# **Detecting if LTE is the Bottleneck** with BurstTracker





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My video quality is only 360p (1.5 Mbps). **The cellular downlink must be slow.** 









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My video quality is only 360p (1.5 Mbps). **The cellular downlink must be slow.** 





### But a speed test says the downlink is **10 Mbps**. **What's going on?!**









### We can not conclusively determine if the cellular downlink is the bottleneck.











Where is the bottleneck?



Network









slow server code?

Where is the bottleneck?



Network









### **App Server**

slow server code?

Where is the bottleneck?













### **App Server**

slow server code?

Core Cellular Network throttling at middlebox? Where is the bottleneck?



Radio Access Network

congestion?









### **App Server**

slow server code?

**Core Cellular** Network

Where is the bottleneck?











### **App Server**

slow server code?

Where is the bottleneck? verizon slow app code? **Core Cellular** Network **Radio Access** throttling at middlebox? Network congestion?







### A Developer's Perspective of Network Bottlenecks







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If empty, traffic bottlenecked **on the way** to the base station.

Queues

### Radio (wireless) Link









### **Base Station**

If empty, traffic bottlenecked on the way to the base station.

Queues

If nonempty, bottleneck is *at base station*.

### Radio (wireless) Link







## The cleal Metric



Providers know the status of the queues; but no one else does. **BurstTracker estimates this metric at the client.** 









### Providers know the status of the queues; but no one else does. BurstTracker estimates this metric at the client.







### User











### User



Resources scheduled to purple user in this millisecond.













### User











### User











### User









# Block (RB) Resource



### User











### User













### User









# Block (RB) Resource



### User













### User



Purple user not given all resources; its queue has drained out.









- Likely 1
- **Begin** 
  - (D) End







### A user only needs to know their resource allocation to infer their queue status.









# Block (RB) Resource





**Burst** 

Begin  $(\triangleright)$ 

End 

### A user only needs to know their resource allocation to infer their queue status.









### 1 Mbps over 1 min Cumulative Probability 0.22 - 0.20 - 50 0

Resources allocated in each time slot

### **Provider: Verizon**

)

100



### **Provider: Verizon**



### Resources allocated in each time slot





Resources allocated in each time slot

### Slow transfer was aggregated into bursts that used most of the resources.

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## Is BurstTracker Accurate?

Application	BurstTracker Median Error (%
File Download	7.2
Video Streaming	6.9



### **Experiment Setup**

- 100 runs of each workload
- Network conditions ~ 2–12.5 Mbps

Partnered with Tier-1 provider to get ground-truth queue status measurements.





## **S Burst Tracker Accurate?**

Application	BurstTracker Median Error (%
File Download	7.2
Video Streaming	6.9

### **BurstTracker achieves a median error of 7% for different classes of mobile apps.**



### **Experiment Setup**

- 100 runs of each workload
- Network conditions ~ 2–12.5 Mbps

Partnered with Tier-1 provider to get ground-truth queue status measurements.







# Case Study: Video Streaming



### We found that, surprisingly, the LTE downlink was not the bottleneck.

100	150	200
time (s)		



# Case Study: Video Streaming



### We found that, surprisingly, the LTE downlink was not the bottleneck.

200 time (s)



# 1 Video Segment at the Client

### **Resource Allocation Trace for a Single Video Segment**





# **1 Video Segment at the Client**

### **Resource Allocation Trace for a Single Video Segment**





# 1 Video Segment at the Client

### **Resource Allocation Trace for a Single Video Segment**



BurstTracker indicates that it might be TCP Slow-Start.

![](_page_44_Picture_4.jpeg)

# **Slow-Start Restart at the Middlebox**

![](_page_45_Figure_1.jpeg)

- Only HTTP and HTTPS traffic used middlebox.
- Nonstandard port (7777) bypasses middlebox.

![](_page_45_Picture_4.jpeg)

![](_page_45_Picture_7.jpeg)

![](_page_45_Picture_8.jpeg)

![](_page_45_Picture_9.jpeg)

# Slow-Start Restart at the Middlebox

![](_page_46_Figure_1.jpeg)

![](_page_46_Figure_2.jpeg)

- Only HTTP and HTTPS traffic used middlebox.
- Nonstandard port (7777) bypasses middlebox.

![](_page_46_Picture_5.jpeg)

![](_page_46_Picture_8.jpeg)

![](_page_46_Picture_9.jpeg)

![](_page_46_Picture_10.jpeg)

# **Slow-Start Restart at the Middlebox**

![](_page_47_Figure_1.jpeg)

![](_page_47_Figure_2.jpeg)

- Only HTTP and HTTPS traffic uses middlebox.
- Nonstandard port (7777) bypasses middlebox.

### **Split-TCP proxies were forcing Slow-Start restart.**

![](_page_47_Picture_7.jpeg)

![](_page_47_Figure_10.jpeg)

![](_page_47_Picture_11.jpeg)

![](_page_47_Picture_12.jpeg)

- Tool to determine if cellular downlink is the bottleneck
- Showed that we can infer base station queue status from resource allocation
- Discovered that carrier's middlebox was bottleneck for video streaming

### github.com/arjunvb/bursttracker

![](_page_48_Picture_5.jpeg)

![](_page_48_Picture_6.jpeg)