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Throughput prediction based on mobile device context in Cellular Network

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Background

- **Prevalence of cellular networks**
  - Mobile Traffic is expected to grow rapidly in the near future [Cisco VNI White Paper]
  - 4G LTE network with much higher bandwidth (100 Mbps downlink and 50 Mbps uplink) and lower RTT (<5ms user-plane latency) [3GPP TR 25.913]
  - Several measurement tools targeting at cellular network performance

Challenges

- **How can mobile devices better utilize the cellular network resources?**

	Bartendr	ARO	IMP	SALSA	DWRA	Our Approach
Layer	A	A/T	A	A	T	**A/T**
Scheduling?	✓	✗	✓	✓	✗	✓
Use context	Location RSSI	RRC state	net type	net type, RSSI	RTT	**RSSI, RRC state**
Efficient context?	✗	✓	✓	✓	✓	✓
Different network?	✗	✗	✓	✓	✓	✓
Throughput prediction?	✓	✗	✓	✓	✗	✓

T: transport layer, A: application layer

Challenges

- **How can we better predict performance?**
  - It's dynamic, yet depending on the context
  - Data analysis: correlating performance (e.g. TCP throughput) with device context
  - Accuracy and overhead of prediction

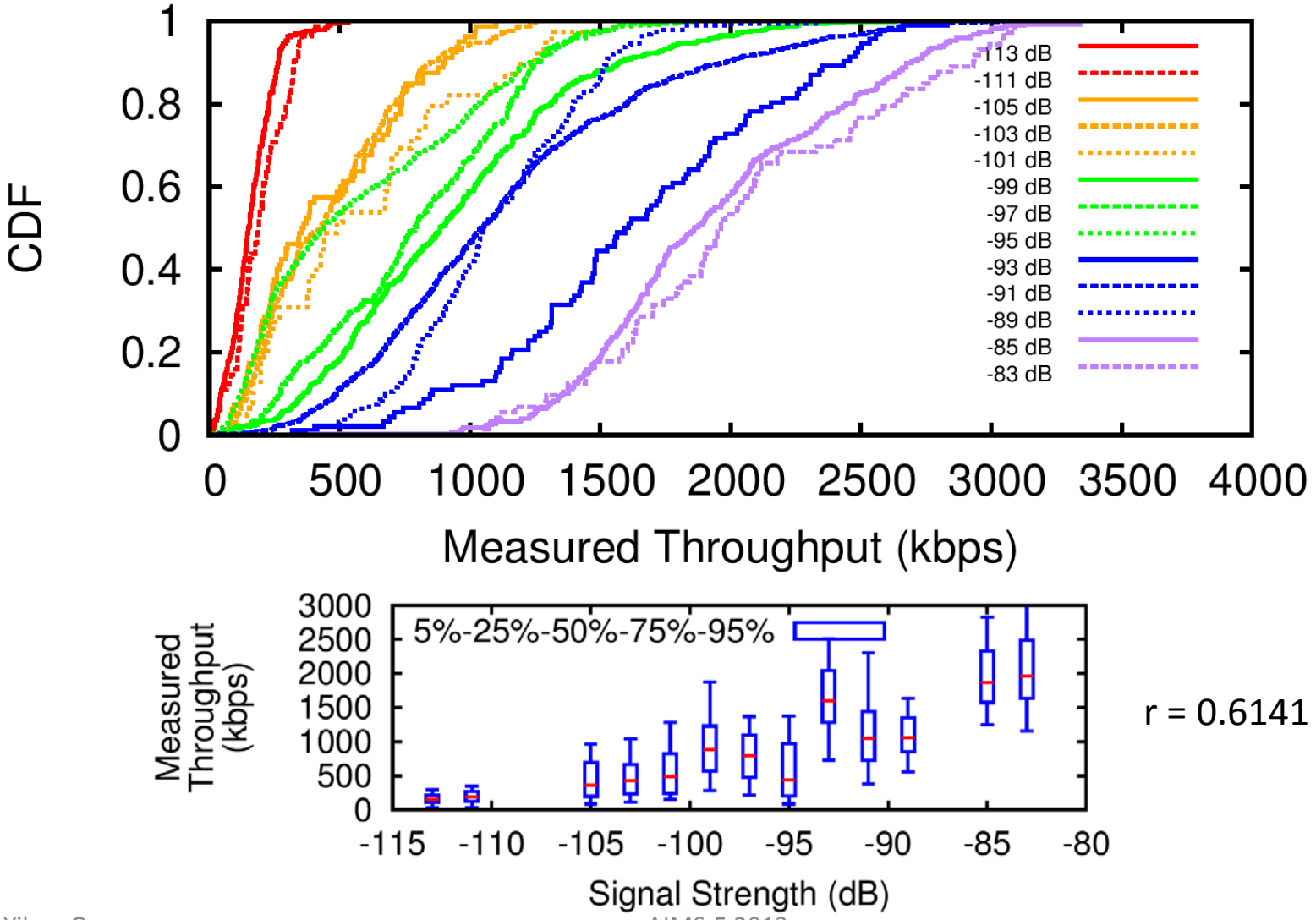
Utilizing the Mobile Device Context

- **Radio Access**
  - Network type, **signal strength**, cell ID, RRC/DRX state, etc.
- **Sensors**
  - Acceleration, GPS coordinates, etc.
- **Other**
  - Device type, screen on/off, time of day, etc.

Measurement Settings

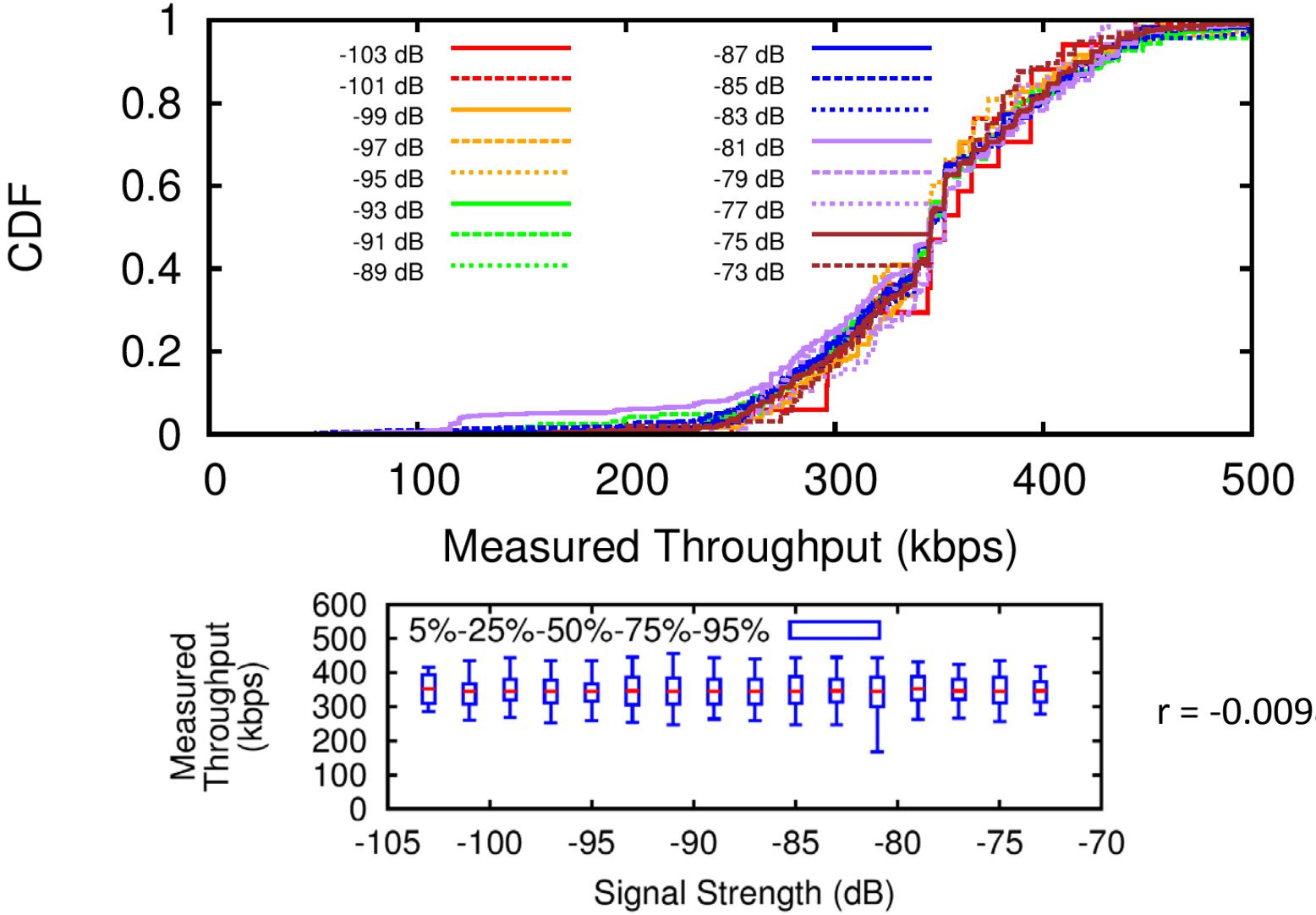
- **Methodology**
  - Mobile Device: Android (with access to a nation-wide ISP)
  - **TCP connection** with continuous randomized data transfer in 2-5 minutes. Phone is kept **stationary** during the data transfer.
  - Skip the first **10 seconds** without sampling
  - Throughput is sampled every 500 ms, device context is collected at the same time, packet traces are collected from both device and server
  - **Downlink**: server -> device, **Uplink**: device -> server
  - Different **areas**/**network types**/**devices** are considered

HSDPA Downlink



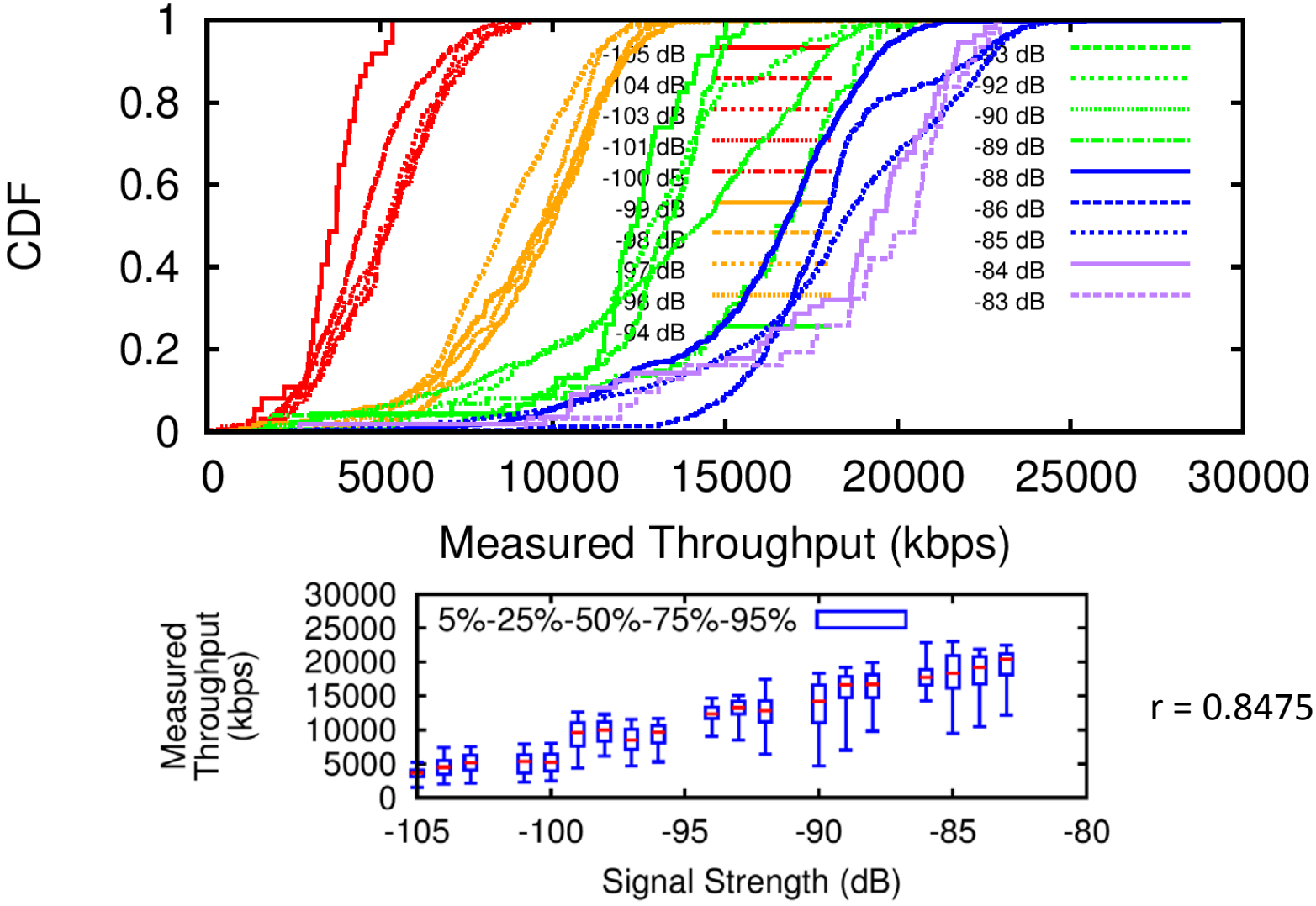
r = 0.6141

HSDPA Uplink



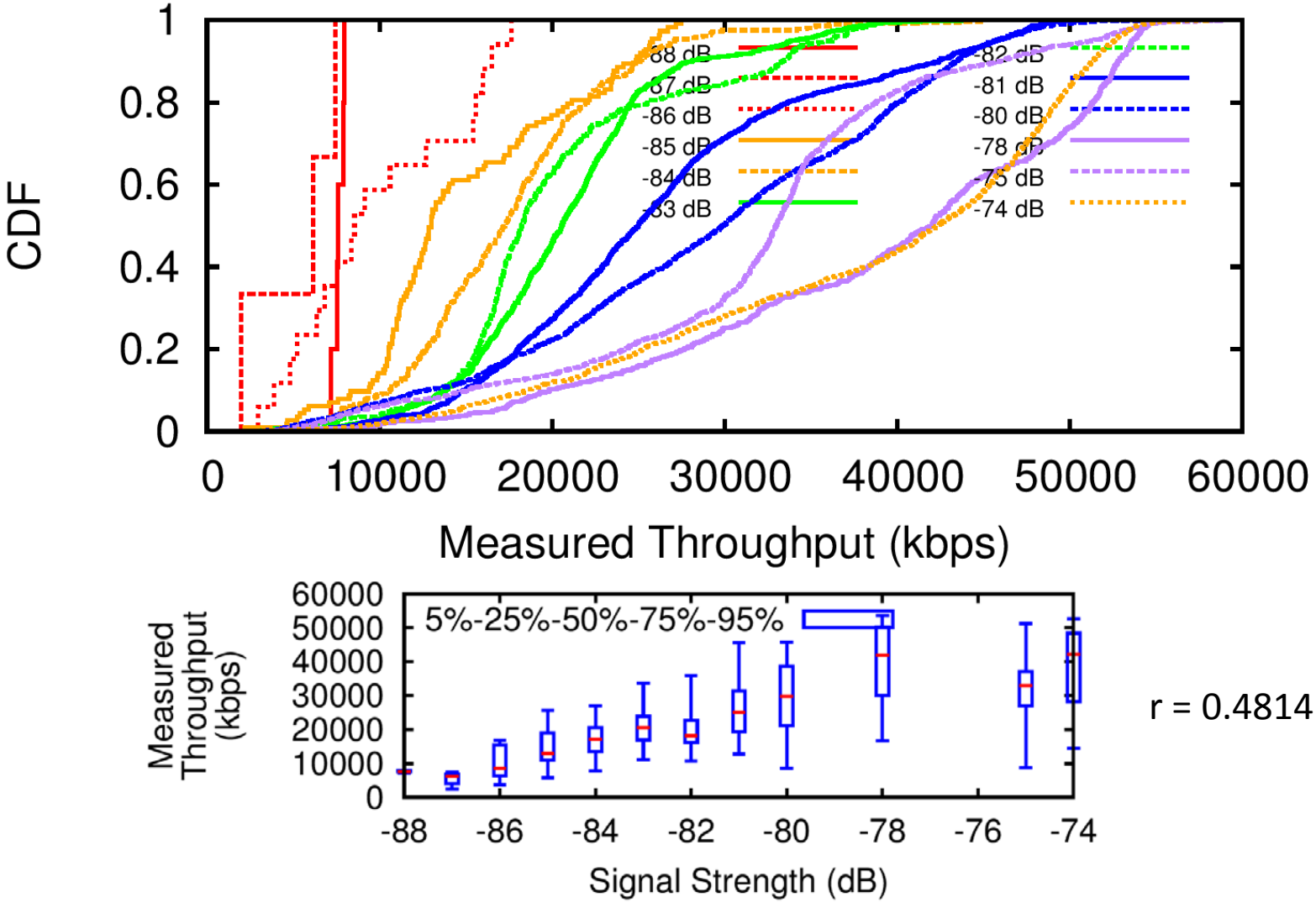
r = -0.0098

LTE Downlink



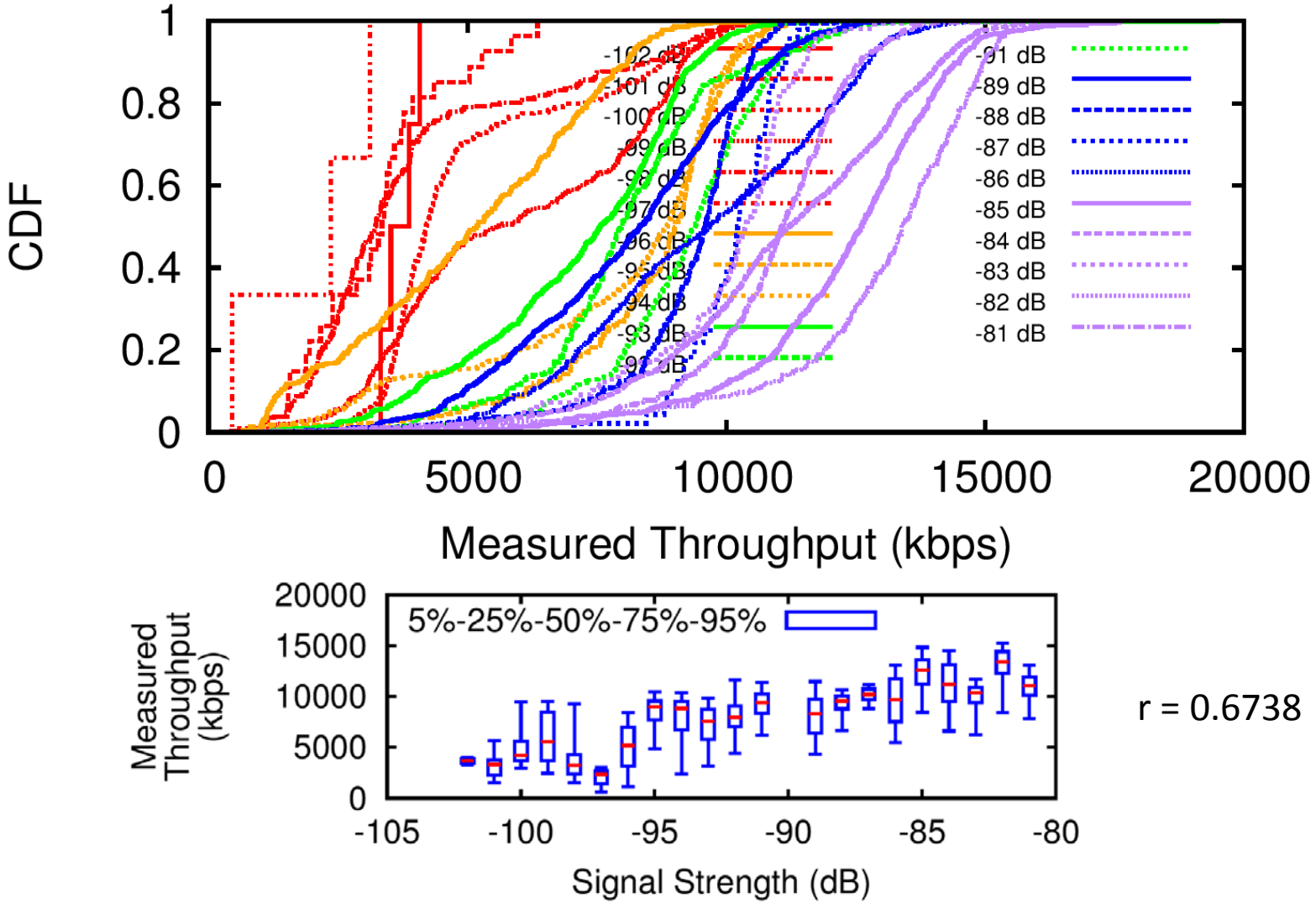
r = 0.8475

LTE Downlink



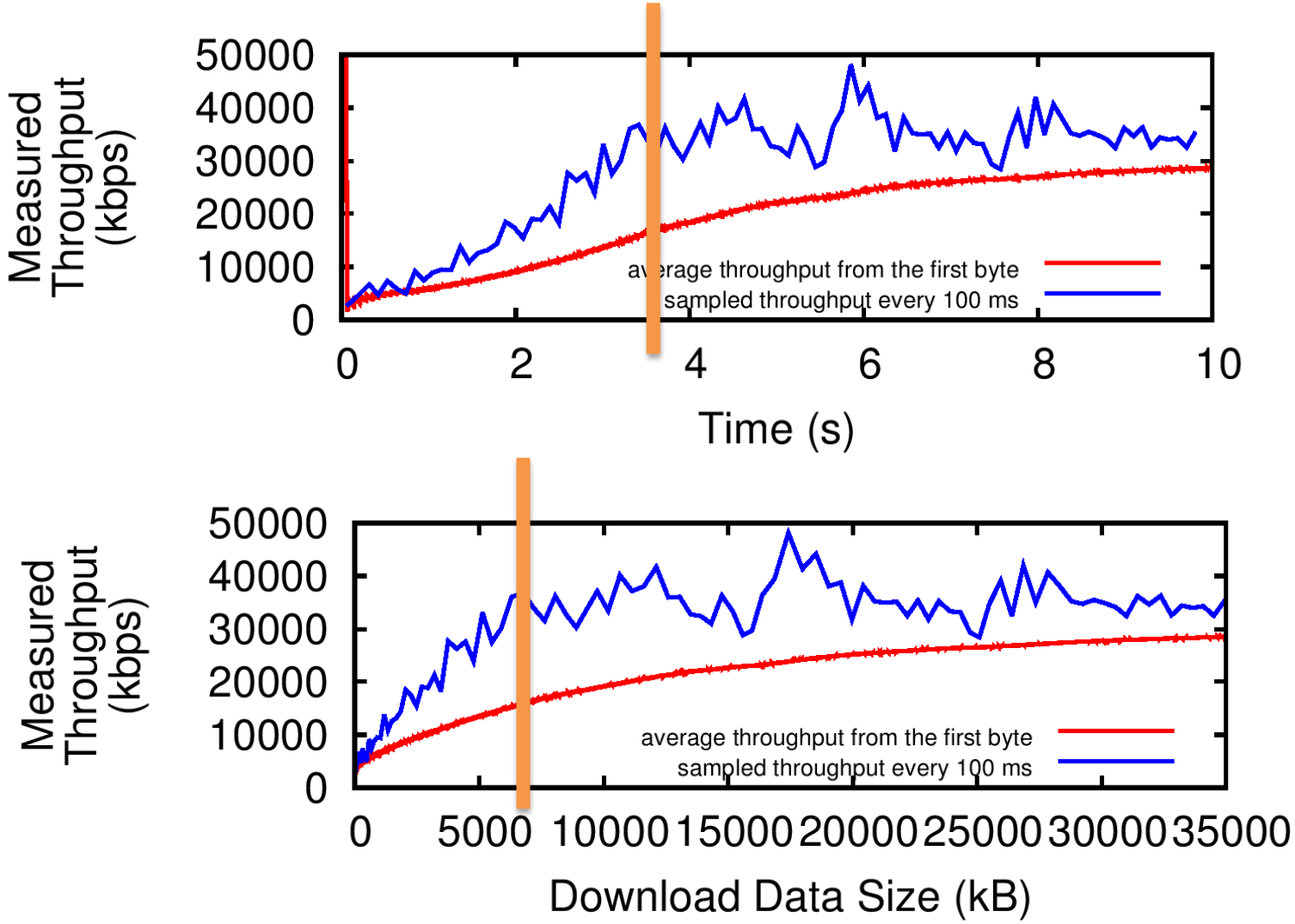
r = 0.4814

LTE Uplink

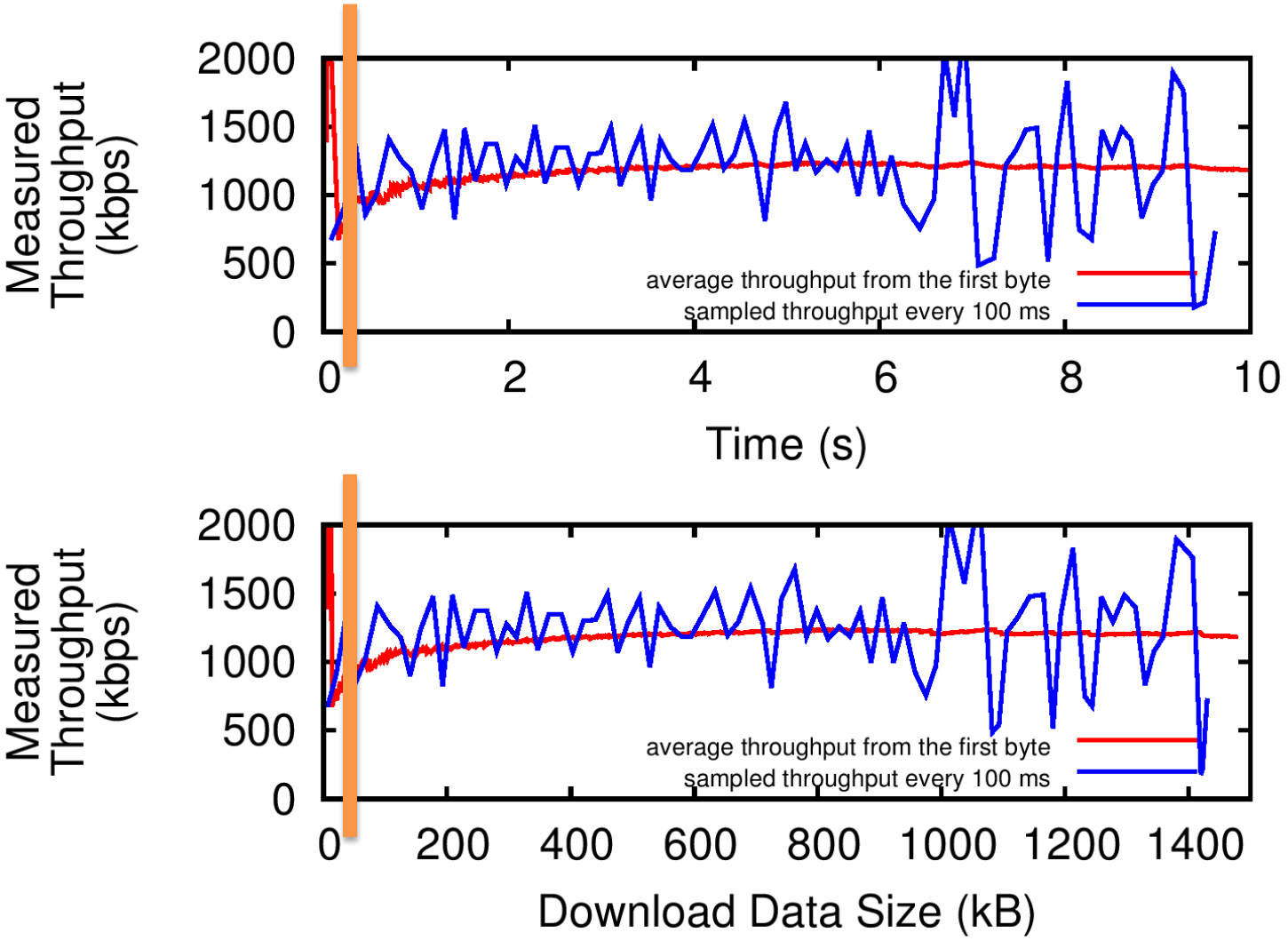


r = 0.6738

TCP Slow Start (LTE Downlink)



TCP Slow Start (HSDPA Downlink)

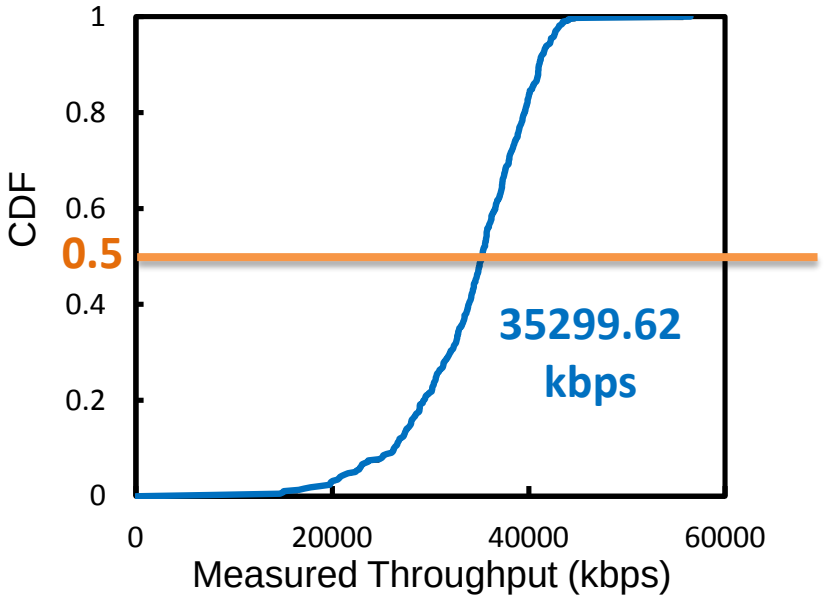


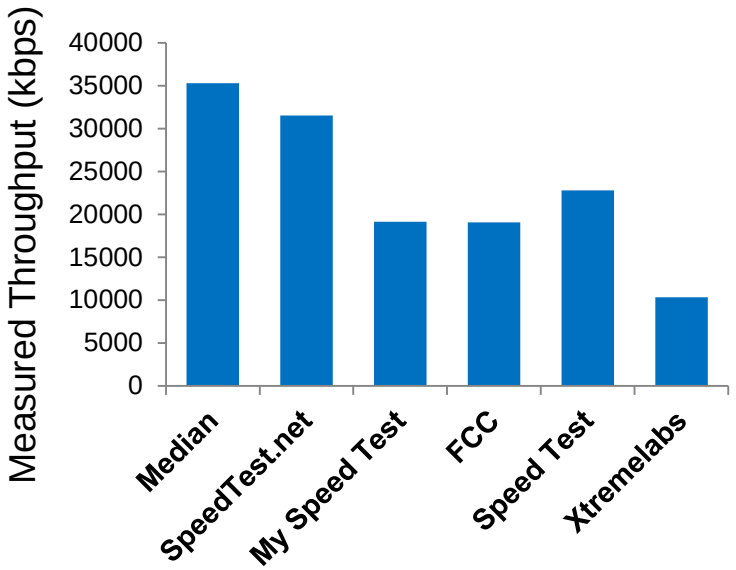
Implications

- **Findings**
  - HSDPA/LTE Downlink, LTE Uplink: positive correlation
  - HSDPA Uplink: nearly no correlation
  - TCP slow start period for LTE can be long
- **How can we make use of the results?**
  - Signal strength is a factor that affects LTE performance
  - May need additional information to improve the prediction (more fine-grained)

Implications

- **How can we make use of the results? (cont'd)**
  - Measurement fails if the bottleneck is not the cellular network part, or TCP connection does not saturate the link
  - Data consumption could be high for a single throughput test (**> 35MB** for ~**30Mbps, 10 s**)





Data Sharing

- **Working on this**
- **Privacy is the main concern**
  - Sensitive information: IMEI, location, phone type, carrier, timestamp

Discussions

- **The effectiveness of throughput prediction in cellular network**
- **Validation on methodology of bandwidth/throughput measurement (to be coherent between datasets)**
- **Management and analysis of measurement data**

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Thank you!