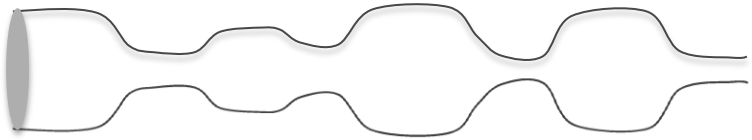


T-Mobile

Demystify the Impact of E2E Latency on Mobile QoE

Dr. Jie Hui (jie.hui@t-mobile.com) , Principal Engineer
QoE Lab, T-Mobile U.S.A
Jun 25, 2013

Acknowledgements to T-Mobile team and contributors: Kevin Lau, Himesh Bagley, Jeffery Smith, Pablo Tapia, Jason Chang, Aaron Drake, Antoine Tran

Introduction of Me

15 years experience in mobile networking R&D, passionate about Quality of User Experience (QoE) and E2E Cross-Layer Optimizations

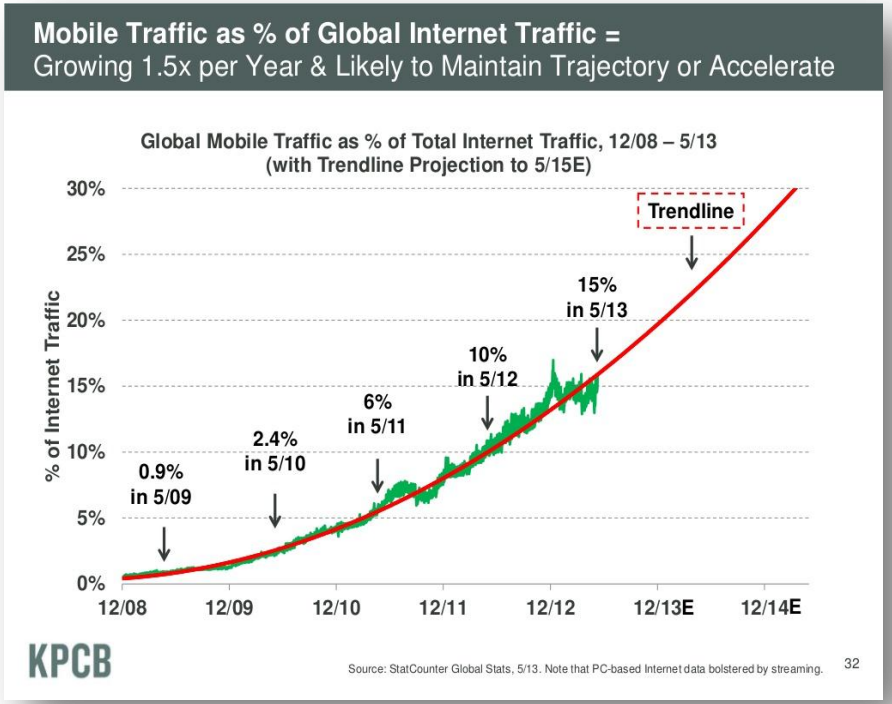
- QoS over UMTS, ZTE, 3G R&D
- QoS over Wi-Fi, NCSU, ECE
- QoS over Wi-Max, Intel Labs, Wireless Network Lab
- QoE over Cellular Network, T-Mobile, QoE Lab

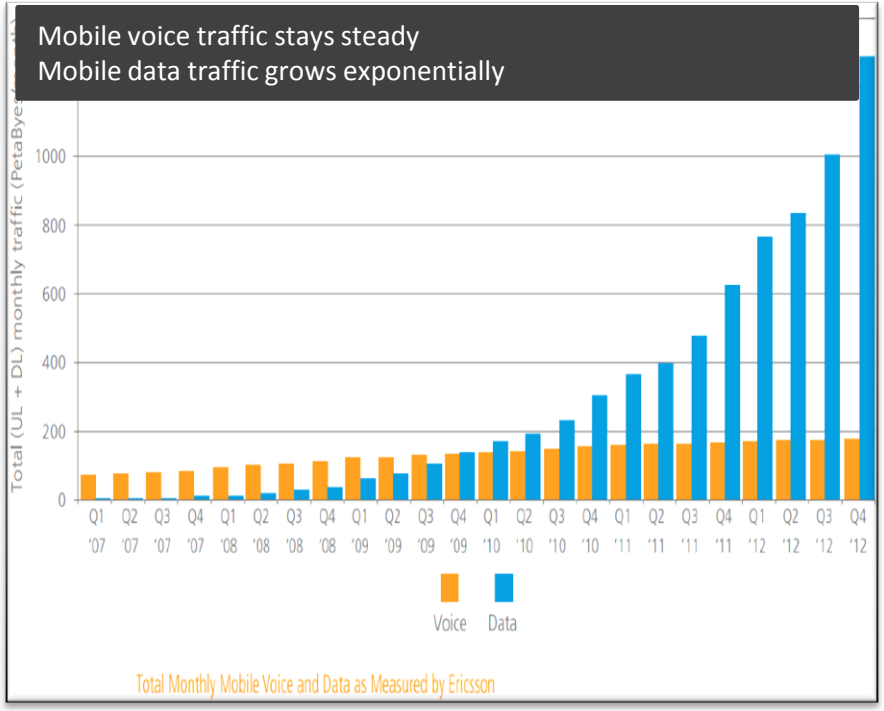
Agenda

- Mobile trends and challenges
- Latency mysteries
- Call for actions

Mobile Trend and Challenges

Aggressive Mobile Data Growth



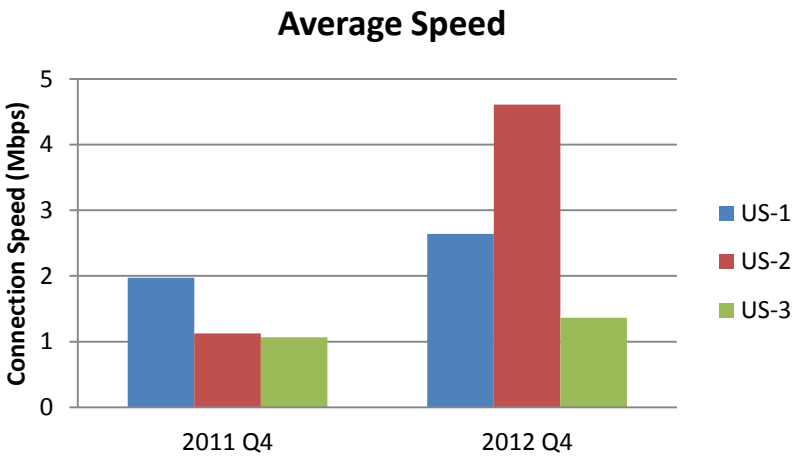


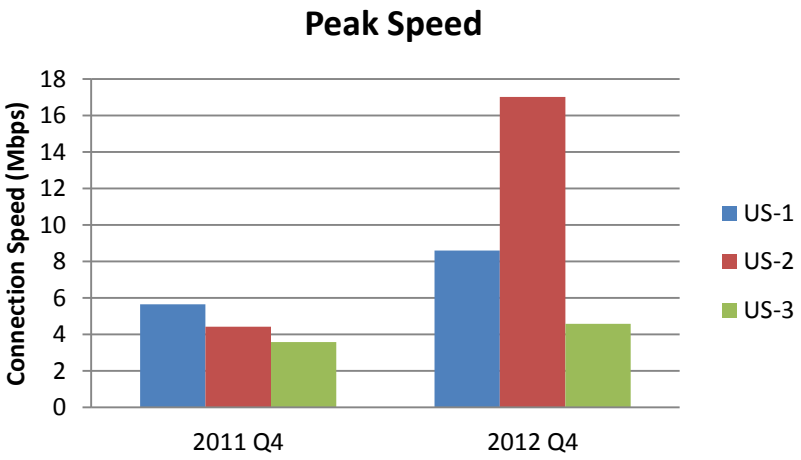
"2013 Internet Trends", KCPB

"The State of the Internet", Q4 2012, Akamai

Faster Mobile Network Speed

- Access technology faster – GSM, EDGE, UMTS, HSPA, HSPA+, LTE
- Mobile connection speed faster





"The State of the Internet", Q4 2011/ 2012, Akamai

Mobile Device Processing Faster

Snapdragon platform examples

	Snapdragon 800	Snapdragon 600	Snapdragon 400	Snapdragon 200
CPU	Up to 2.3 GHz Quad Krait 400 CPU	Up to 1.9 GHz Quad Krait 300 CPU	Up to 1.7 GHz Dual Krait 300 CPU	Up to 1.4 GHz Quad Cortex A5 CPU
GPU	Adreno 330 GPU	Adreno 320 GPU	Adreno 305 GPU	Adreno 203 GPU
DSP	Hexagon, QDSP6V5A, 600MHz	Hexagon, QDSP6V4, 500MHz	Hexagon, QDSP6V4, 500MHz	QDSP5, 384MHz
Video	4k x 2k UHD video capture/playback	1080p HD video	1080p HD video	720p HD Video (30/15 fps)
Modem	3G/4G World/multimode LTE on select processors	No modem	3G/4G World/multimode LTE on select processors	3G CDMA/UMTS/GSM on select processors

http://www.qualcomm.com/snapdragon/processors/800-600-400-200/specs

Is The Mobile Experience Faster?

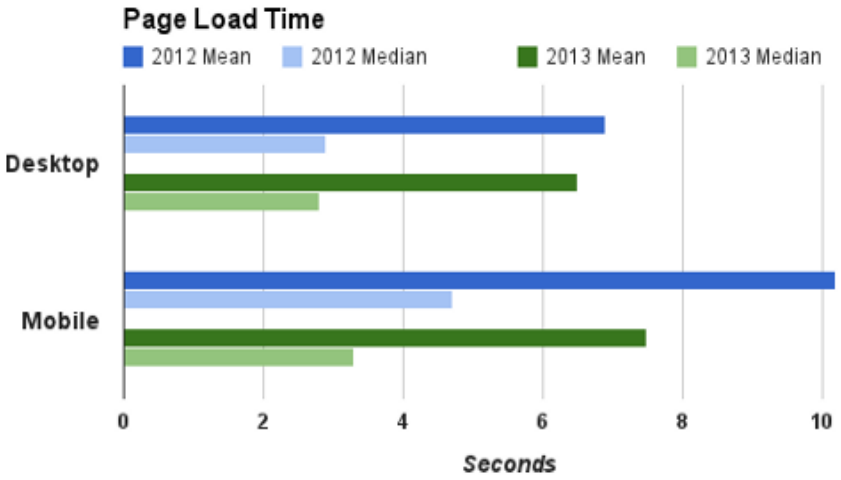
People expects mobile experience as fast as desktop

Usability Engineering 101

Delay	User reaction
0 - 100 ms	Instant
100 - 300 ms	*Feels sluggish*
300 - 1000 ms	Machine is working...
1 s+	Mental context switch
10 s+	I'll come back later...

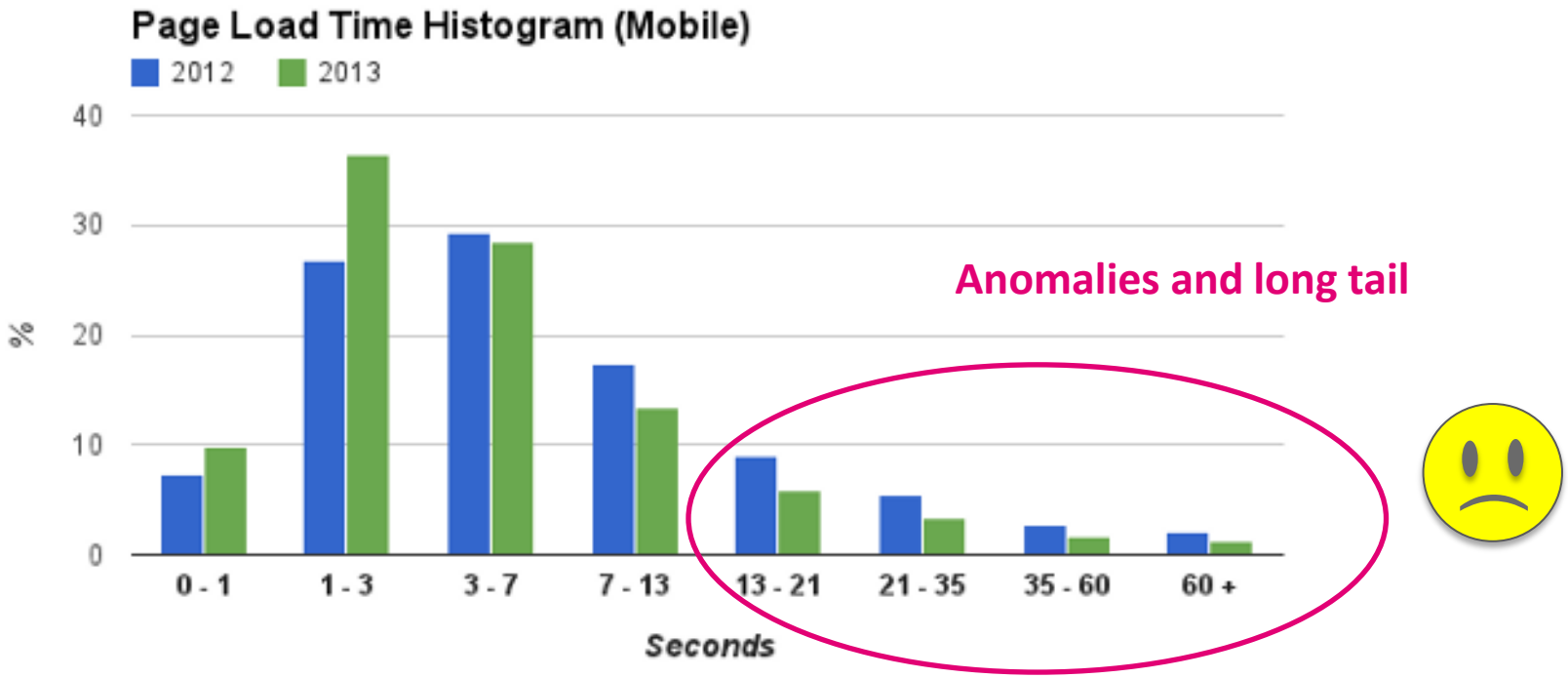
"Building faster mobile websites", Ilya Grigorik, Google

Mobile web 30% faster
Desktop web 5.7% faster



"Is the web getting faster?", Google Analytics Blog

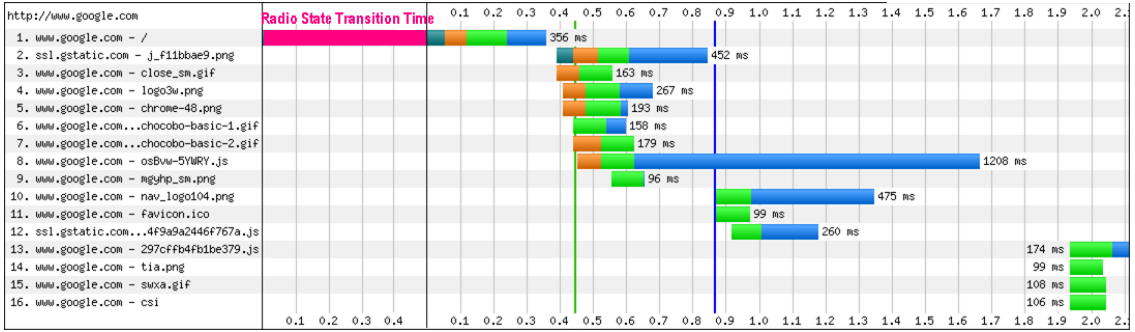
Great, But There Are Still Challenges

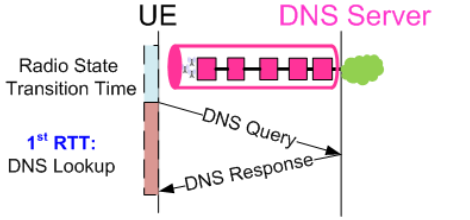


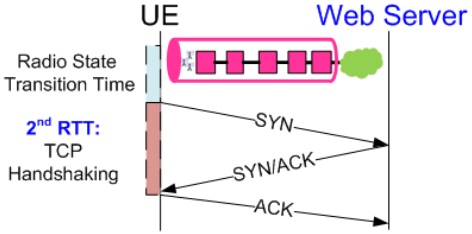
"Is the web getting faster?", Google Analytics Blog

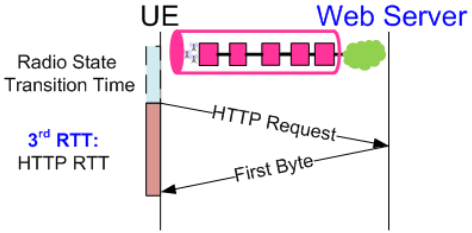
Latency Mysteries

Mobile Browsing QoE Investigations



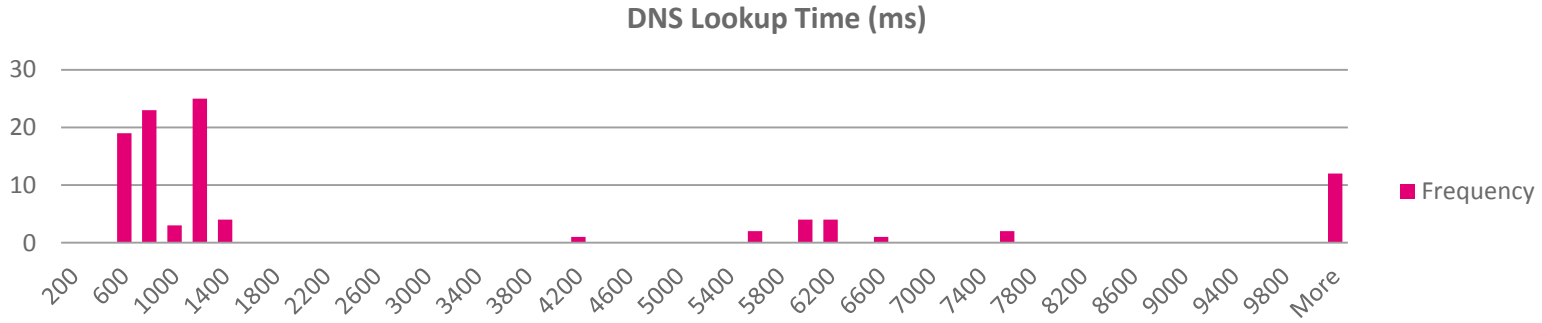


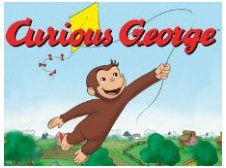




Mystery 1 – Long DNS Lookup Time

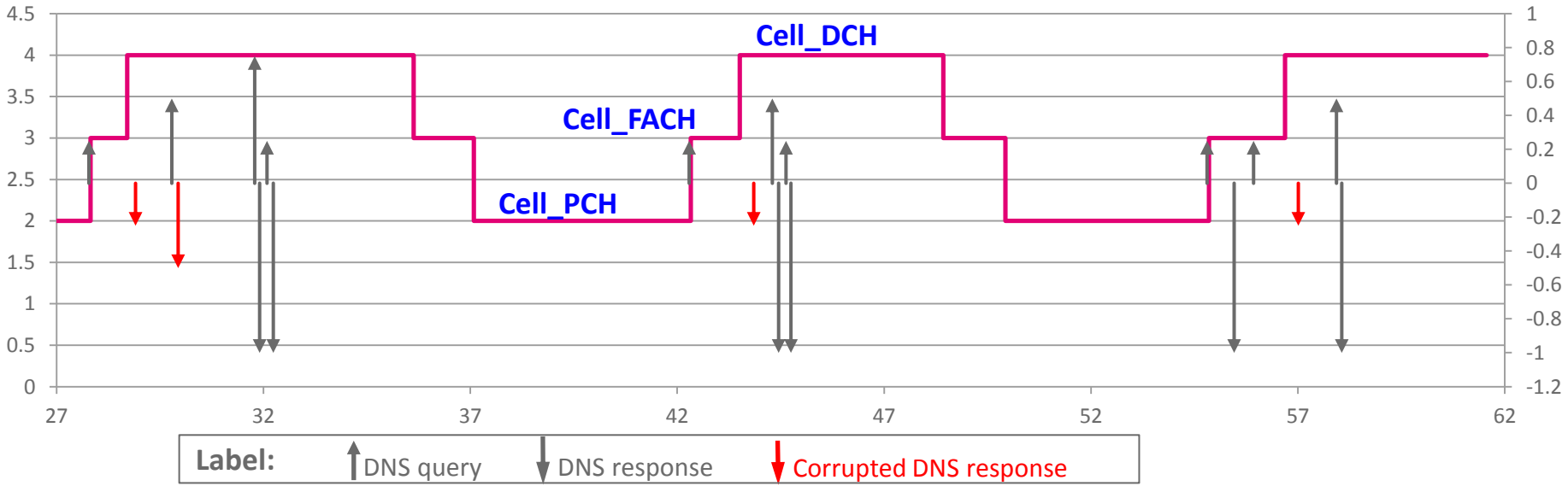
- Aggregated average DNS lookup (network side) = 222 ms
- Curious Georges looked into distribution and outliers (10s+) from device side





No.	Time	Protocol	Length	Transaction ID	Time	Info
155	2011-11-08 21:50:10.310845	DNS	7	0xaad6		Standard query A www.livescore.com
156	2011-11-08 21:50:15.335534	DNS	7	0xaad6		Standard query A www.livescore.com
157	2011-11-08 21:50:20.367028	DNS	7	0xaad6		Standard query A www.livescore.com
158	2011-11-08 21:50:20.402795	DNS	7	0x712b		Standard query A www.livescore.com
159	2011-11-08 21:50:20.510553	DNS	23	0xaad6	0.1435	Standard query response CNAME www.livescore.com.
161	2011-11-08 21:50:20.758721	DNS	23	0x712b	0.3559	Standard query response CNAME www.livescore.com.

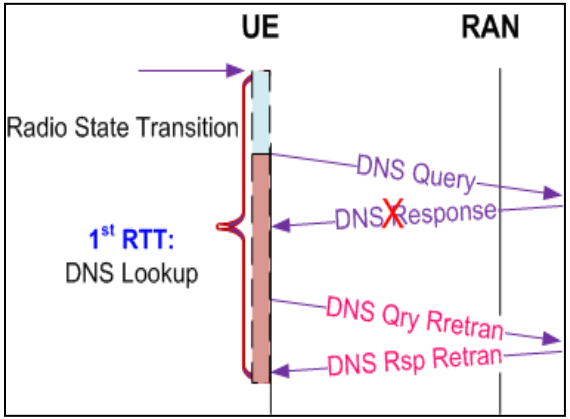
Root Cause: Cross-layer Analysis

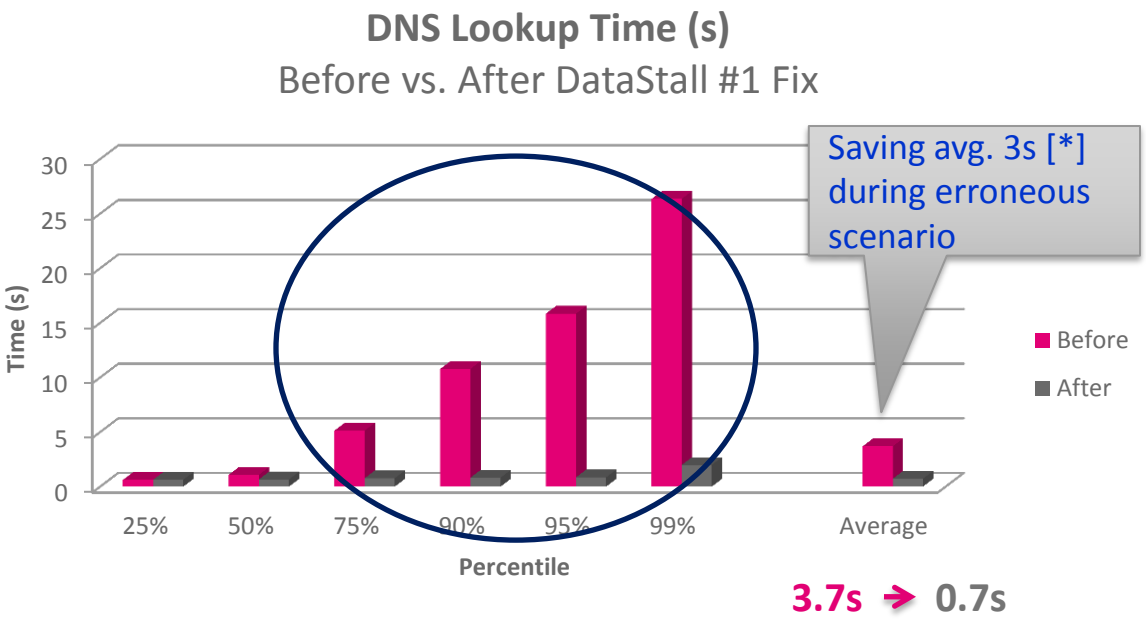


Data Stall #1: Radio network controller corrupts downlink packets due to key out-of-synch after radio state transition (Cell PCH → Cell FACH)

Improvements After Fix

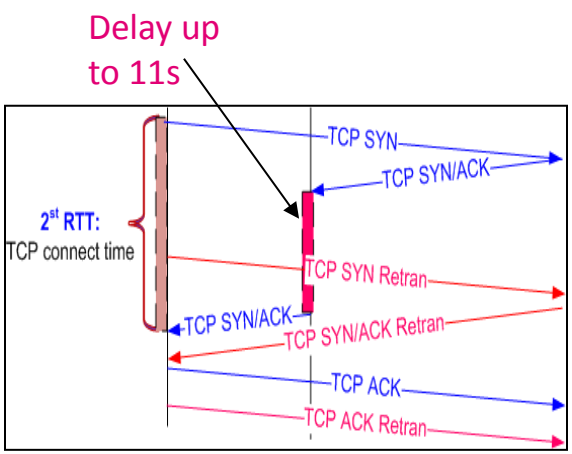
When DNS lookup is initiated from Cell_PCH state

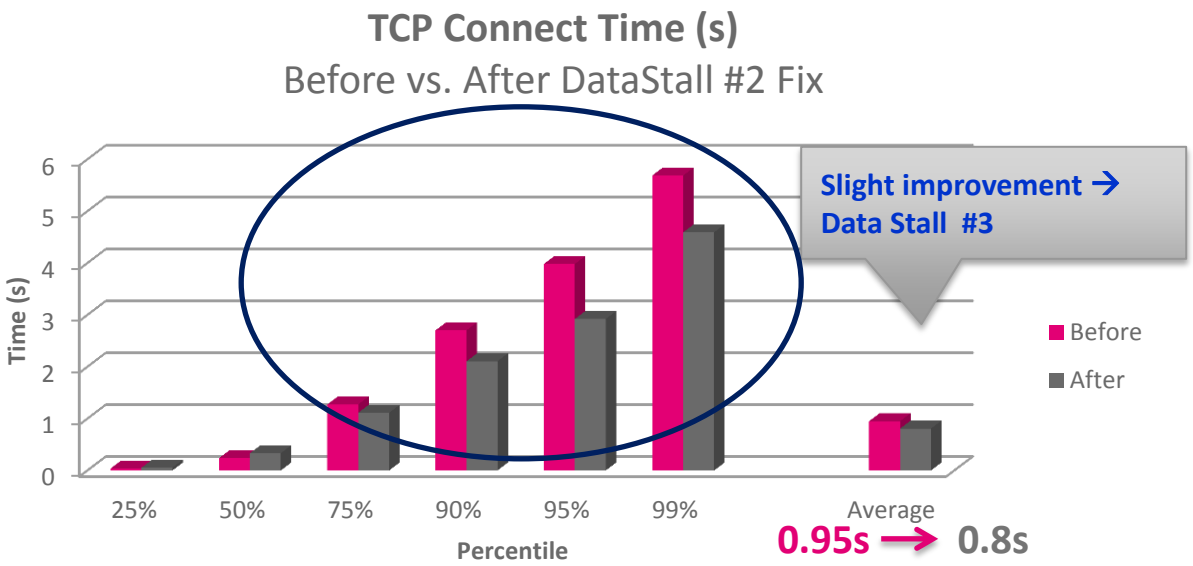




[*] Note: results provide by device testing of 200+ samples.

Mystery 2 – Long TCP Connect Time

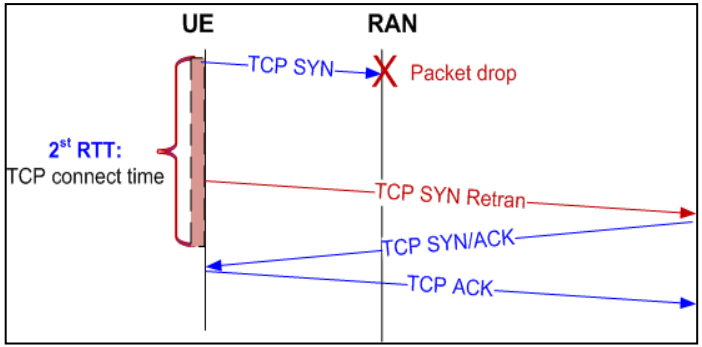


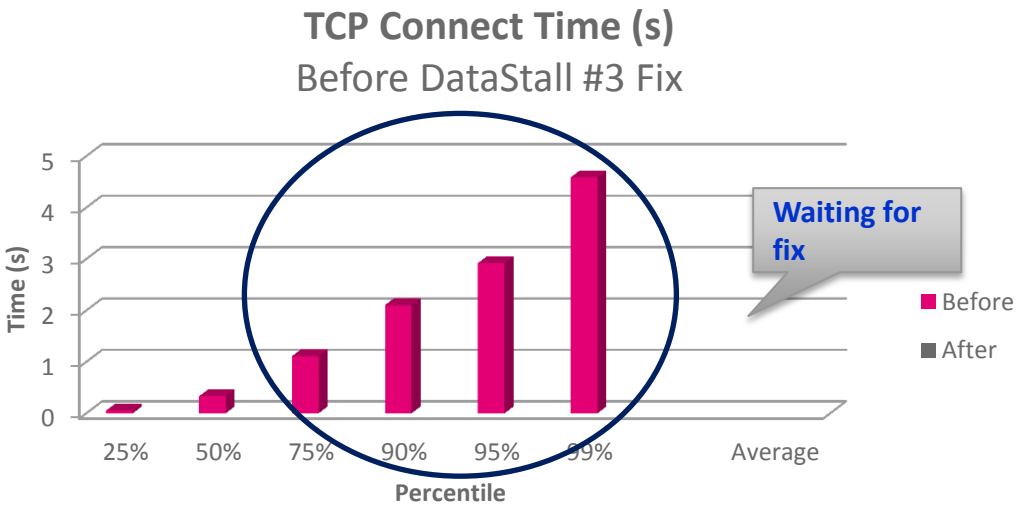


Root Cause: Radio network controller scheduler unnecessarily buffer DL packets up to 11s due to a bug in credit based scheduling algorithm between NodeB and RNC → causes UL RLC retransmissions and RESETs.

[*] Note: results provide by device testing of 2000+ samples.

Mystery 3 – TCP Connect Time Still Long



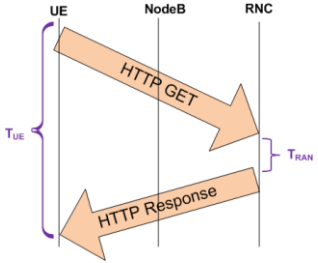


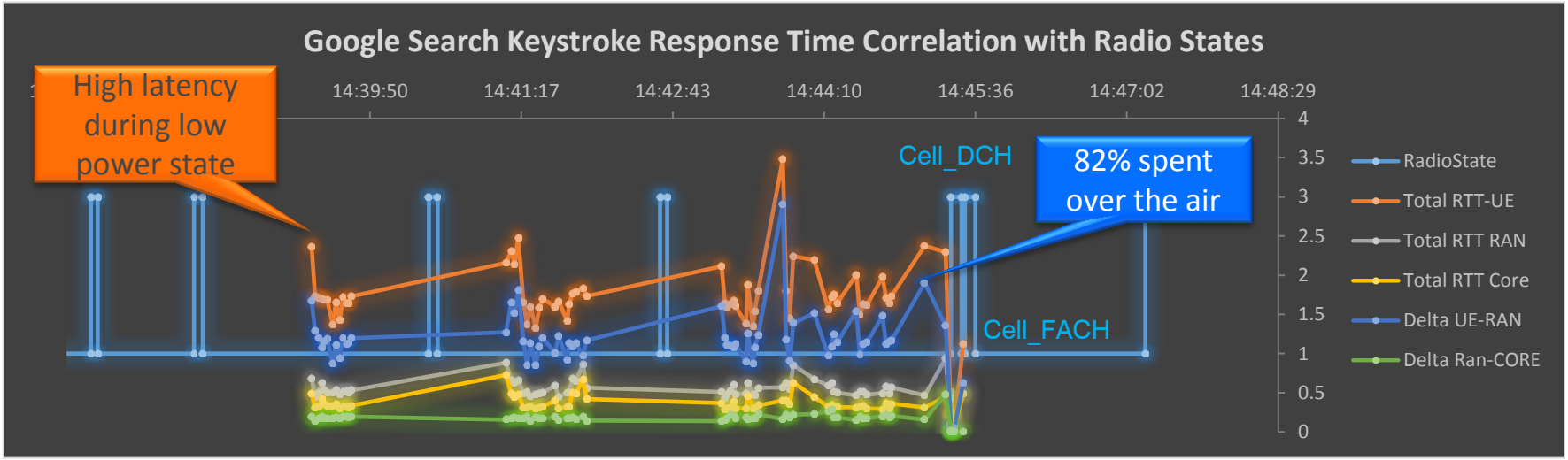
Root Cause: Radio network controller UL scheduler drops UL packets during channel switching from DCH to FACH, same problem happens during HS←→R99, DCH←→FACH

[*] Note: results provide by device testing of 2000+ samples.

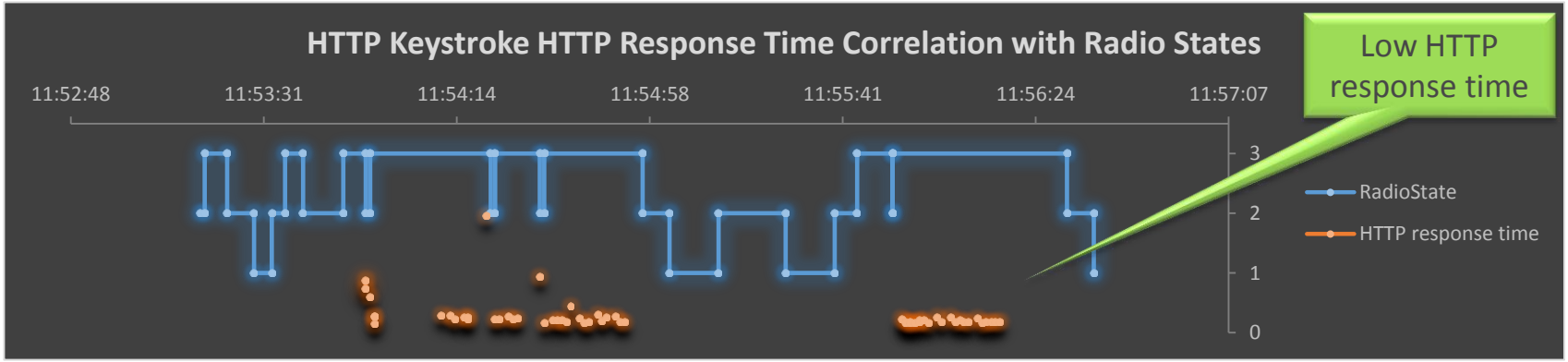
Mystery 4 – Long HTTP Response Time

Keystroke HTTP response time

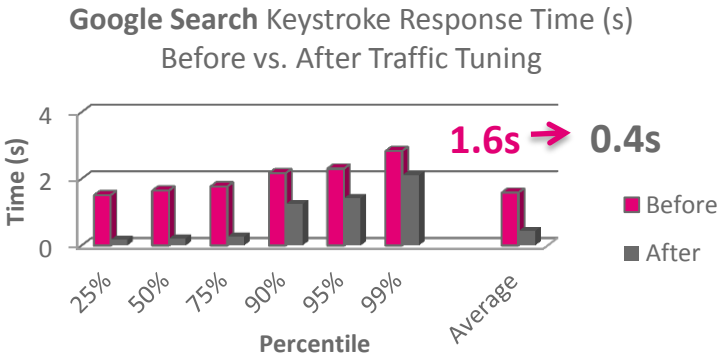




Cross-Layer Analysis After Search Traffic Change

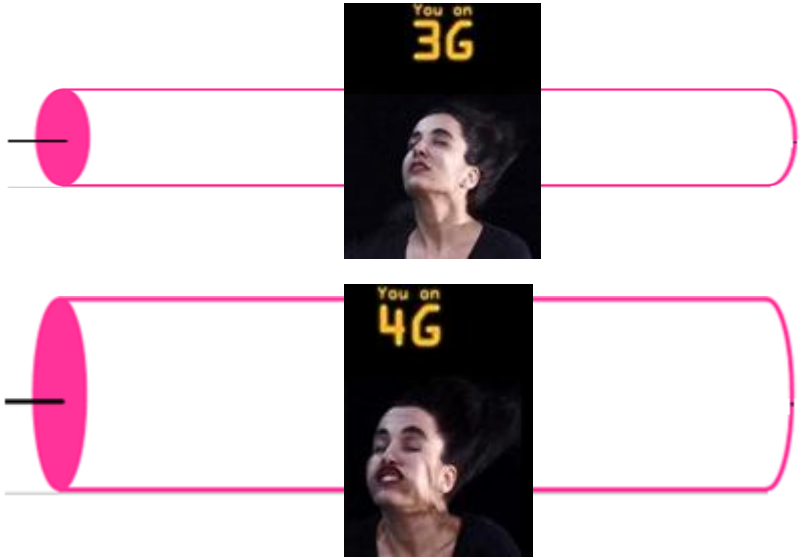


Keystroke HTTP requests and responses mostly happen in **high power state (Cell_DCH)** on dedicated channel due to large packet size (~1200B) therefore experience **high data rate and low latency**.



Misperception

Front End

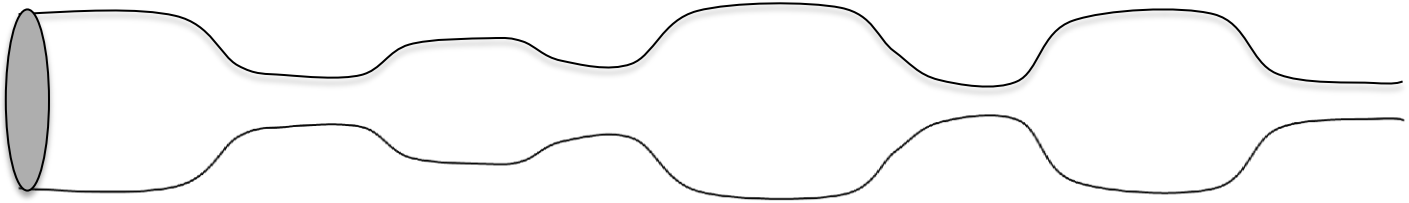


Back End

3G, 4G speed facial illustrations from http://www.intomobile.com/2012/04/18/tmobile-and-att-top-network-speed-tests/

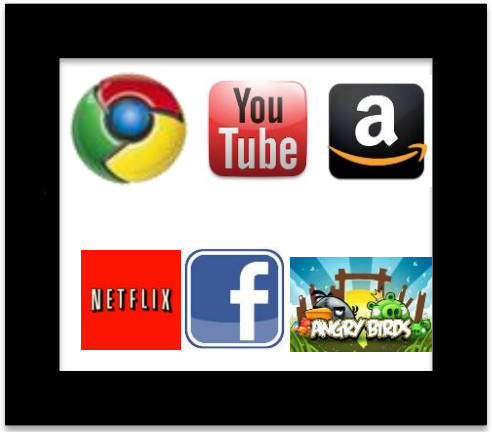
Demystify

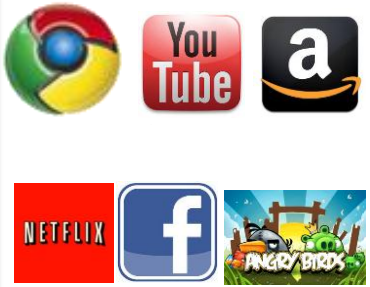
It is an elastic pipe!



- Shared channel
- Power limitation
- Traffic dependent – You have the power to tune your traffic to be radio aware!

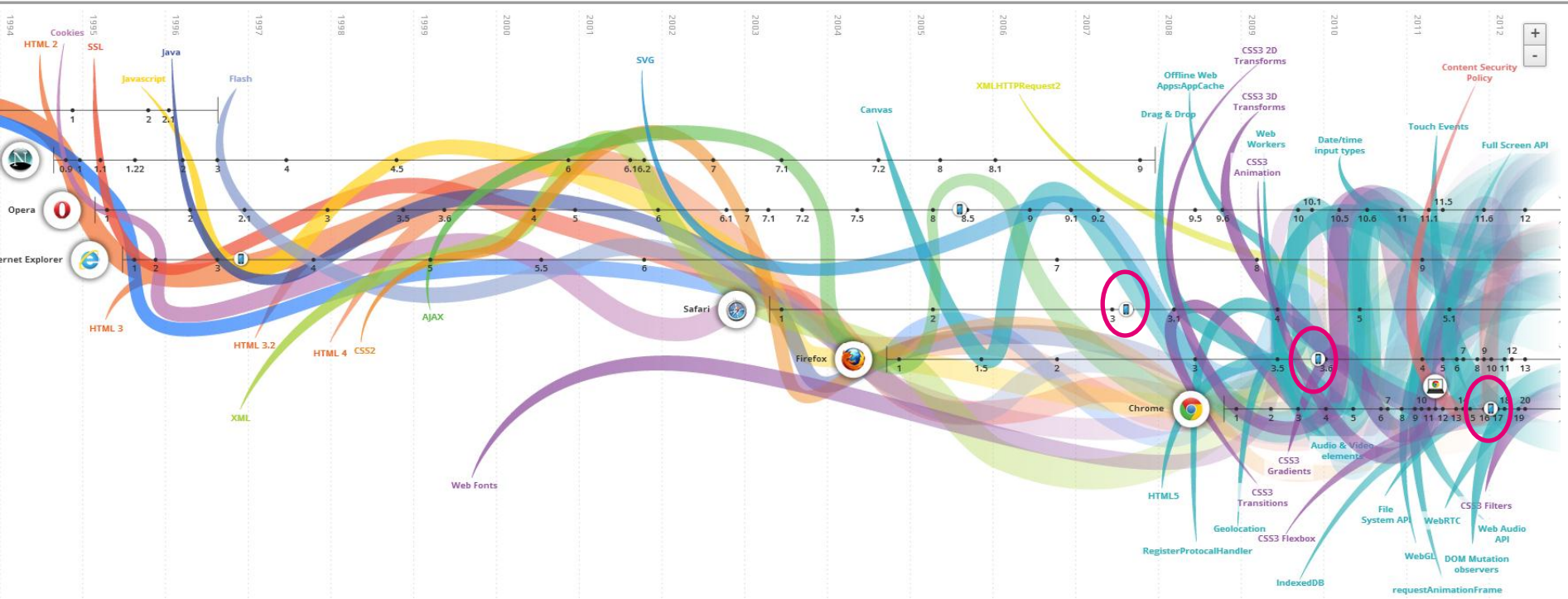
Perhaps The Biggest Mystery Of All…





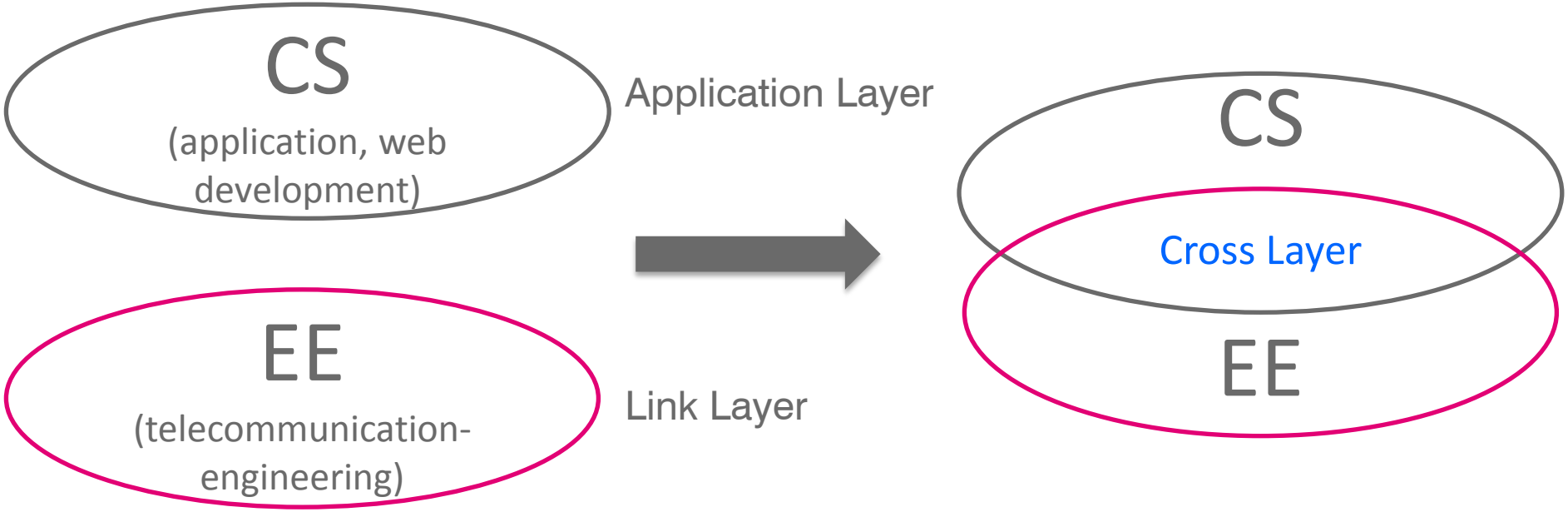
Call for Actions

Inspirations - Fast Web Evolution and Open Innovations



http://www.evolutionoftheweb.com

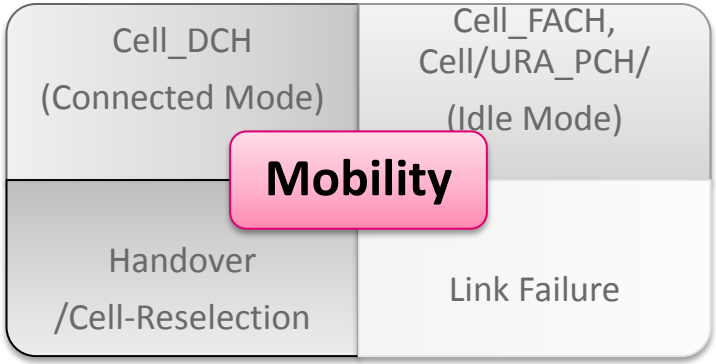
More Open Innovations & Inter-disciplinary R&D

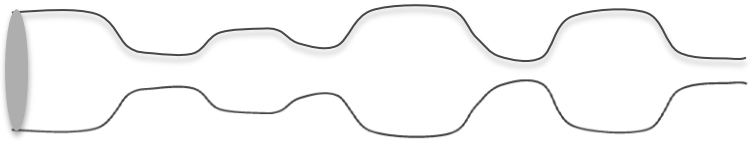


Area 1:
Transient State Performance and Resilience

Problem:

- **Automatically** characterize and instrument transient state mobile application performance
- Packet loss and retransmissions observed during transient states [*]
- **Cross-layer analysis and optimizations** still not fully explored!



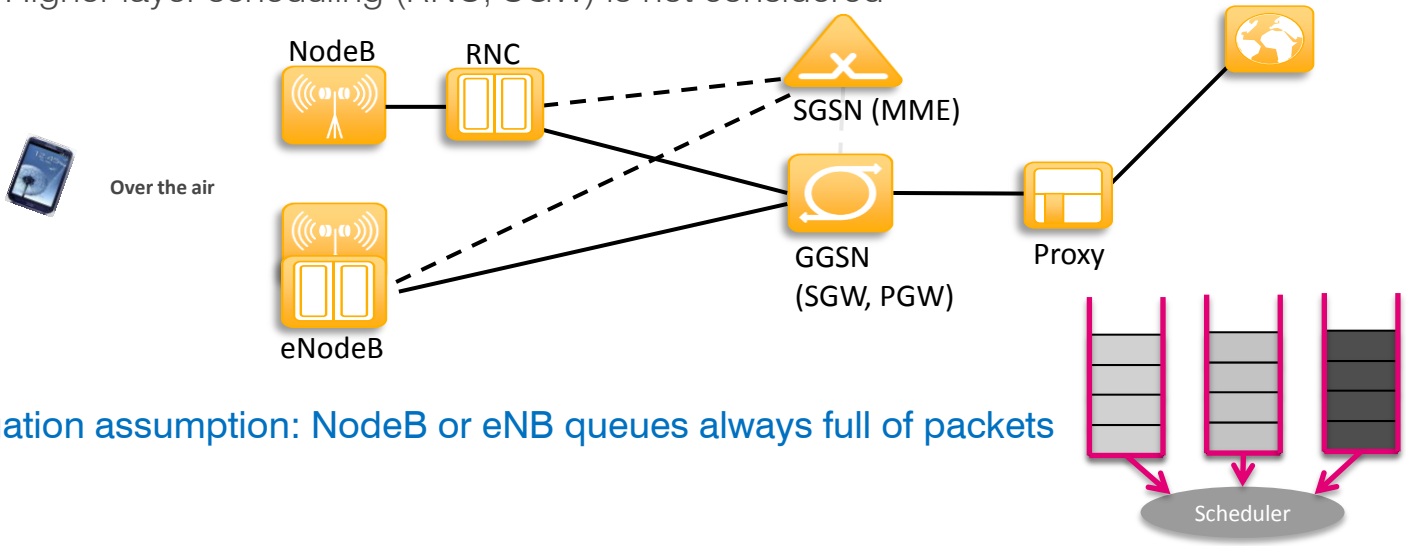


[*] "Discovering RRC Transient States, Behavior and Performance Implications in Cellular Networks", Sanae Rosen, Haokun Luo, Z. Morley Mao, Jie Hui, Aaron Drake, Kevin Lau, submitted to IMC 2013

Area 2:
Interactive Traffic Modeling and Scheduling

Problem:

- 3GPP radio scheduling designed mostly with Full Buffer Traffic model
- Higher layer scheduling (RNC, SGW) is not considered



Evaluation assumption: NodeB or eNB queues always full of packets

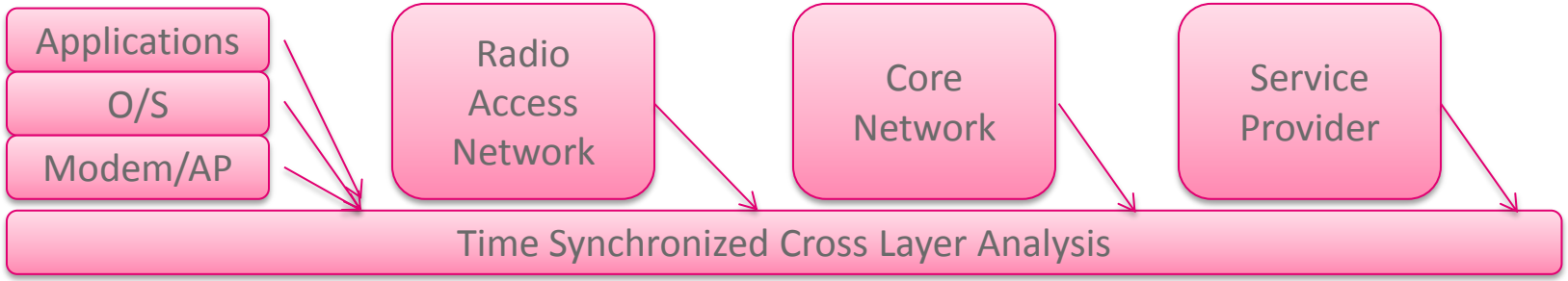
"Traffic models impact on OFDMA scheduling design", P Ameigeiras et al. EURASIP Journal on Wireless Communications and Networking 2012

Quality of User Experience (QoE) Lab

Work with us!

Unique approach

- Measure end user experiences from the device perspective
- Seek success by improving not only averages but also the **spread** and **long tail**
- Leverage key industry and academic partners for joint R&D and **Real User Measurement (RUM)**
- Analyze cross functionally to achieve cross layer intelligence and automation



Thank You!

Questions?

Jie.hui@T-Mobile.com