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

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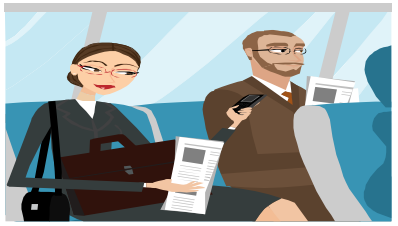
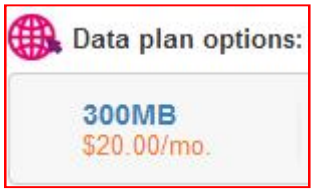
Mobile Data Access

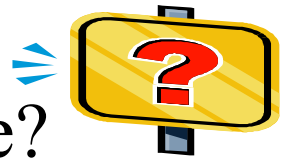
- Mobile data access during driving is popular

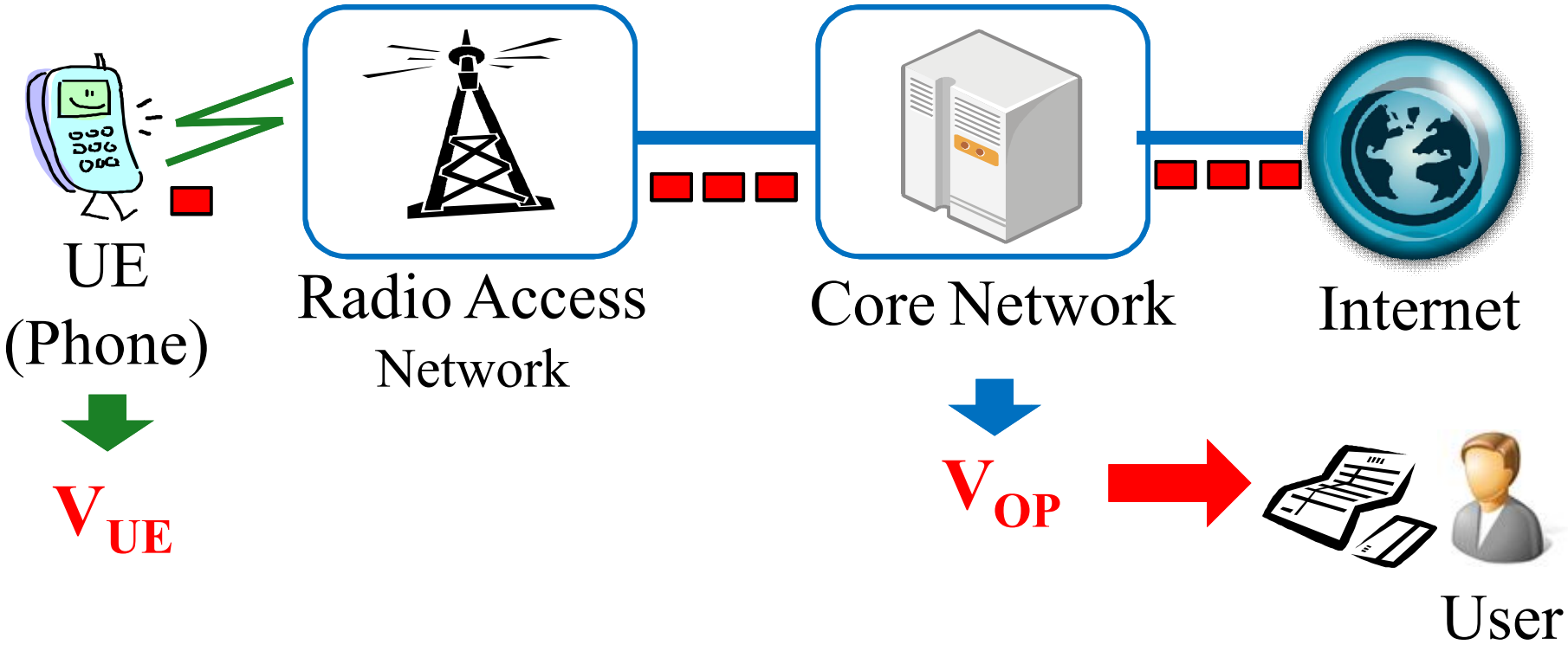
- However, it is not free.
  - Usage-based charging is broadly used.

AT&T 

Verizon 

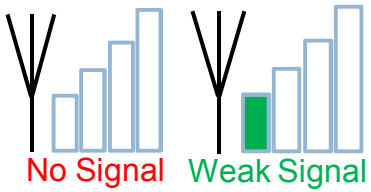
- How operator accounts the mobile data usage? 

Accounting in Cellular Networks



Previous Work

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



- How about mobility case ?

  - Gap exists?

  - No-signal/weak-signal still cause gap?

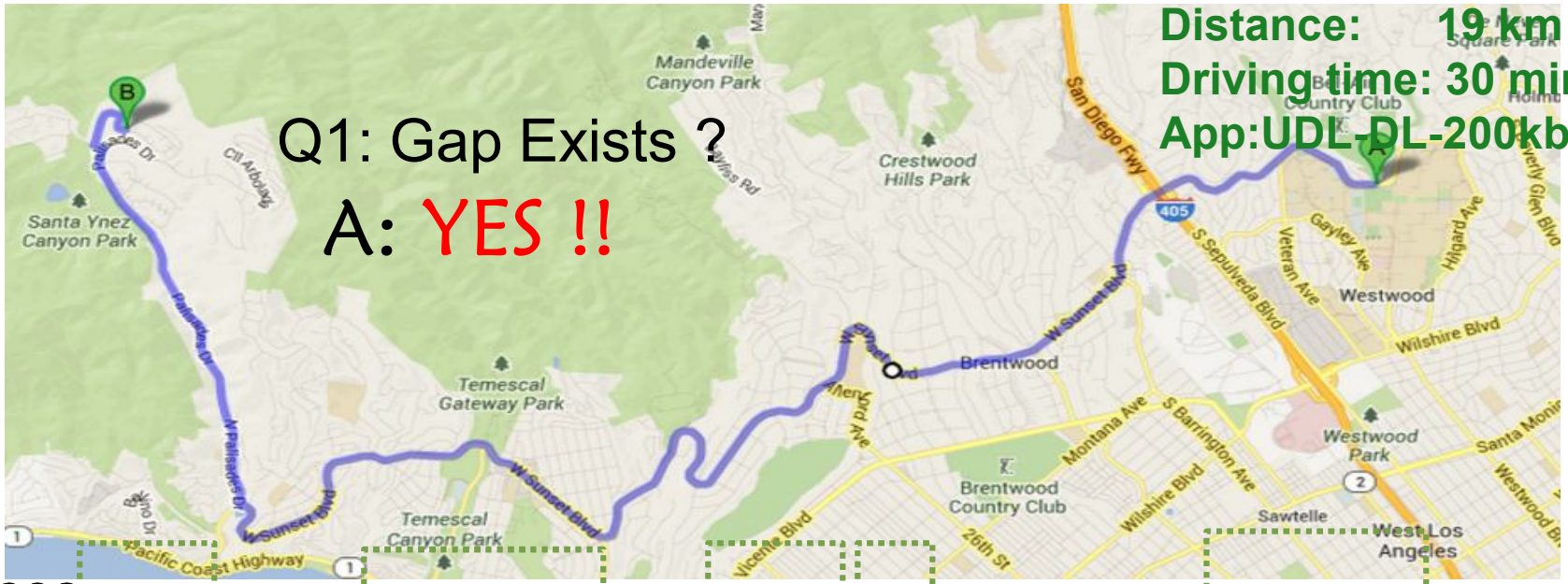
  - Are they the only reasons like indoor case?

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

The Rest of Talk

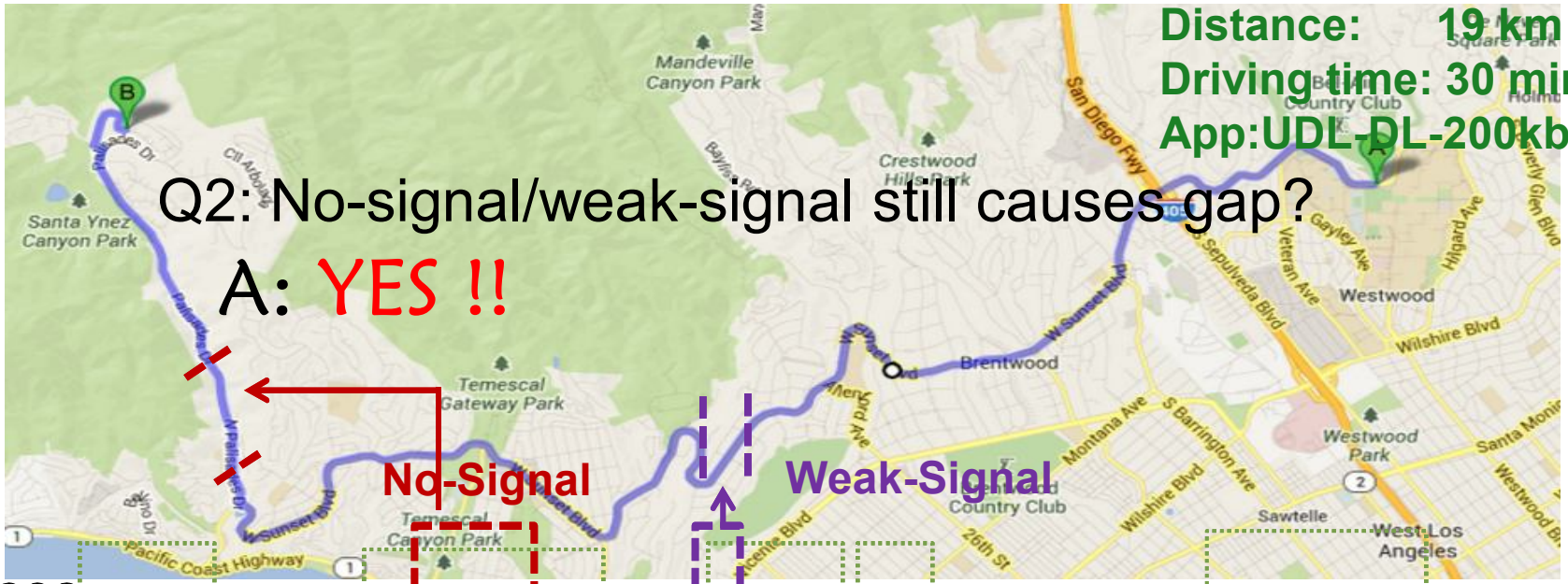
- An Example
  - Diversified Root Causes
  - Factor Impacts
- More results
- Insights
- Solution
- Conclusion

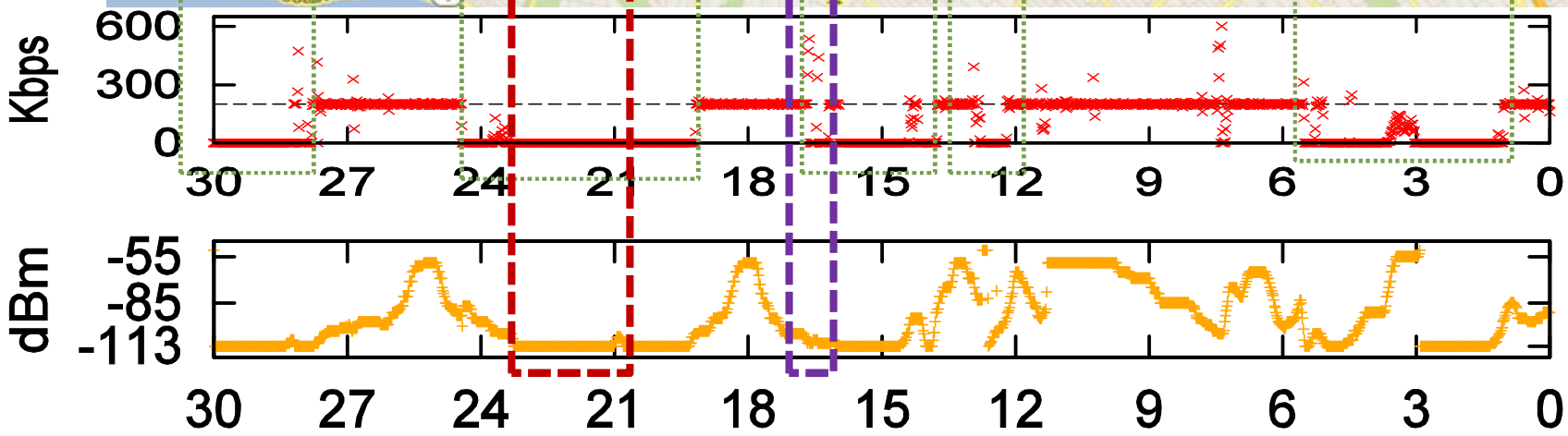
An Example: Mobile User in LA



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

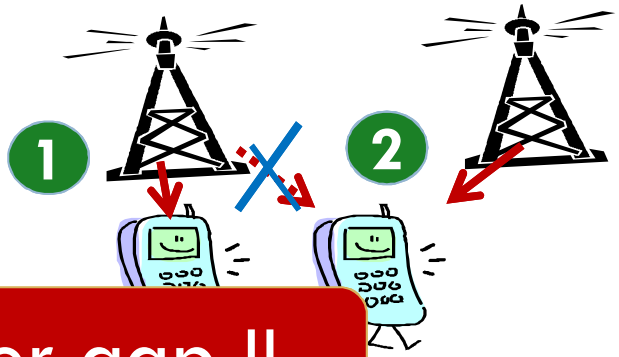




An Example: Mobile User in LA

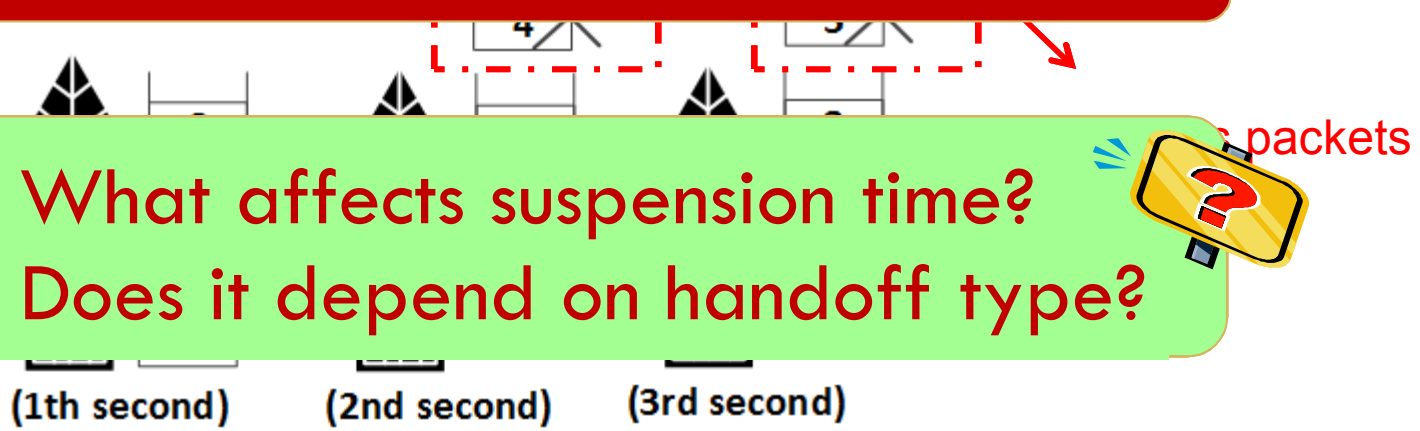
Why handoff caues gap?

- Data transmission suspends during handoff



- Packet drops during suspension

Longer suspension time, larger gap !!



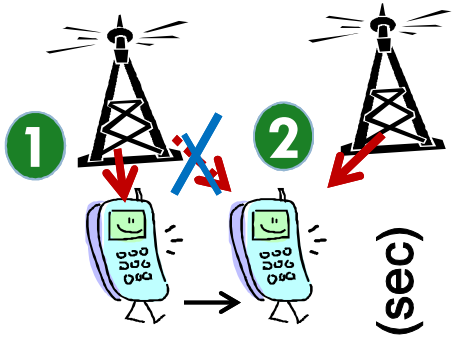
Q: What affects suspension time?

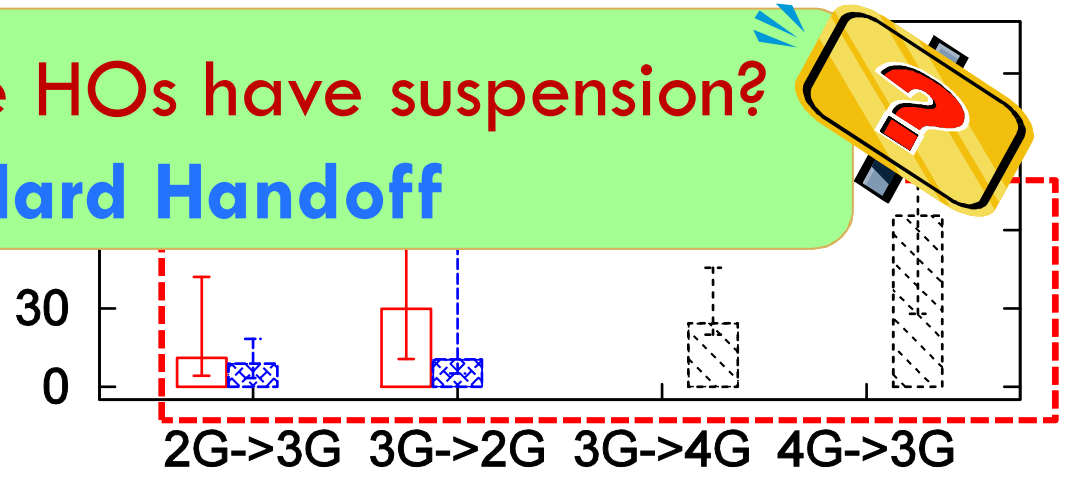
Q: Does it depend on handoff type?

Suspension Time vs. HO type

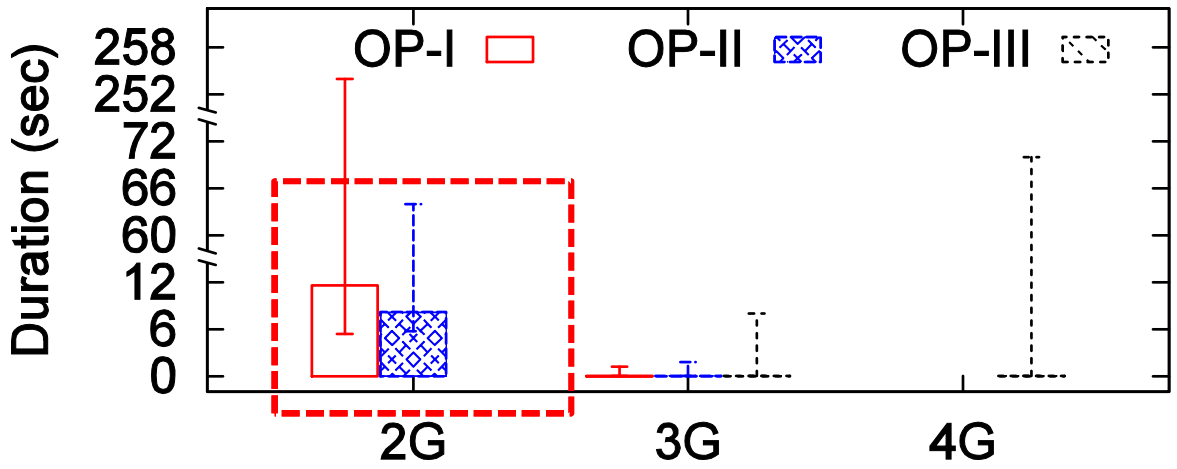
Q: Why these HOs have suspension?

A: Hard Handoff



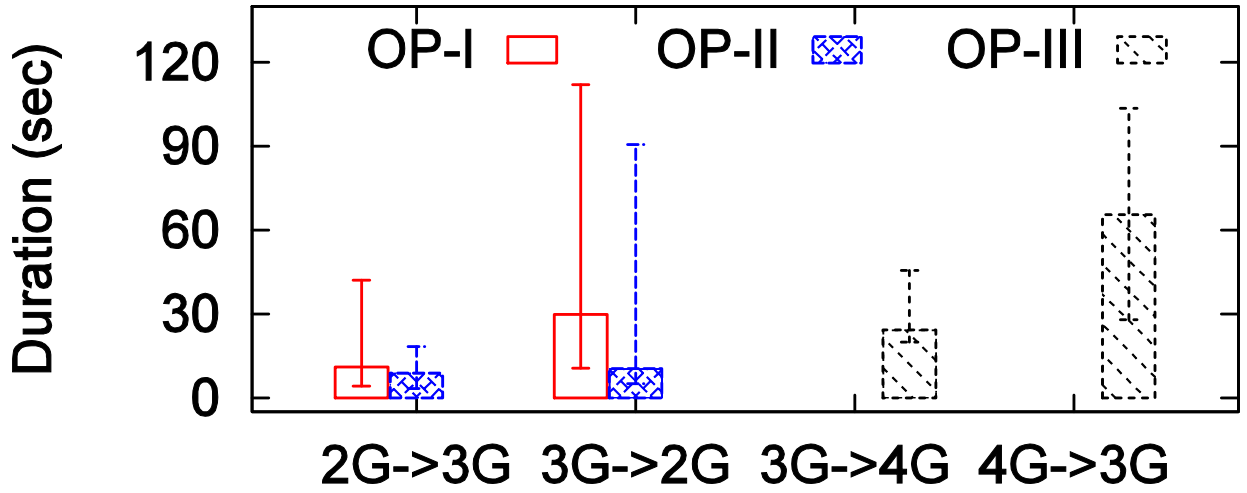


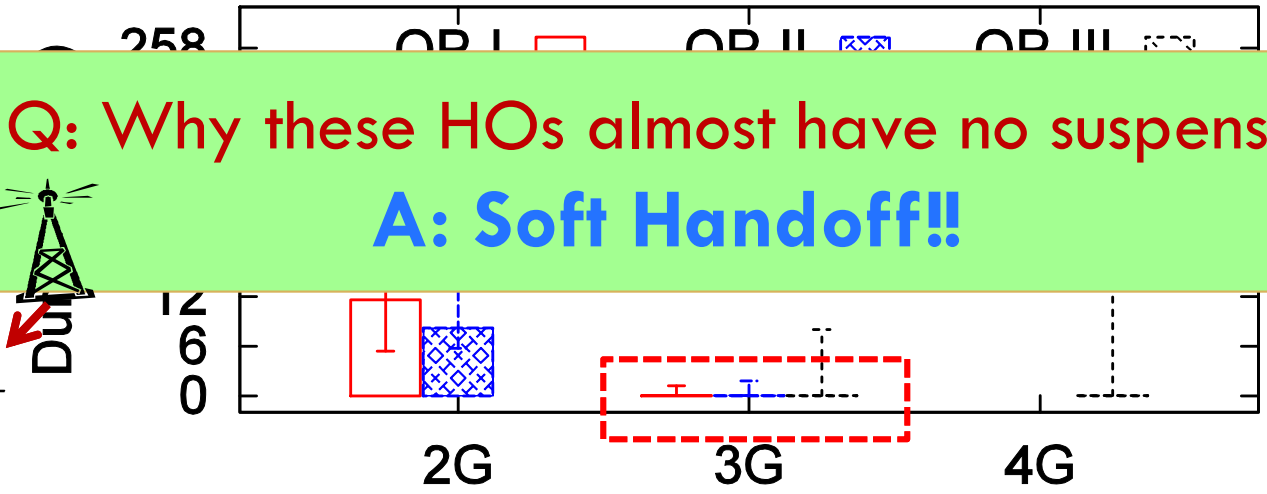
(a). Inter-System HO



(b). Intra-System HO

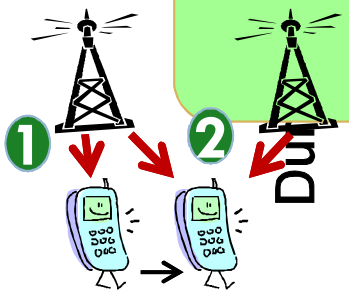
Data Suspension Time



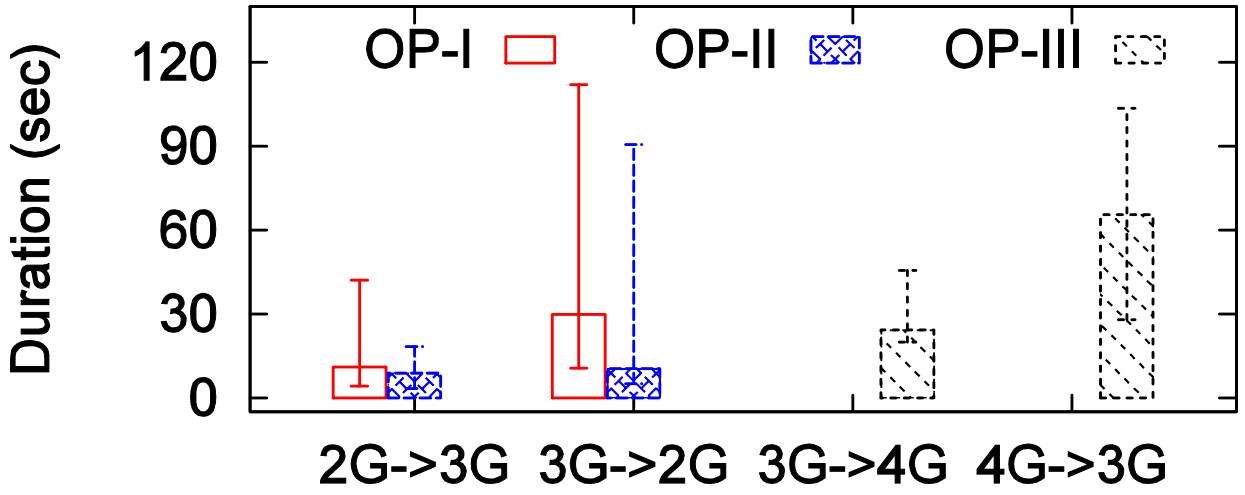


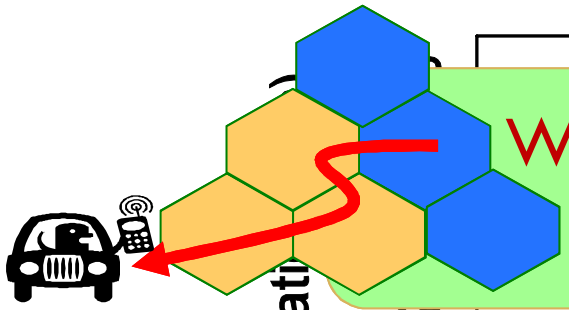
Q: Why these HOs almost have no suspension?

A: Soft Handoff!!



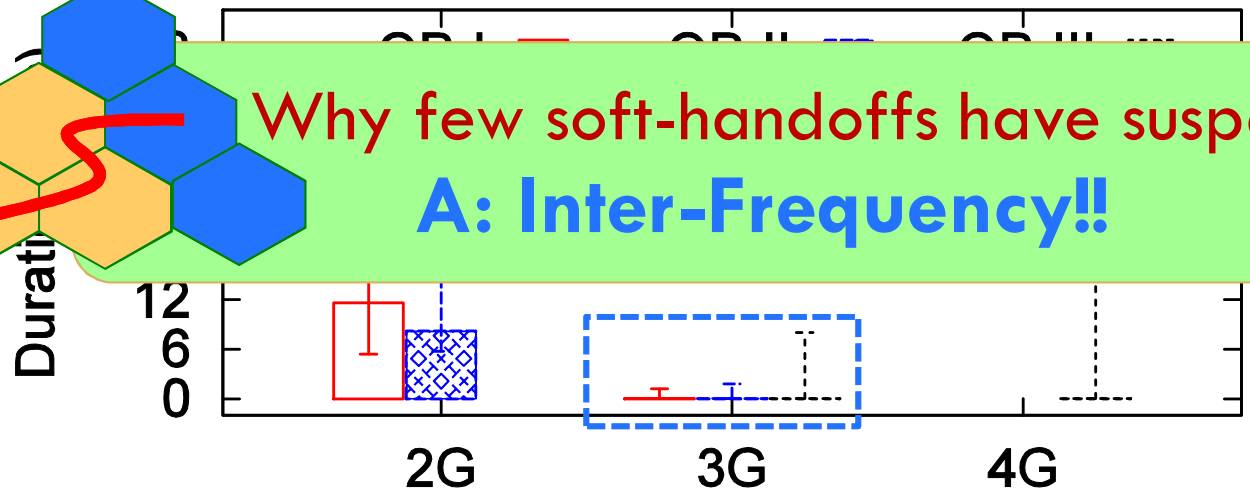
Data Suspension Time



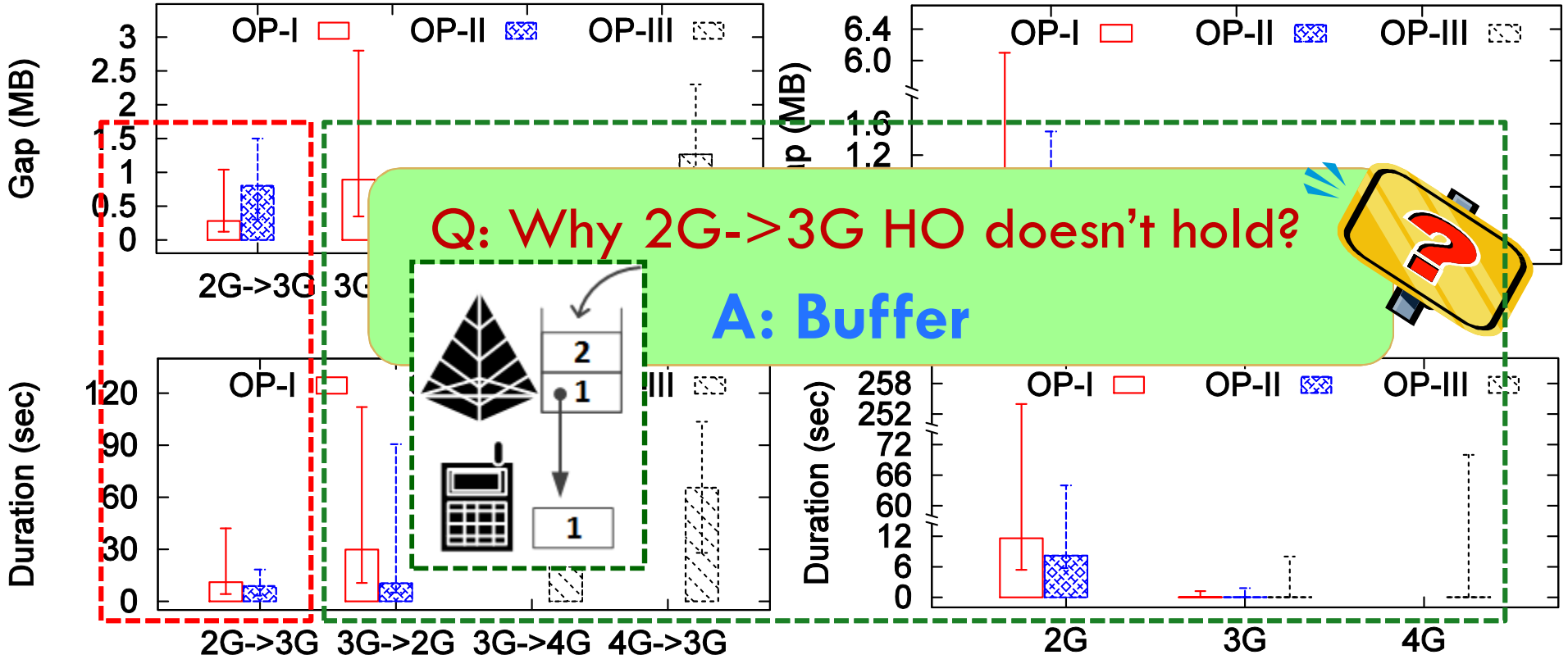


Why few soft-handoffs have suspension?

A: Inter-Frequency!!



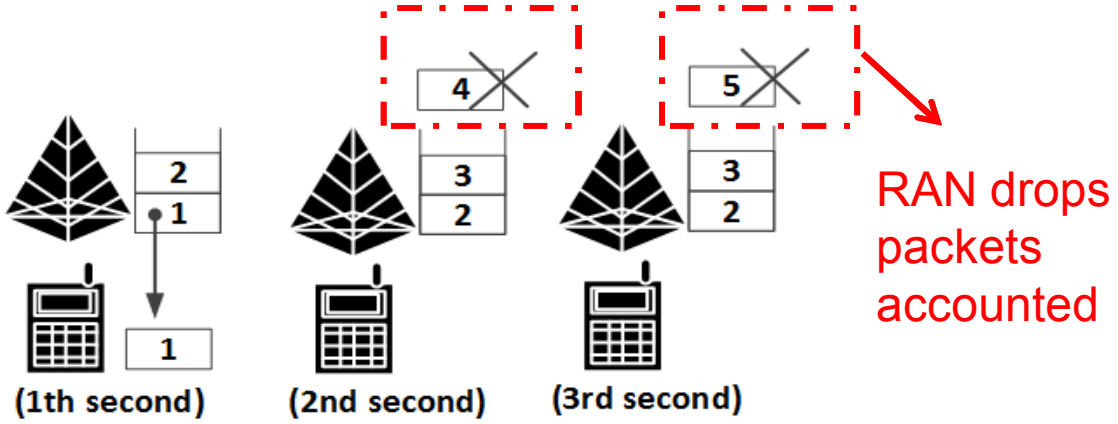
Accounting Gap vs. Suspension Time



Gap is *usually* proportional to suspension time.

Why buffer causes gap?

- Recall…



  - 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

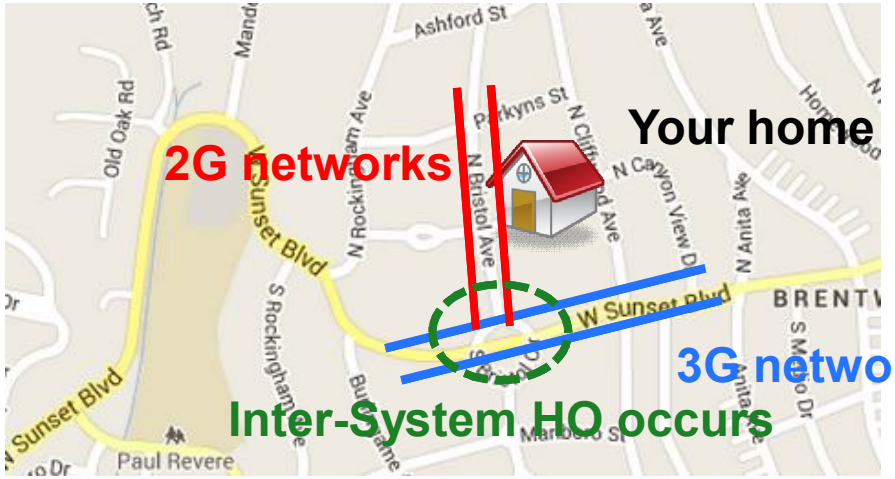
Q: Is it so perfect?

A: Depends !!

- Reduce gap caused

Hybrid Network

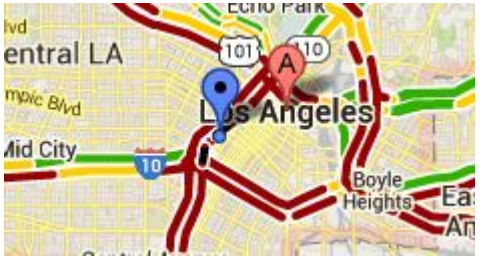
- An Example



Suffer over-accounting issue every day !!

More Results

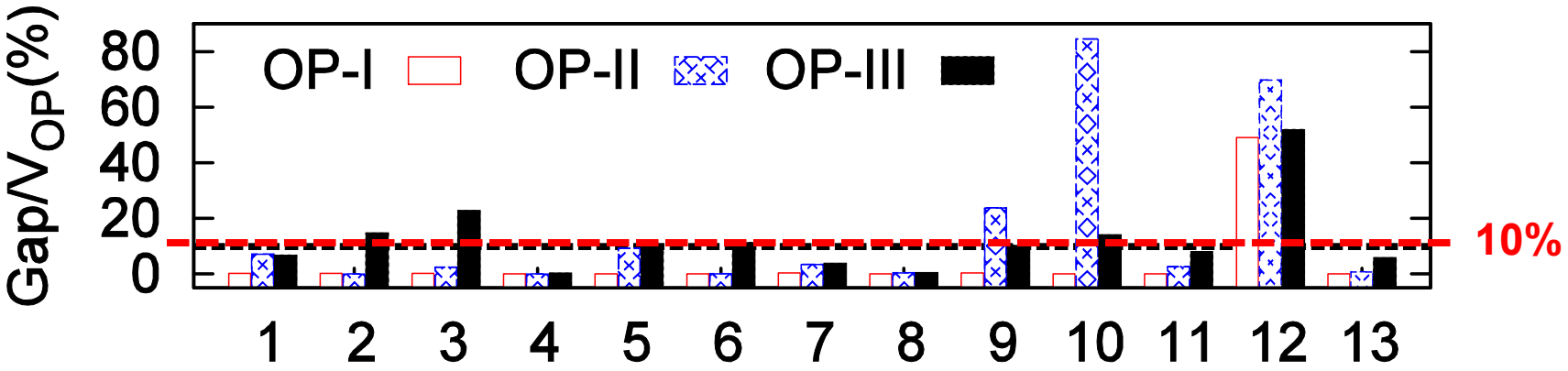
- 3 US major operators
- 13 routes (232.3 km in total)
  - 2 regions: New York and Los Angeles
  - Downtown + suburb
  - Freeway & local
- Real applications



I-10 in LA

I-405 in LA

Accounting Gap



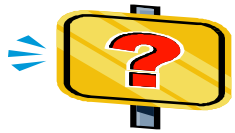
UDP downlink datagram with constant rate 200Kbps

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

	Web sing				
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%

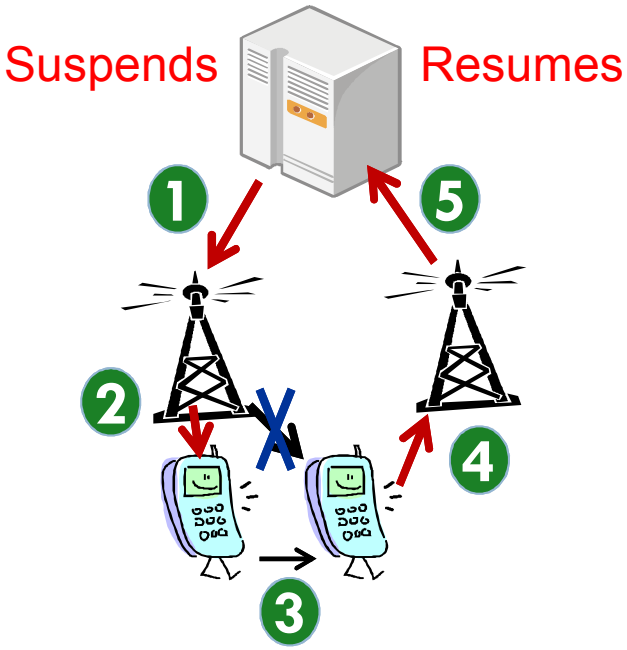
Average accounting gap ratio (Gap/Vop(%)) with real applications on Route 12.

Go Further: Root Causes

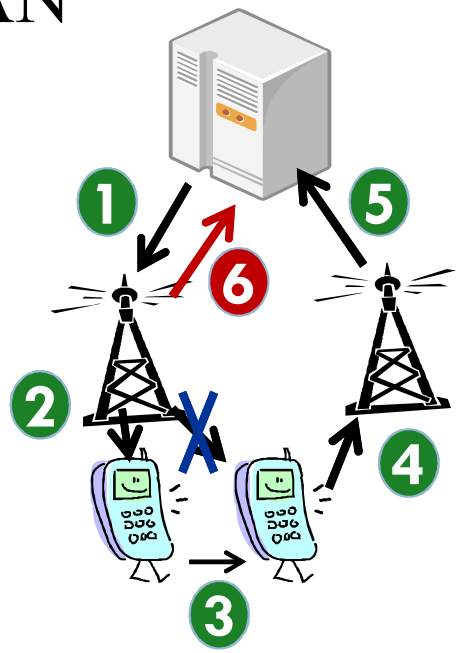
- Gap for no-signal/weak signal
  - Insufficient coverage
- Gap for handoff
  - Transmission suspends but accounting doesn't stop
  - Is it possible to address this issue? 
    - Handoff is triggered by operators instead of mobile device
    - Operators know when/what kind of handoff is performed

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?

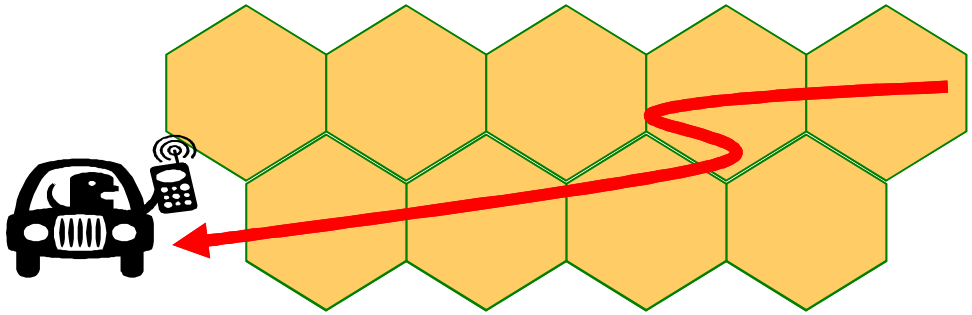
Daily Use Results

	OP-I		OP-II		OP-II
User	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%

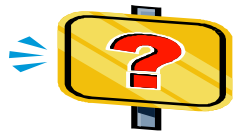
Accounting gap for driving commuters during March 18-29, 2013

Mobility Speed

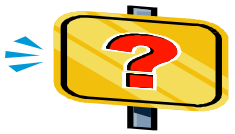
- Higher mobility speed, more handoffs



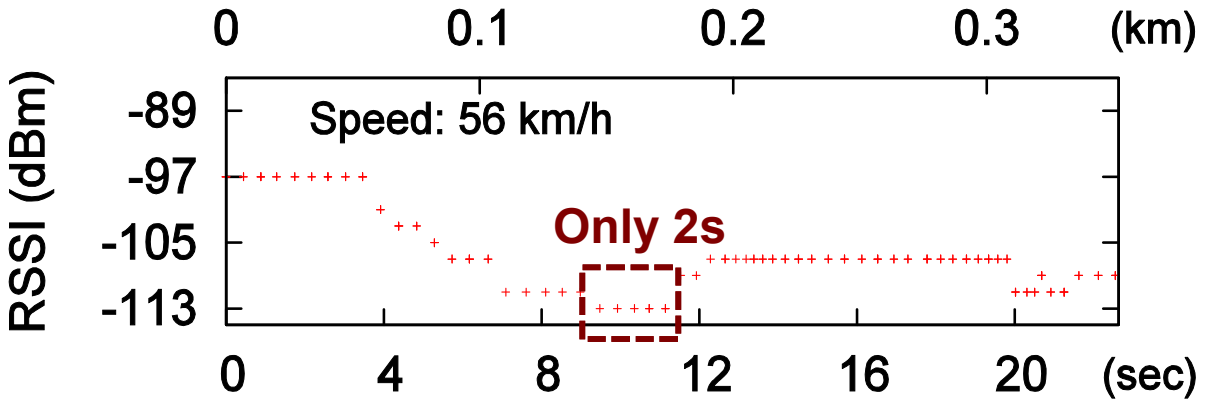
- Does it mean larger accounting gap?



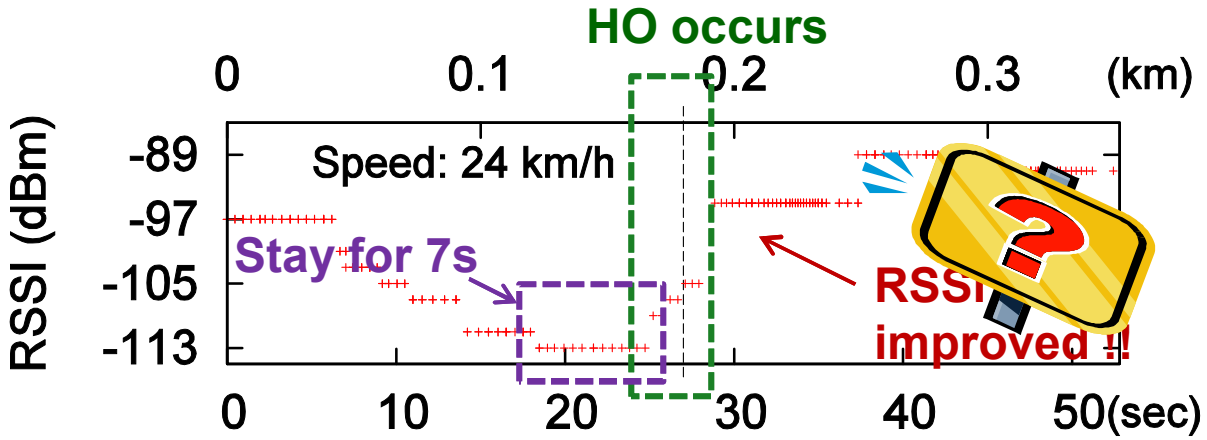
  - NO
- Higher mobility speed, more inter-system handoff ?
  - Not always



An Example: Mobility Speed



(a). High Mobility Speed



(b). Low Mobility Speed