

# Discovering Fine-grained RRC State Dynamics and Performance Impacts in Cellular Networks

Sanae Rosen \*    Haokun Luo \*    Qi Alfred Chen \*  
Z. Morley Mao \*    Jie Hui #    Aaron Drake #    Kevin Lau #

\*University of Michigan

#T-Mobile USA Inc.<sup>1</sup>

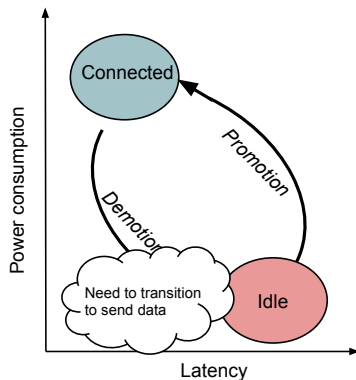
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<sup>1</sup>The views presented here are as individuals and do not necessarily reflect any position of T-Mobile.

# Why RRC states?

- Radio Resource Control (RRC) states balance **performance** and **power consumption**
- Carriers: How do RRC transitions affect users?
- Mobile systems/apps: How to account for RRC transitions in scheduling traffic? <sup>1</sup>

RRC state example  
(details vary by network type)

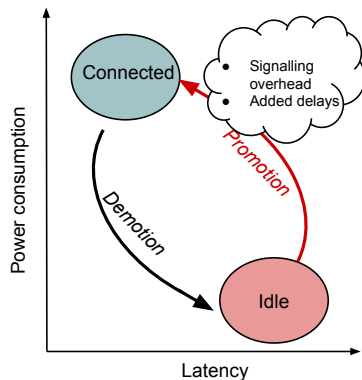


<sup>2</sup>Balasubramanian et al, IMC 2012

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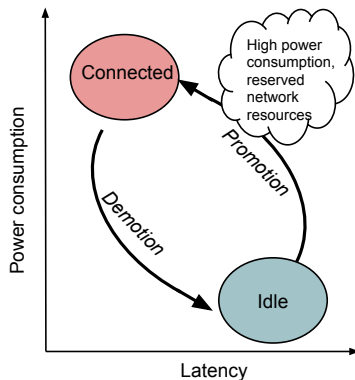


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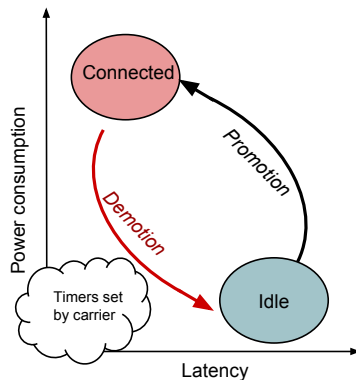


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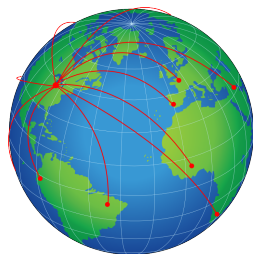
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# Contributions

- Methodology for crowdsourcing RRC measurements
  - Impact of **demotions/promotions** on latency
- Perform a worldwide study of RRC performance
  - Previously unknown latency problems
- Cross-layer analysis from link layer to application layer
  - Through crowdsourcing and controlled experiments



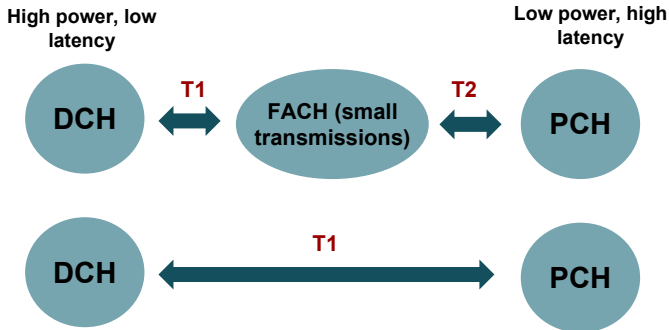
## Related work

- RRC states impact performance (controlled experiments)<sup>1,2</sup>
  - We characterize the performance impact globally
- Bad interactions between applications and RRC state timers<sup>3</sup> and how to avoid them<sup>4</sup>
  - We focus on state transition problems
- Client measurements to understand networks<sup>5</sup>
  - Large-scale RRC measurements not yet addressed

<sup>1</sup>Qian et. al, MobiSys 2011 <sup>2</sup> Huang et. al, MobiSys 2012 <sup>3</sup> Vallina-Rodriguez et. al, IMC 2013

<sup>4</sup>Liu et. al, MobiArch 2011 <sup>5</sup>Shepard Hotmetrics 2010 and many others

## RRC state background

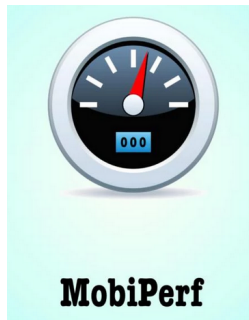


3G UMTS Implementation Examples

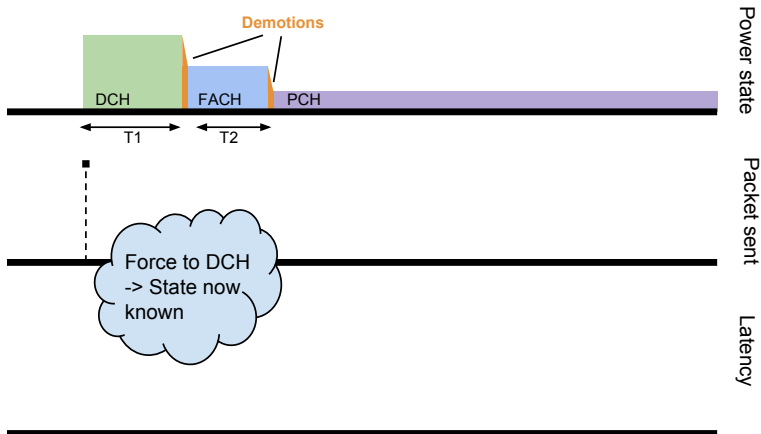


# Crowdsourcing RRC measurements

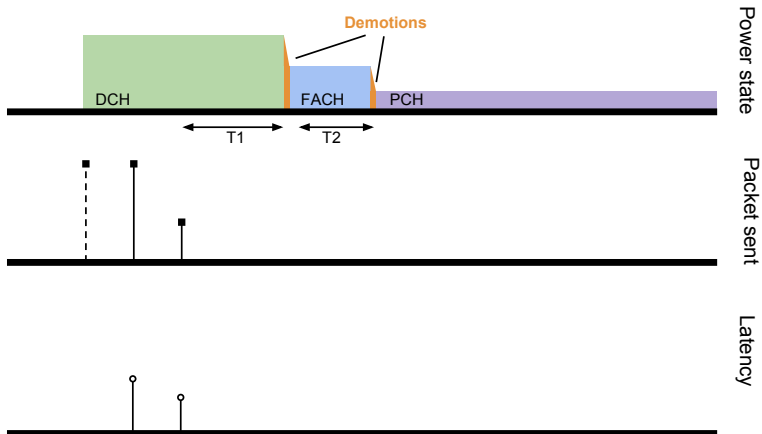
- Android application runs on unmodified user devices to collect network measurements
- As part of Mobiperf (U of M/Northeastern joint project)
- Application, source code, data:  
[www.mobiperf.com](http://www.mobiperf.com)
- Data is anonymized
- App respects user data/battery constraints



# How to infer RRC states

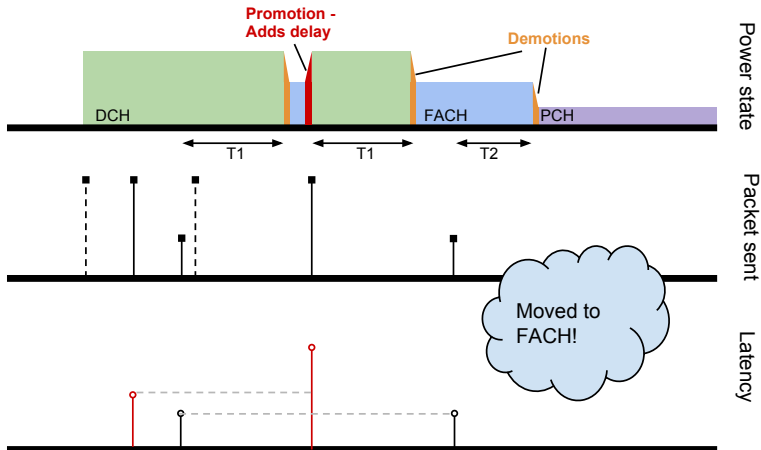


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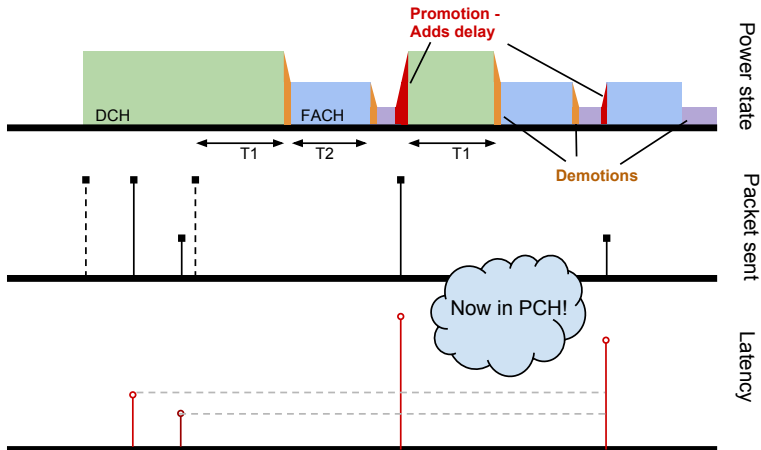
Adapted from Qian et al, IMC 2010

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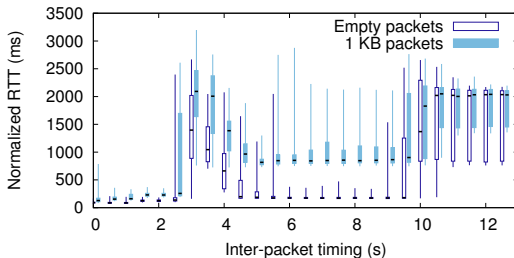
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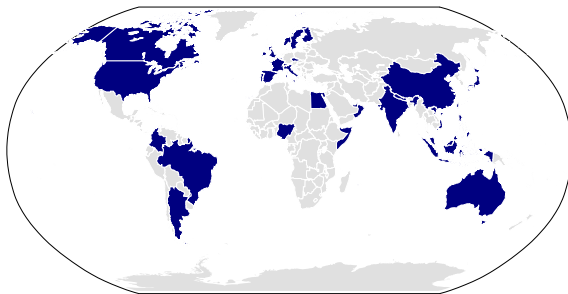
## Data collection

- Use `/proc/net` to observe and avoid interfering traffic
- Long-term data collection to deal with noisy data
- Similar technique to measure higher level protocols
- Validated results with Qualcomm's QxDM
  - Reveals radio link layer messages



# The deployment

Using Mobiperf, a popular mobile app for measuring mobile network performance<sup>1</sup>:

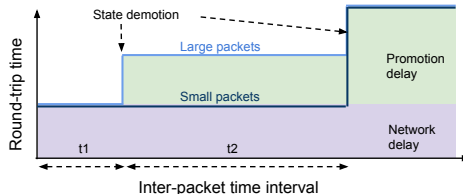


650 000 sets of tests, 7 distinct network technologies

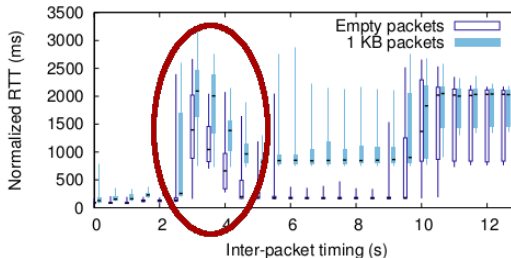
<sup>1</sup> Blank map from [https://en.wikipedia.org/wiki/Wikipedia:Blank\\_maps#mediaviewer/File:BlankMap-World6.svg](https://en.wikipedia.org/wiki/Wikipedia:Blank_maps#mediaviewer/File:BlankMap-World6.svg)

# Demotion delays: a previously unknown problem

Expected results:

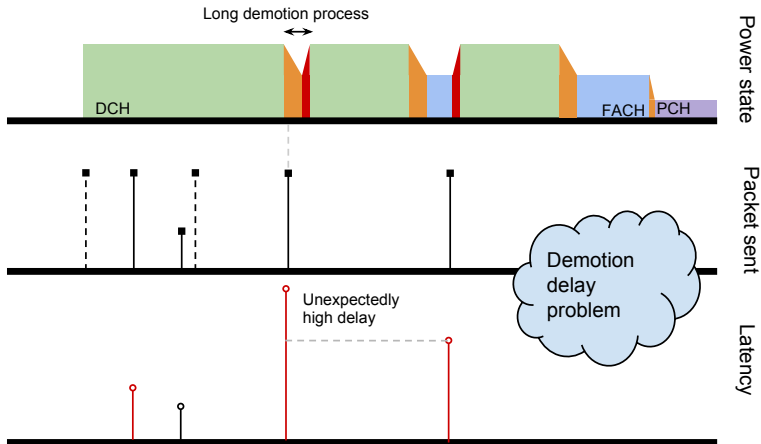


Actual results:





## How to infer RRC states

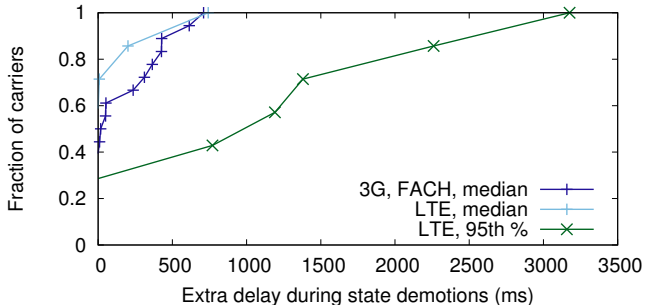


Confir

through cross-layer analysis with Qualcomm's QxDM

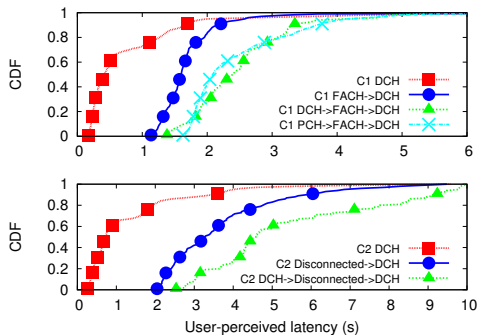
# Prevalence of demotion delays

Distribution of additional delays seen across carriers



## Application impact

Using a custom application controller to simulate web browsing



Measurements of page loading times for two major carriers

# Takeaways

For carriers:

- Client-based performance measurements are critical
- We have identified several RRC implementation pitfalls
- Simpler state machines may perform better than complex ones

For mobile system developers:

- Systems exist for scheduling traffic around RRC states
- Adapt to carrier RRC state characteristics?

# Conclusion

- Methodology to accurately measure RRC transitions on uncontrolled user devices
  - Measures user-perceived performance directly
  - Collect data accurately and efficiently by intelligently scheduling measurements
- Allowed creation of largest RRC performance data set to date
  - Revealed previously unknown performance problems
  - Essential as networks continue to evolve
- Cross-layer analysis with a custom application controller tool
  - Confirm, analyze in depth problems detected in the wild

# Thank you!