Accounting for Roaming Users on Mobile Data Access: Issues and Root Causes

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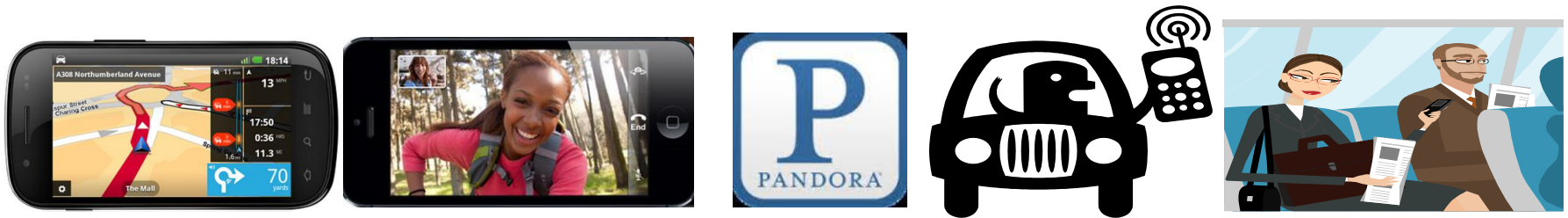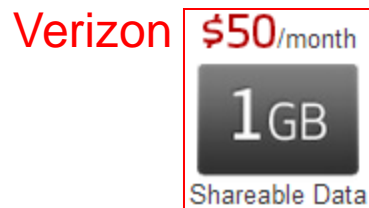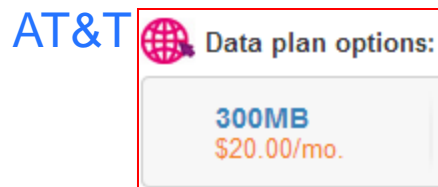+Peking University, Beijing, China

Mobile Data Access

- Mobile data access during driving is popular

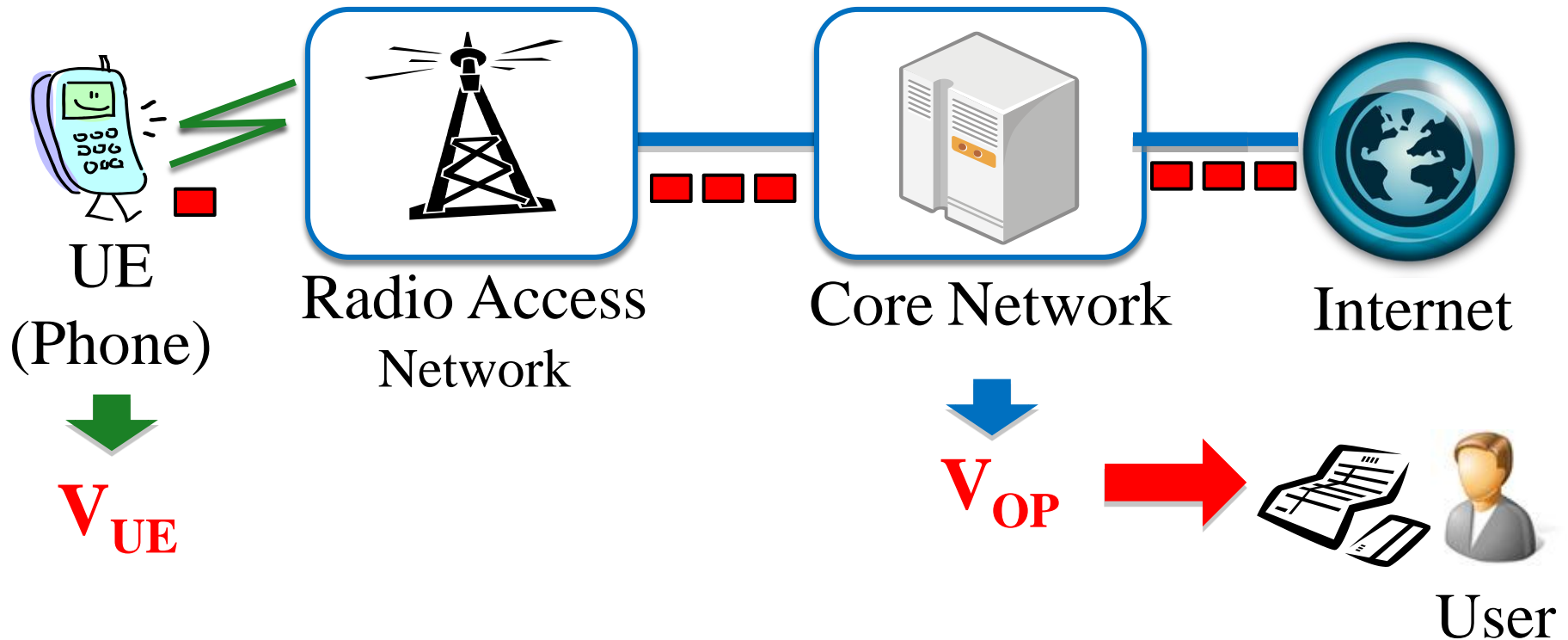- However, it is not free.
  - Usage-based charging is broadly used.

AT&T **Data plan options:**
300MB
$20.00/mo.

Verizon **$50**/month
1GB
Shareable Data

- How operator accounts the mobile data usage?

Accounting in Cellular Networks

UE
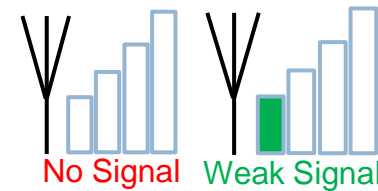(Phone)

Radio Access
Network

Core Network

Internet

V_{UE}

V_{OP}

User

Previous Work

- Our previous work shows that over-accounting occurs in indoor scenario
  - No-signal/weak-signal area.

No Signal   Weak Signal

- How about mobility case ?
  - Gap exists?
  - No-signal/weak-signal still cause gap?
  - Are they the only reasons like indoor case?

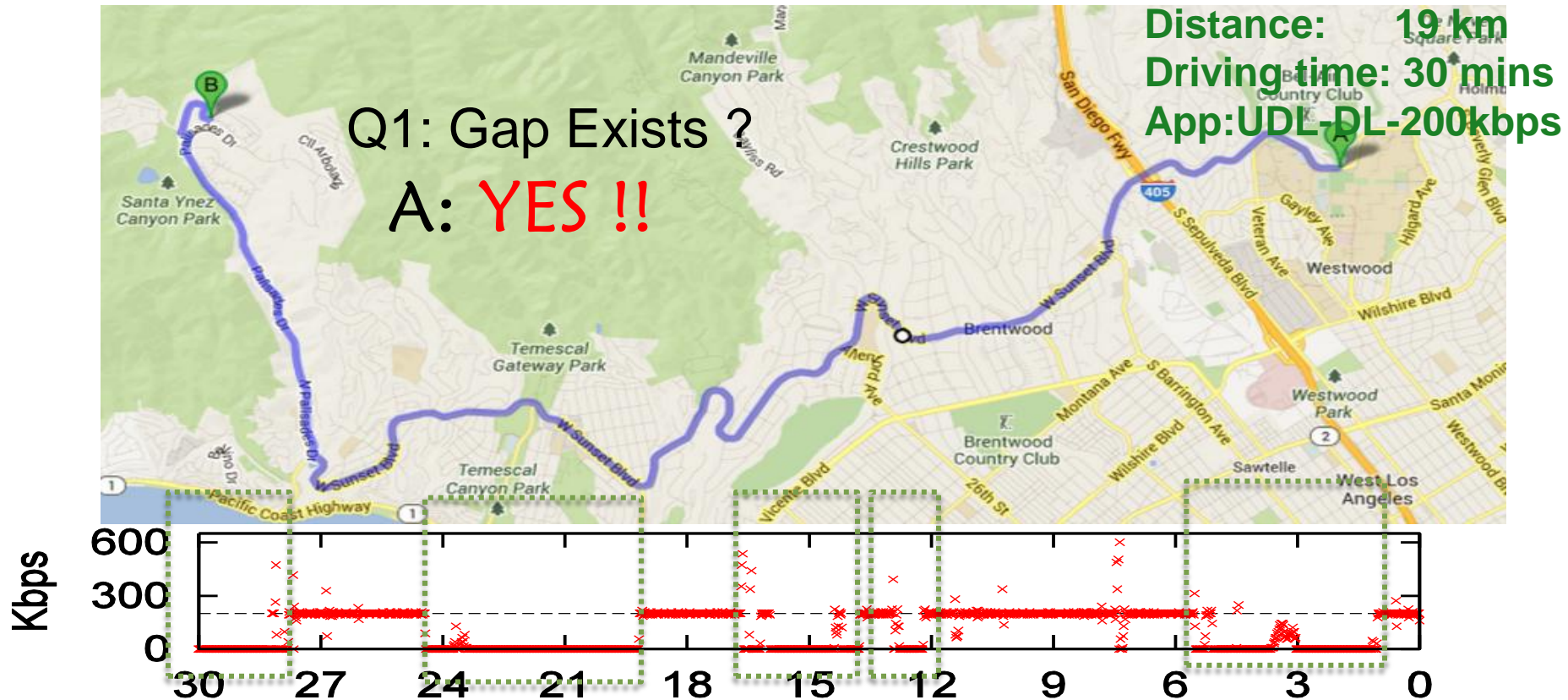Source: "Can We Pay for What We Get in 3G Data Access?," Mobicom'12, Aug. 2012.

The Rest of Talk

- An Example
  - Diversified Root Causes
  - Factor Impacts
- More results
- Insights
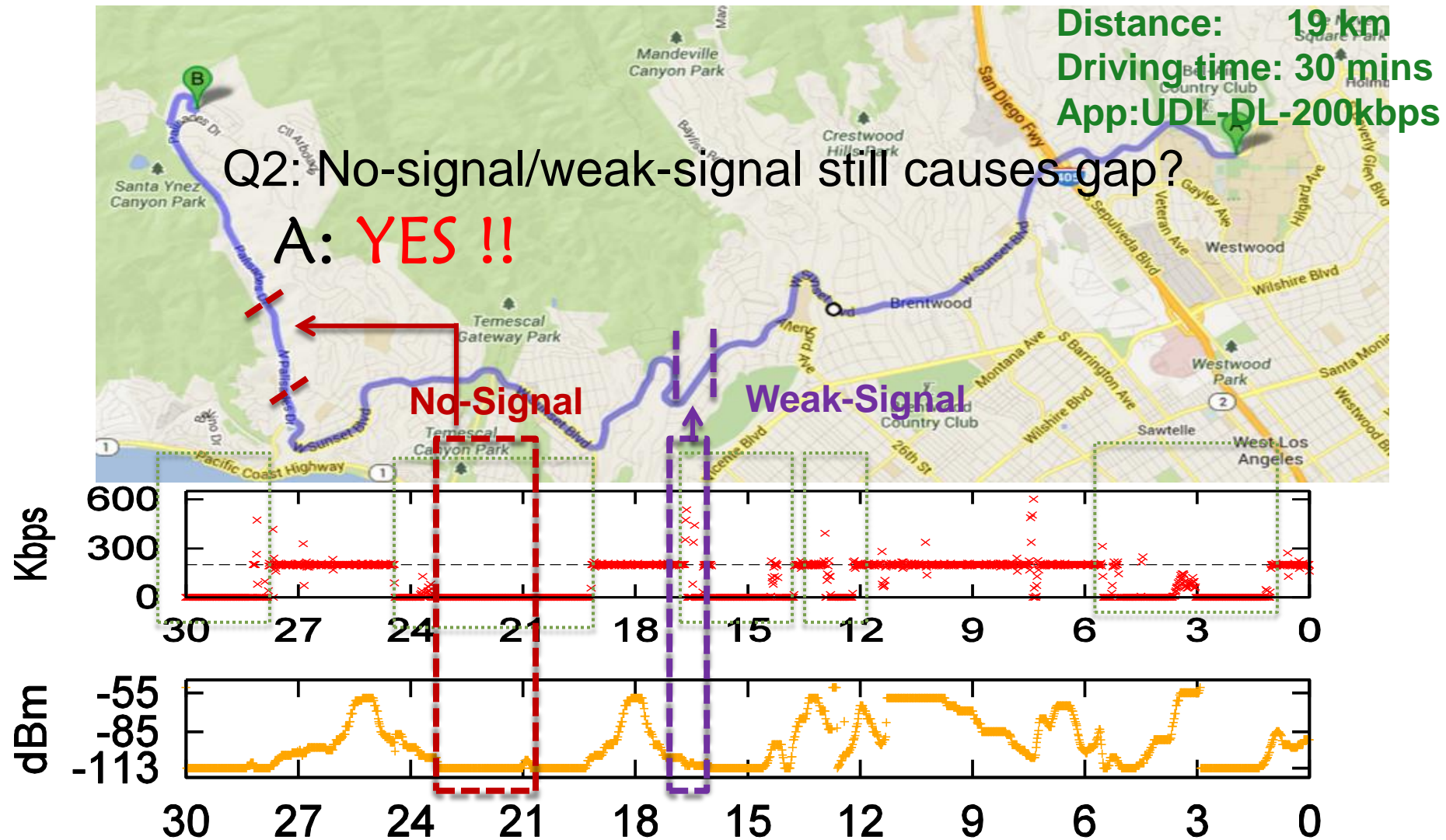- Solution
- Conclusion

An Example: Mobile User in LA

Distance: **19 km**
Driving time: 30 mins
App:UDL-DL-200kbps

Q1: Gap Exists ?

A: **YES !!**

Data Received (V_{UE}):   13.5MB
Data Accounted(V_{OP}):   44.3MB
Accounting Gap (V_{GAP}):   **30.8**MB

An Example: Mobile User in LA

Distance: 19 km
Driving time: 30 mins
App:UDL-DL-200kbps

Q2: No-signal/weak-signal still causes gap?

A: YES !!

No-Signal   Weak-Signal

An Example: Mobile User in LA

Distance: **19 km**
Driving time: 30 mins
App:UDL-DL-200kbps

Q3: Are no/weak-signal the only reasons?
A: NO !!

Strong-Signal has gap.
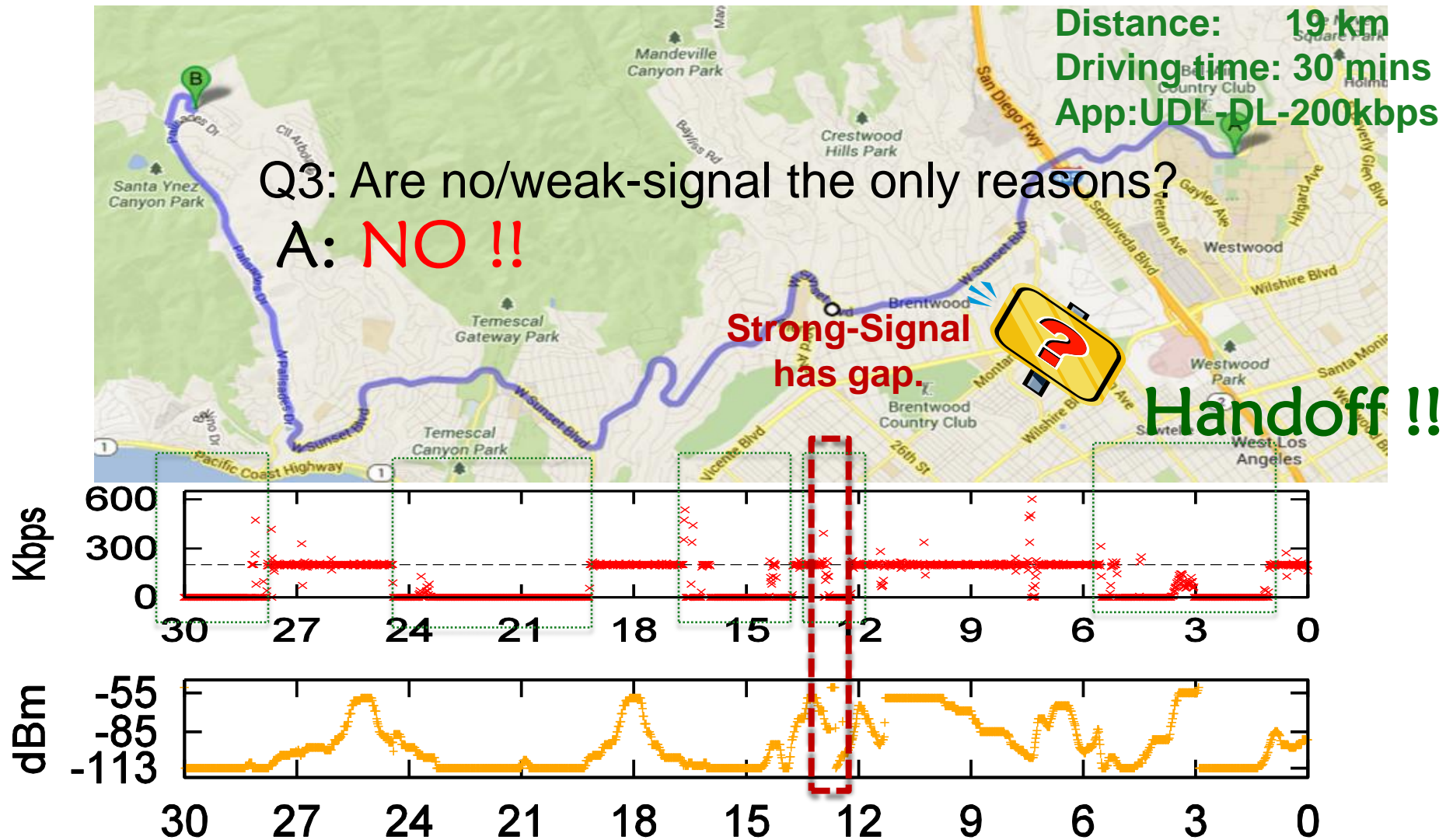
Handoff !!

Why handoff caues gap?

- Data transmission suspends during handoff

- Packet drops during suspension
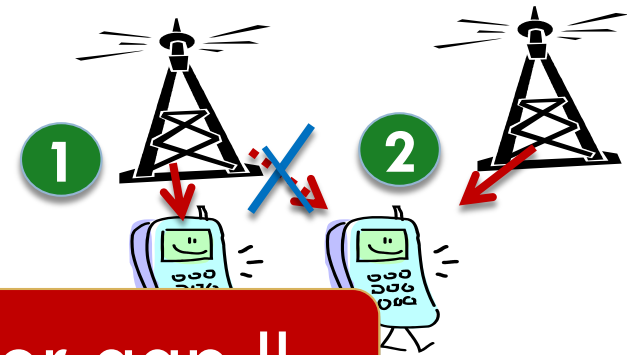
Longer suspension time, larger gap !!

Q: What affects suspension time?
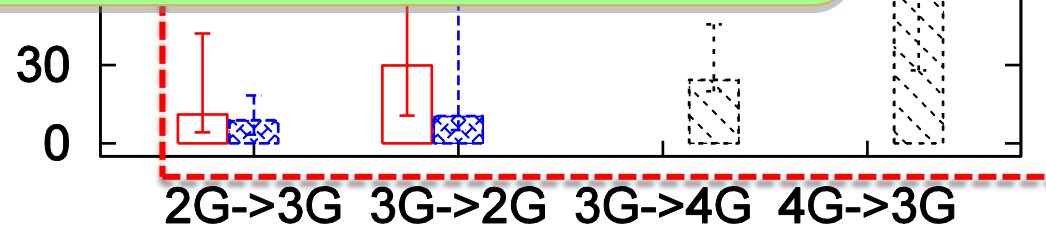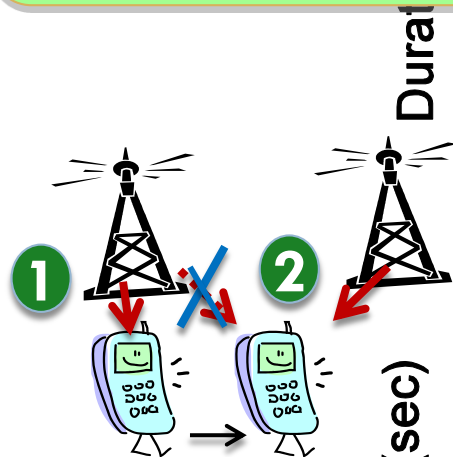Q: Does it depend on handoff type?

packets

(1th second)   (2nd second)   (3rd second)
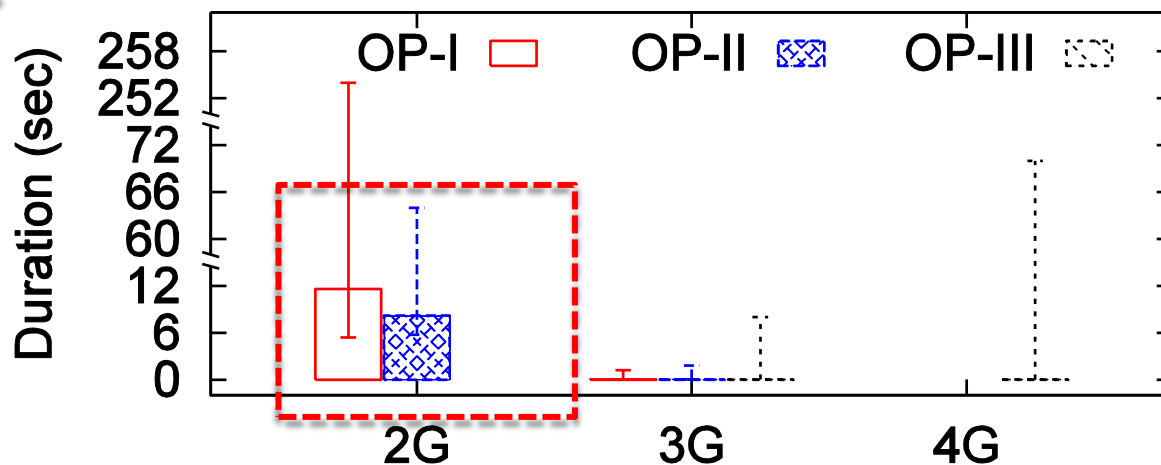
Suspension Time vs. HO type
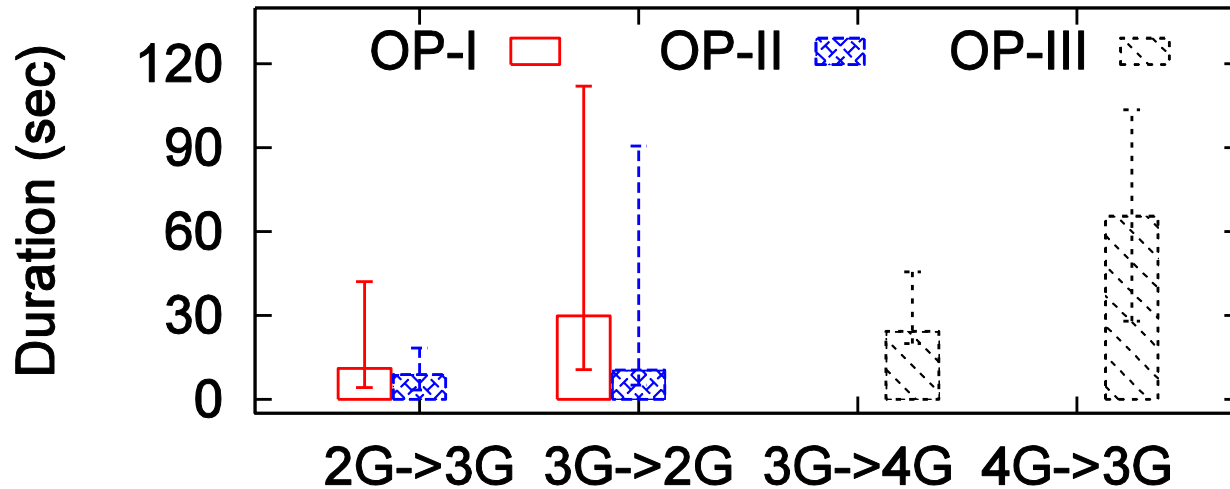
Q: Why these HOs have suspension?
A: Hard Handoff

(a). Inter-System HO

(b). Intra-System HO

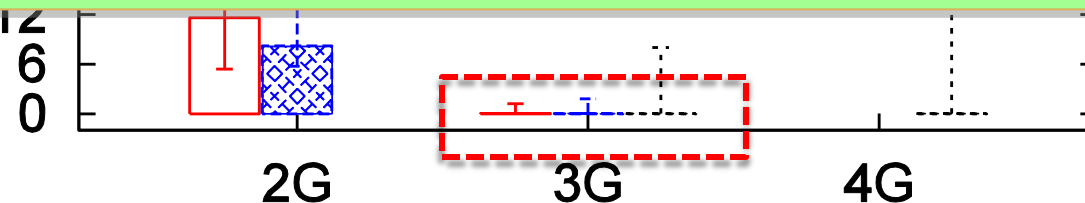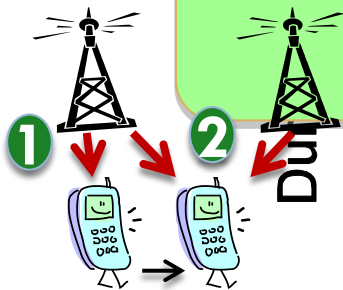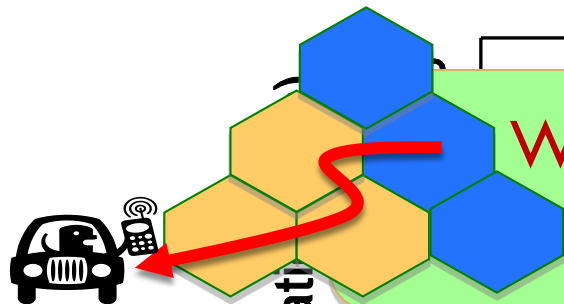# Data Suspension Time

Data Suspension Time
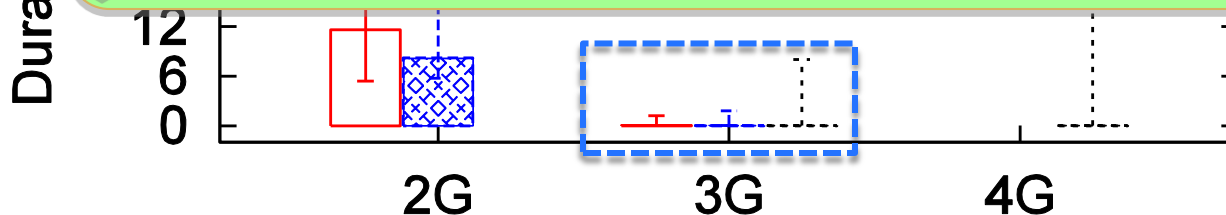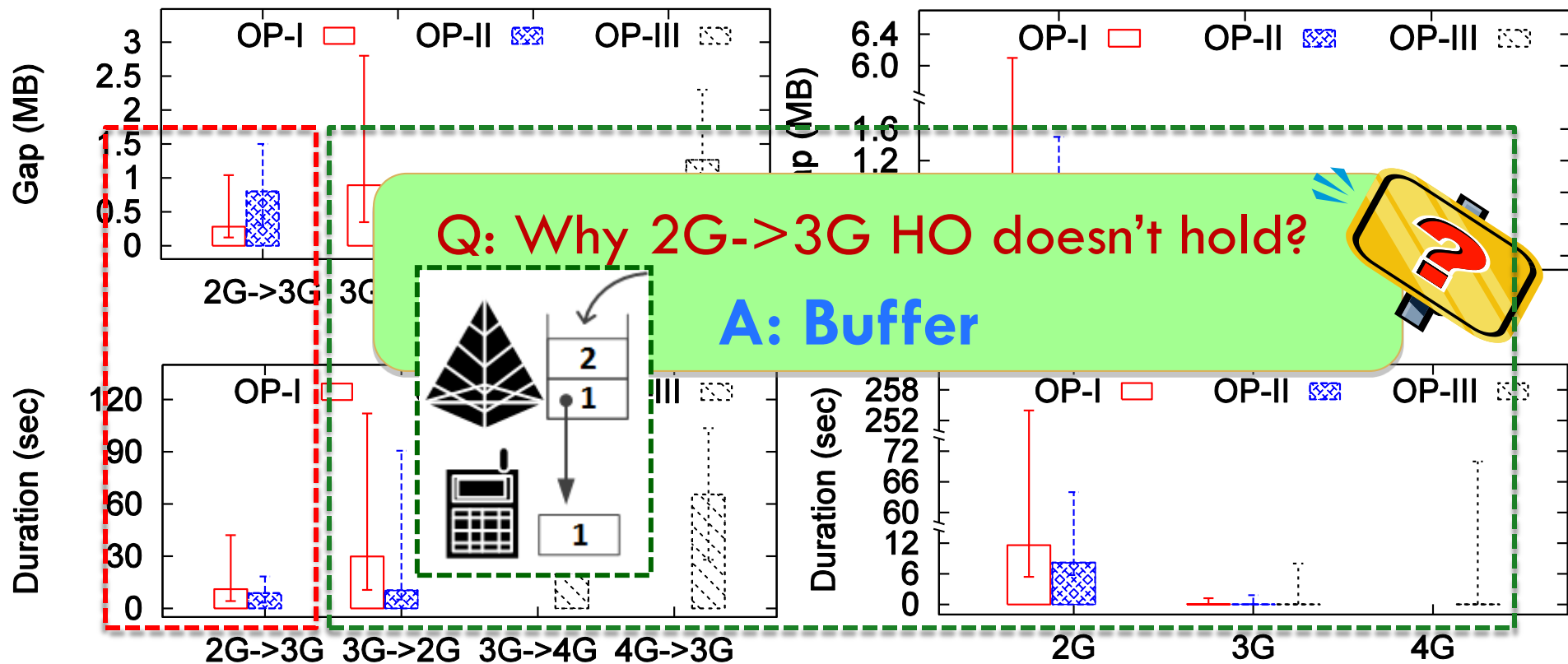
Why few soft-handoffs have suspension?
A: Inter-Frequency!!

Accounting Gap vs. Suspension Time

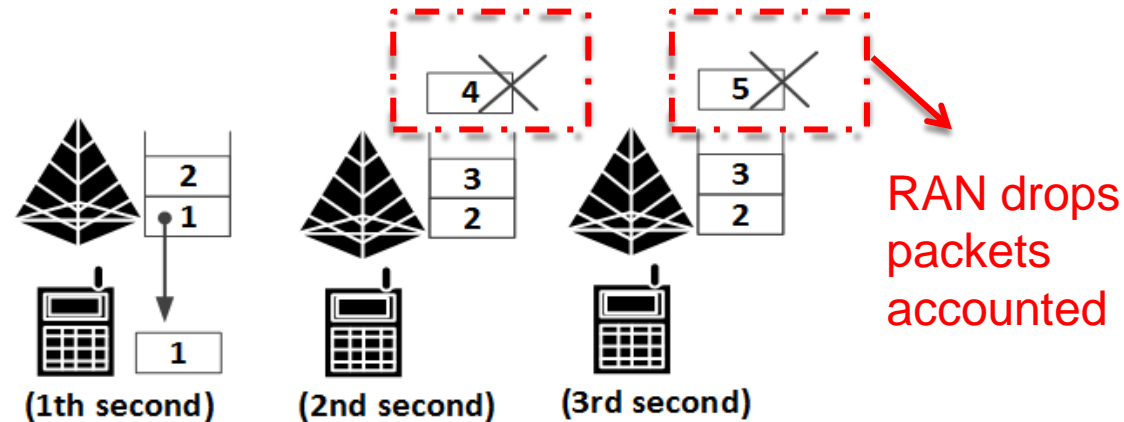**Gap is *usually* proportional to suspension time.**

Why buffer causes gap?

- Recall…

RAN drops packets accounted

(1th second) (2nd second) (3rd second)

- Larger buffer, smaller gap
  - However, it doesn't always hold in all cases.
- When *inter-system handoff* occurs, all packets in buffer are *lost*
  - Larger buffer, *larger* gap

Factor Impacts

- Application source rate, mobility speed, real mobile users daily use, vehicle traffic, hybrid network,..
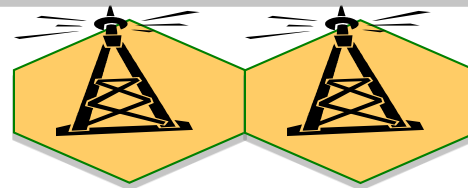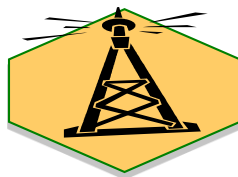
- Hybrid network is widely observed in practice
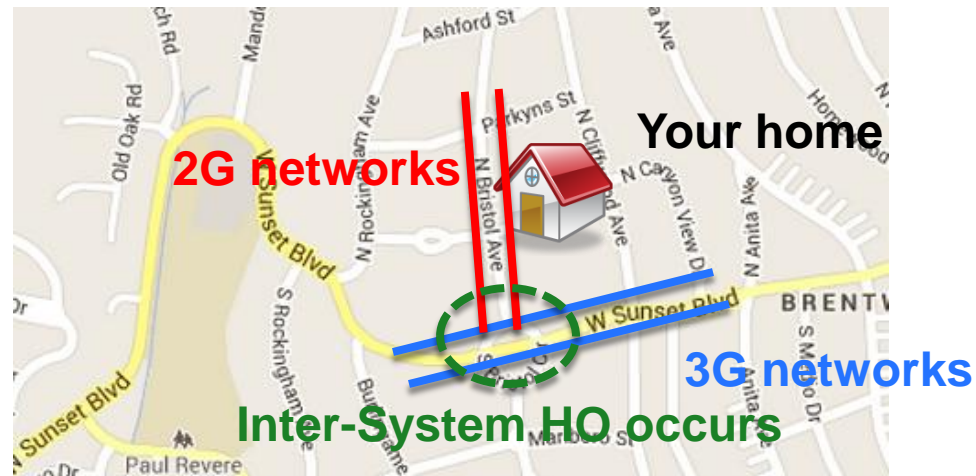

Q: Is it so perfect?
A: Depends !!

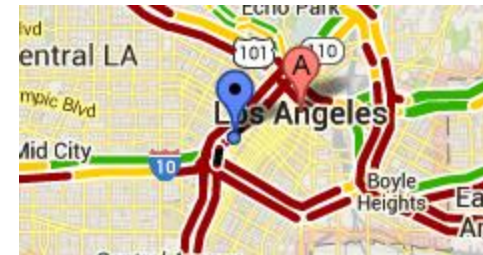- Reduce gap caused

Hybrid Network

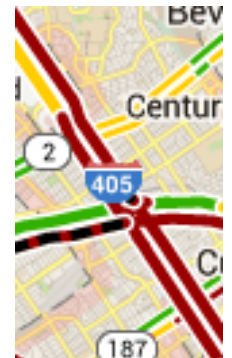- An Example

Suffer over-accounting issue every day !!

More Results

- 3 US major operators
- 13 routes (232.3 km in total)
  - 2 regions: New York and Los Angeles
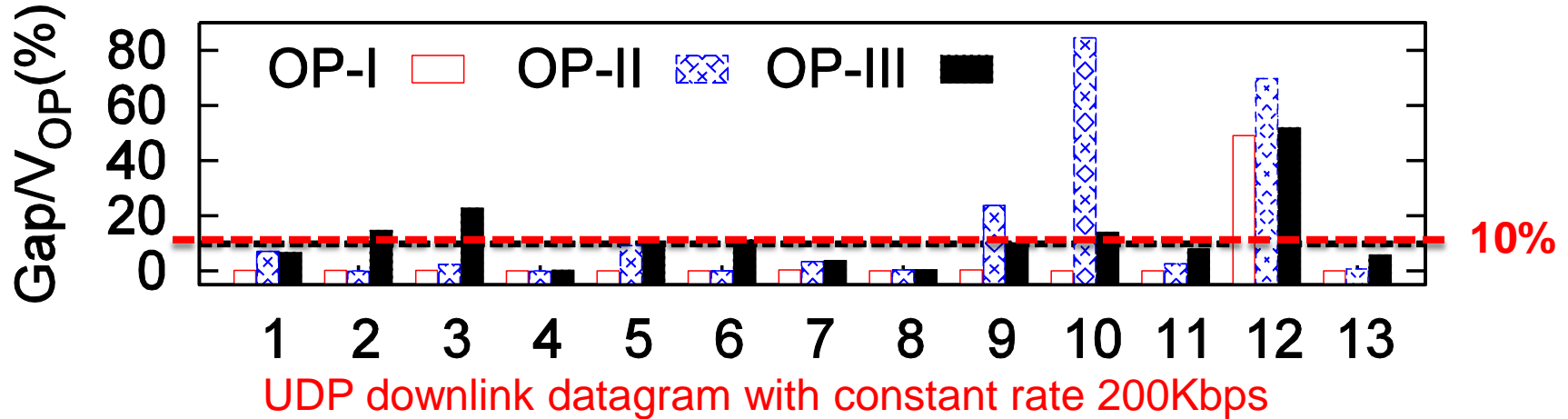 - Downtown + suburb
  - Freeway & local
- Real applications

I-10 in LA

I-405 in LA

Accounting Gap

Gap/V_{OP}(%)

OP-I ☐   OP-II ⊠   OP-III ■

80 60 40 20 0

1 2 3 4 5 6 7 8 9 10 11 12 13

10%

UDP downlink datagram with constant rate 200Kbps

☐ **5** of 13 routes show 10% gap ratio

	Web Browsing		YouTube	
OP-I	0.0%	0.0%	0.6%	0.7%	24.8%
OP-II	0.0%	0.0%	0.6%	1.6%	40.1%
OP-III	0.0%	0.0%	0.6%	0.7%	21.3%

Average accounting gap ratio (Gap/Vop(%)) with real applications on Route 12.

Go Further: Root Causes

- Gap for no-signal/weak signal
    - Insufficient coverage
- Gap for handoff
    - Transmission suspends but accounting doesn't stop

    - Is it possible to address this issue?
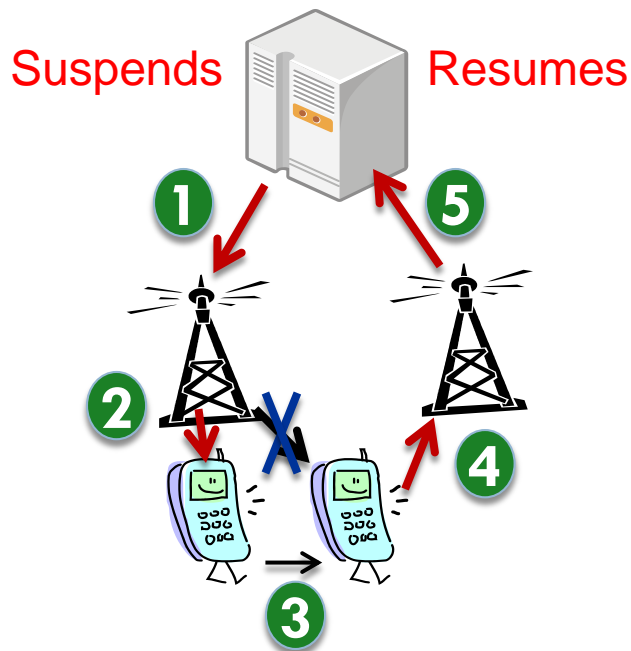   - Handoff is triggered by operators instead of mobile device
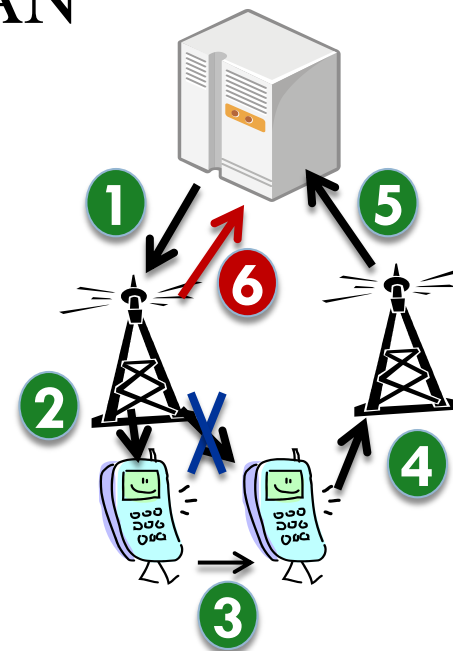   - Operators know when/what kind of handoff is performed

Solutions

- Suspends accounting during HO
- Refer to unsent packet volume reported by RAN

Conclusion

- Accounting gap exists in mobility
  - Route-specific and operator-specific
- Two major causes: *no-signal* and *handoff*
  - Gap caused by handoff is dependent on
    - *Suspension time + buffer size + handoff type*
  - Hybrid network offers good coverage with low cost, however leads over-accounting issue.

# Questions?

Daily Use Results

User	OP-I		OP-II		OP-II
	1	2	3	4	5
Apps	Line, Gmail	Whatsapp, Gmail,Weather Channel	Facebook Messenger, PPS, Line, Gmail	Pandora Radio, Gmail, Whatsapp, Stock	Facebook, Whatsapp Skype, Line, Gmail
Dis.	41.9km	75.5km	89.6km	76.8km	18.8km
V_{UE}	37.2	198.7	1204.3	387.2	73.9
V_{OP}	37.2	199.6	1249.7	389.8	74.3
Gap	0.0	0.9	48.0	2.6	0.4
Ratio	0.0%	0.4%	3.6%	0.6%	0.5%

Accounting gap for driving commuters during March 18-29, 2013

Mobility Speed

- Higher mobility speed, more handoffs
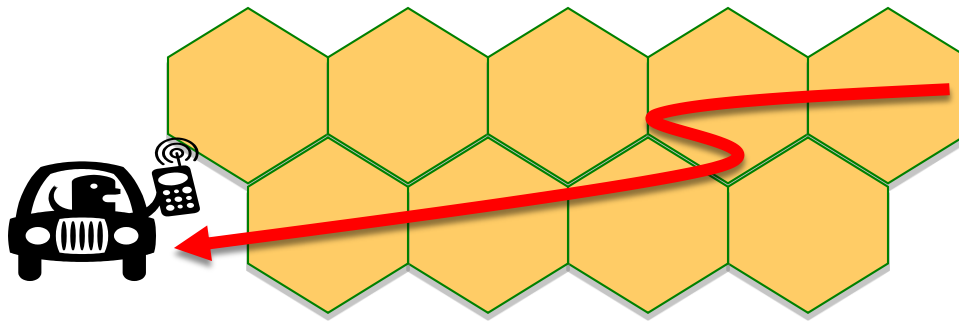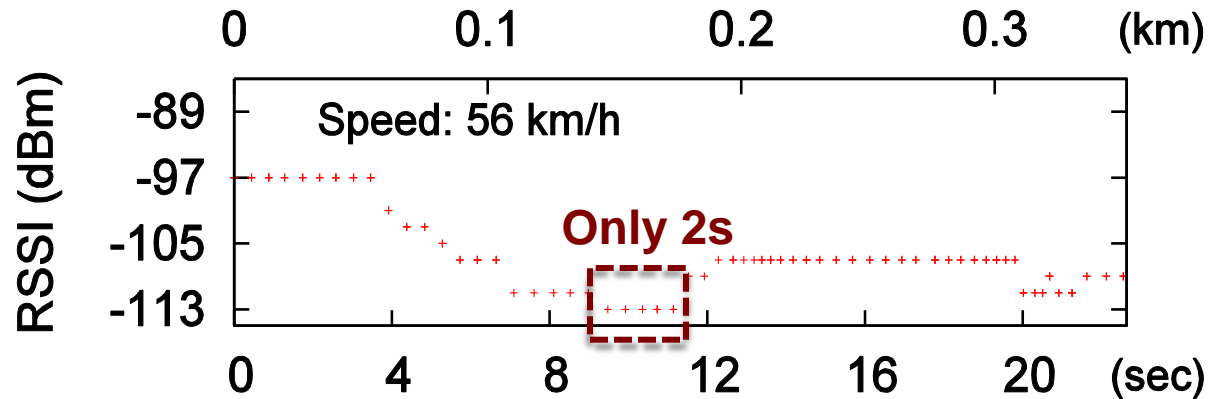

- Does it mean larger accounting gap?
  - NO
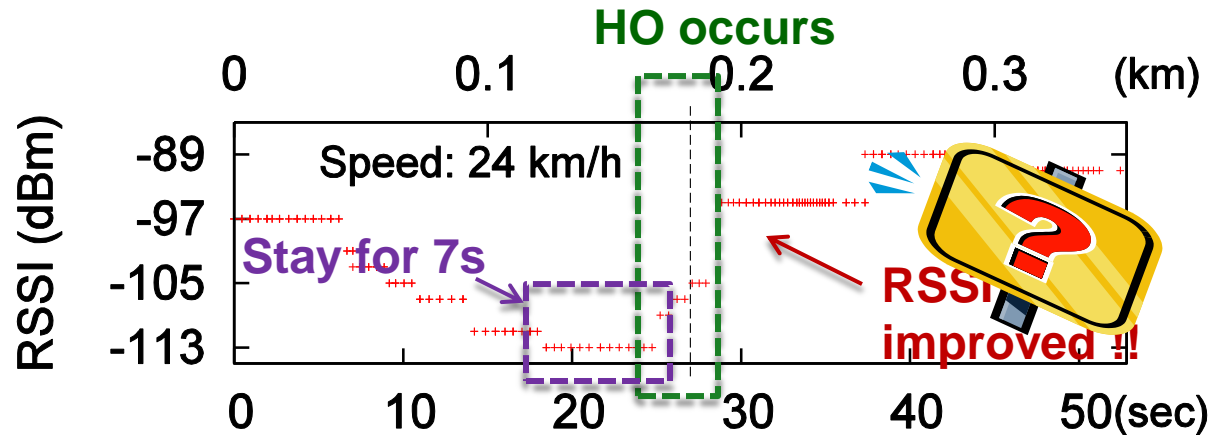- Higher mobility speed, more inter-system handoff ?
  - Not always

An Example: Mobility Speed

(a). High Mobility Speed

(b). Low Mobility Speed