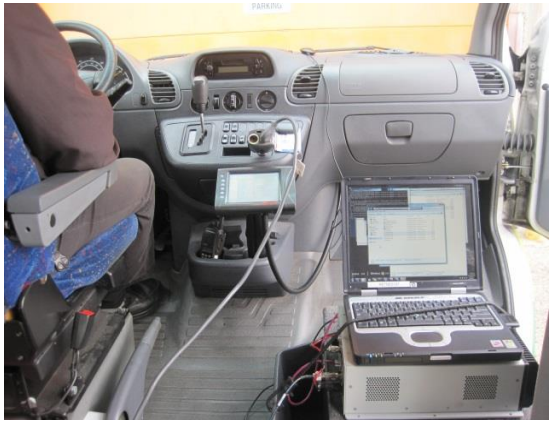


Oct. 16, 2009

Accessing from the office

WS Antenna on Bldg 42

WS antenna on MS Shuttle



Accessing from inside a MS Shuttle

THE WALL STREET JOURNAL.
Digital Network

MAY 11, 2010, 6:59 P.M. ET

FCC Officials Visit Microsoft To Examine Experimental Network

Aug 14, 2010

The New York Times

F.C.C. Opens Unused TV Airwaves to Broadband

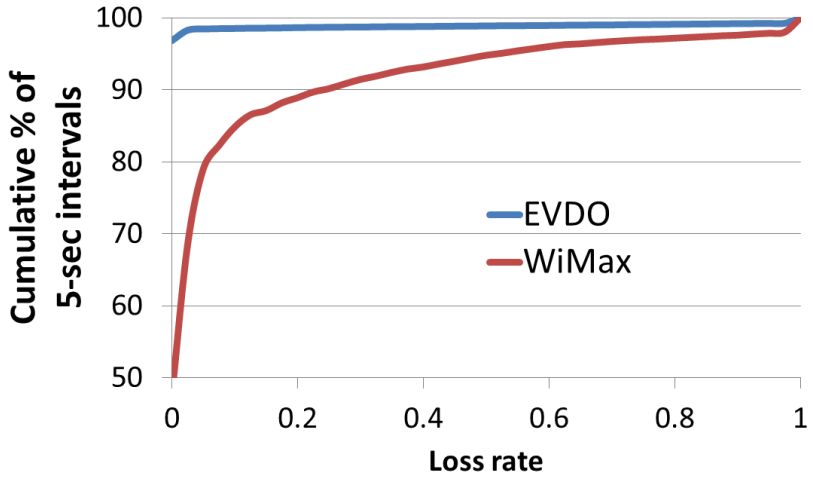
By EDWARD WYATT
Published: September 23, 2010

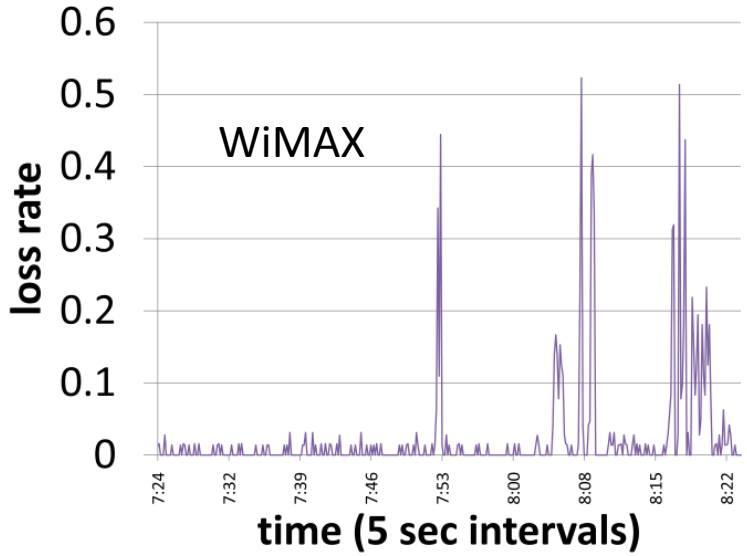
Chairman Genachowski & Microsoft's CTO Craig Mundie, August 14, 2010

Chairman Genachowski and FCC Managing Director Steven VanRoekel Climb aboard the MS Shuttle to look at our WhiteFi Network

FCC Chairman Genachowski looks at our wireless Microphone demo In Bldg. 99, Anechoic Chamber (Room 1651)

Improving cellular connectivity





Vehicular WWAN connectivity is lossy

Paths can have high losses

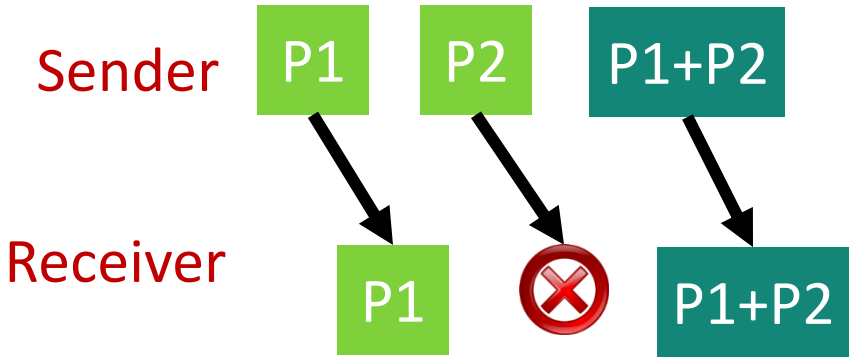
Methods to mask losses

Traditional mechanisms have limited effectiveness

- Prioritization
- Over provisioning
- Retransmissions (ARQ)
  - unsuitable for
  - high delay paths

Erasure coding

- existing methods are capacity-oblivious



Opportunistic Erasure Coding

Use *all* spare capacity for redundancy

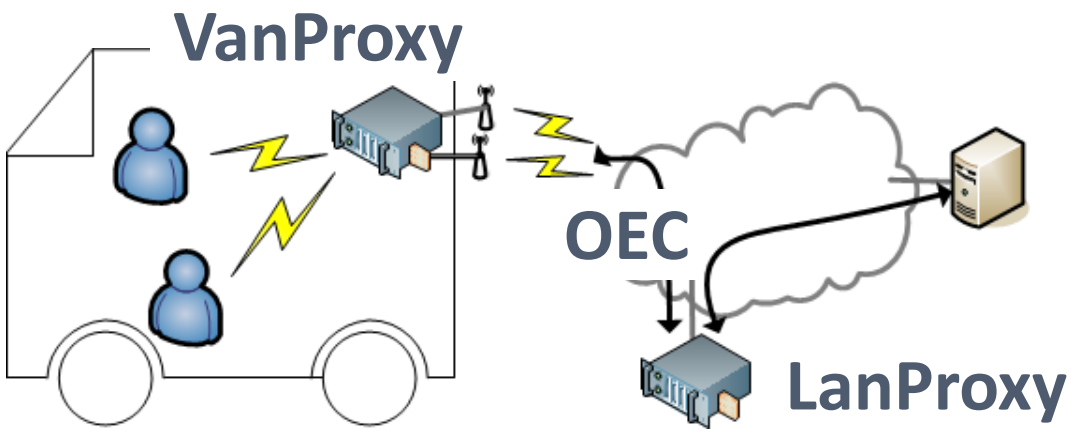
Send erasure coded packets *iff* the bottleneck queue is empty

- Data packets are sent right away

Properties:

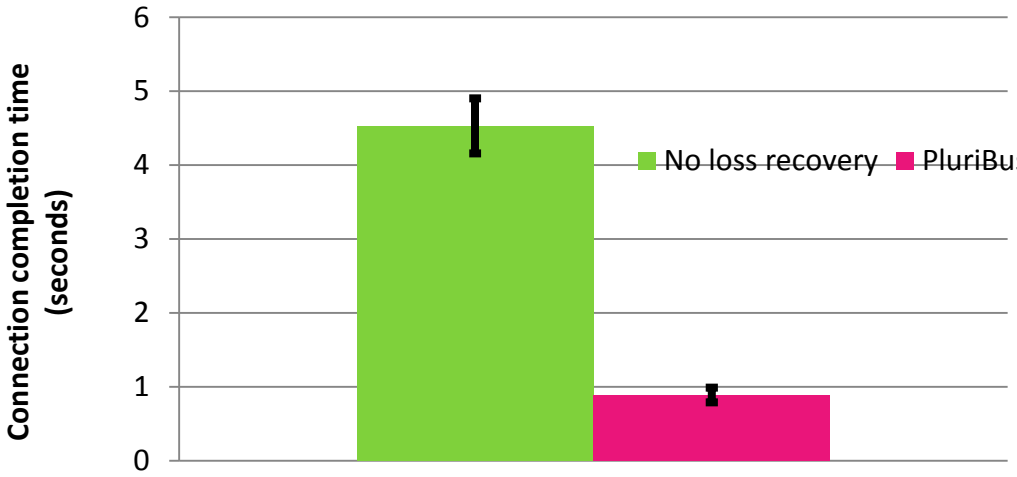
- Dynamically adjusts coding redundancy to match "instantaneous" spare capacity
- Delays data packets by at most one packet

OEC for moving vehicles



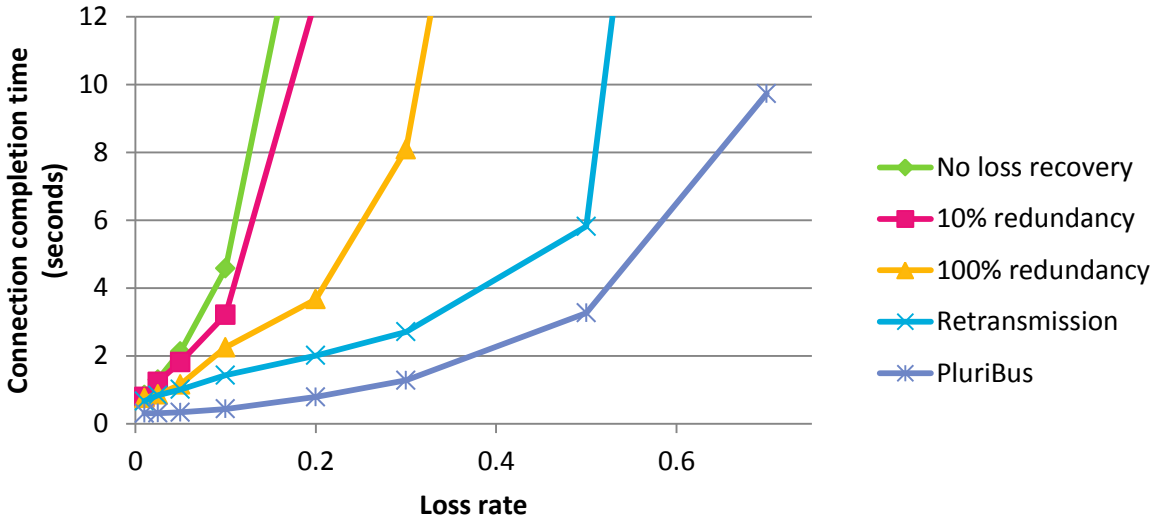
OEC needs	System estimates
Fraction of received packets	Path loss rate
Queue length	Path capacity
Least-delay path	Propagation delay diff.

OEC performance



← Results based on deployment

Results based on emulation →



Cloud services for the car

Hawaii: mobile cloud services platform

Cloud services targeted to mobile applications

- Leverage MSR's expertise in algorithms: graphics, image processing, machine learning, NLP, speech recognition ….

A developer platform to allow ISVs to easily deploy new services and *compose* existing ones

- Hawaii Service Store & Composition Service

Hawaii cloud services

… build world-class cloud services that enable application developers to easily realize the full potential of mobile computing

Examples:

- Rendezvous: Lookup for Relay endpoints
- Relay: Phone to phone data transfer
- Optical Character Recognition
- Speech to Text
- Face Recognition
- Matchmaking for multiplayer gaming
- Path prediction
- GeoFencing
- SMASH – Social Mobile Sharing for ad hoc groups
- Application analytics
- ….

service toolbox

sophisticated resource intensive algorithms running in the cloud typically CPU, memory & storage intensive battery and/or bandwidth hungry

Destination prediction service

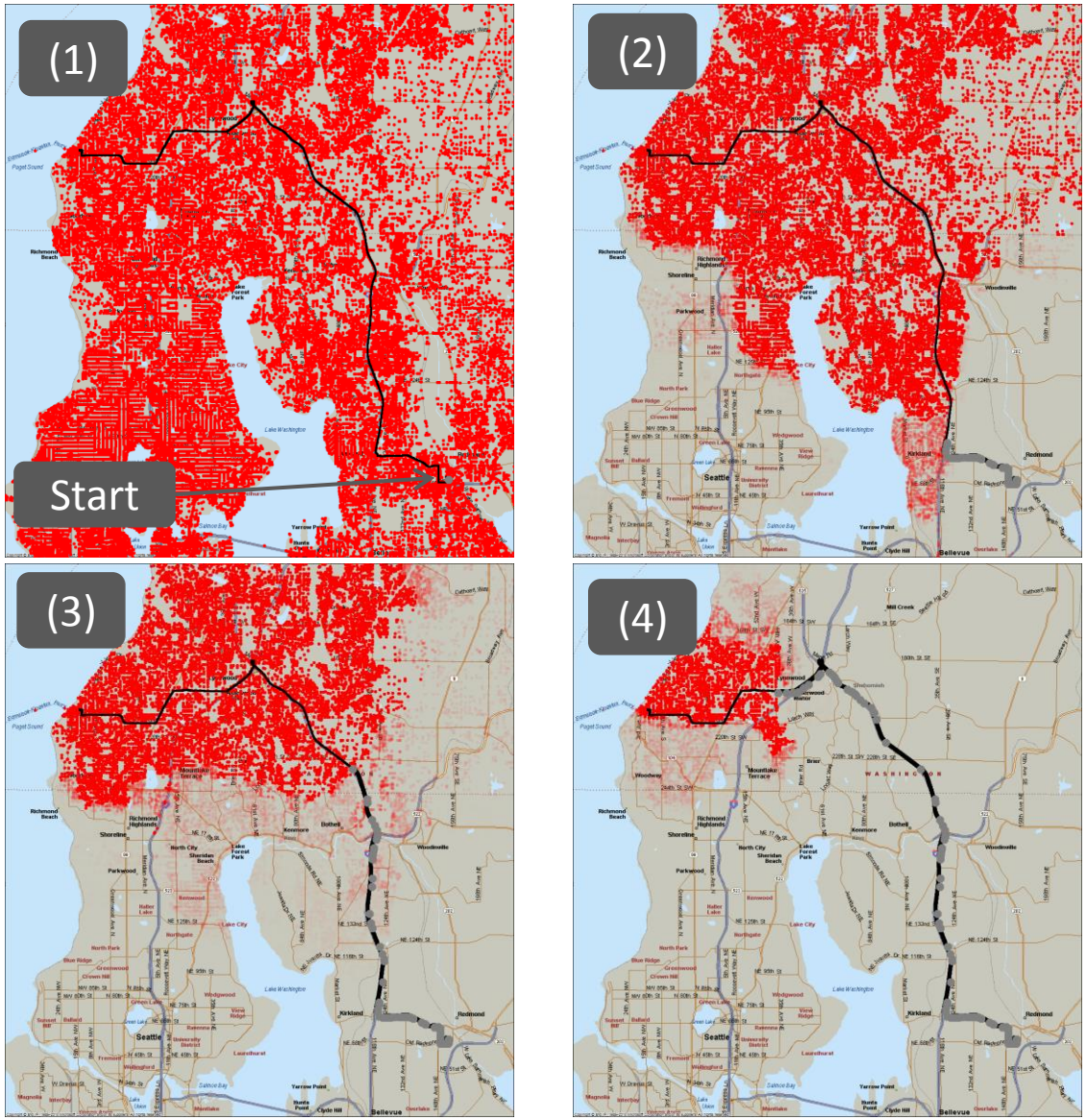
Predict your destination as you drive

Applications

- Warn users of upcoming traffic incidents
- Help find convenient stop (e.g. gas, coffee, food)
- Target local search results to places ahead of you rather than behind you
- Local ads for upcoming businesses

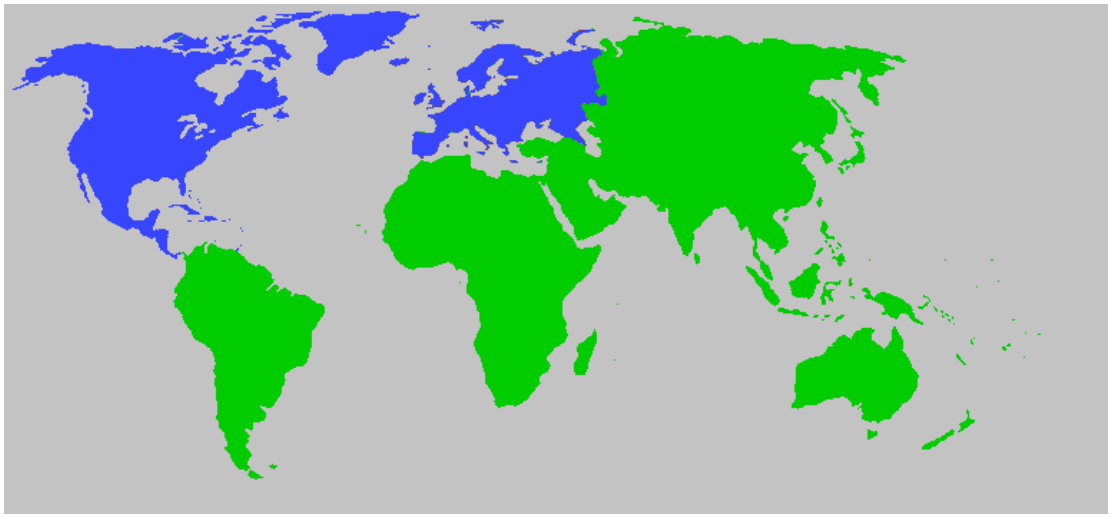
Example trip

- Assumes driver takes (somewhat) efficient route to unknown destination
- Stores no GPS data, so privacy concerns reduced



Algorithm & geographic coverage

- Depends on driving time to ALL candidate destinations (“single-source shortest path”)
- Use PHAST algorithm from MSR SVC to do this really fast



- Prediction algorithm uses road network
- North America/Europe only for now

A bright future

Cloud

offloading + services

+

Rich Devices

Rich Connectivity

=

plethora of mobile computing apps possible

Summarizing

- Lots of research related to improving connectivity, providing cloud services, and NUI for the car
- In all cases driver safety is imperative
- Interested in understanding scenarios that you care most about

Thanks!