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Objective Measurement in Mobile Networks

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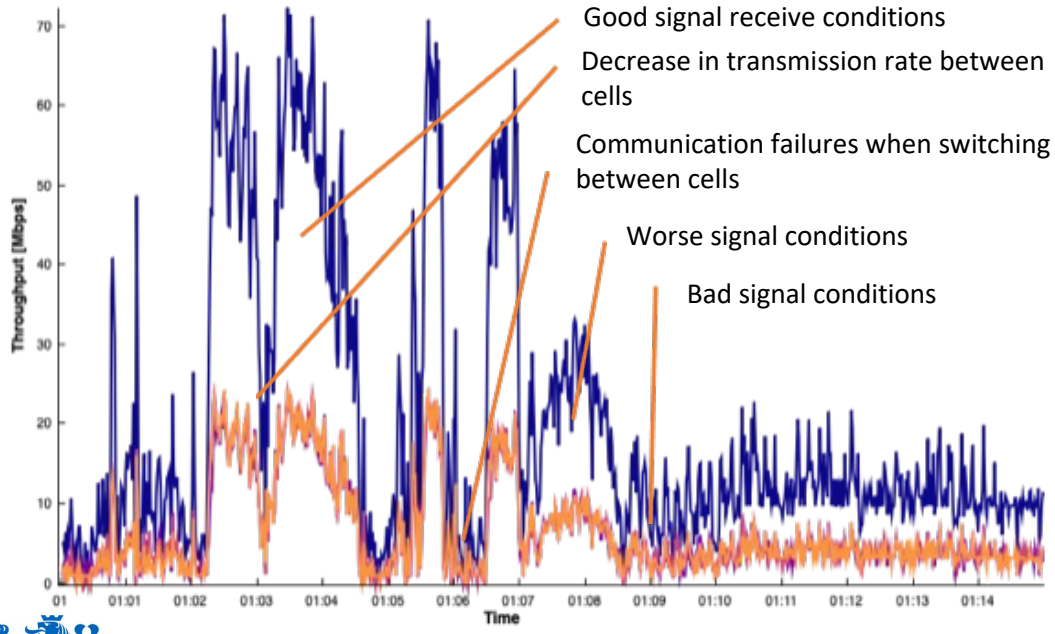
Mobile Networks Measurement Possibilities

- Measurement on physical layer
  - RF parameters
- Measurement on higher layers
  - RAW data flow (L2)
  - TCP/IP
- User terminal location
  - Stationary test
    - Measurement at a fixed location
  - Nomadic tests
    - Measurement at a stable location with a change of position
  - Drive tests
    - Measurement during position change

Specifics of Mobile Networks

- **Dynamic** changes in signal level and bit rate
- **Outages** and **re-establishment** of RF and TCP/UDP connections (incl. change of IP address)
- **Switching** between technologies/network generations
- **Immediate** network load of moving subscribers
- Service **data limits** (limited amount of data)…



Aspects of TCP Measurement in The Mobile Network

- Great variability of deployment
  - Optimization for maximum throughput → reduced ability to respond to network problems, higher RTT, network congestion (TCP Cubic)
  - Optimization for fast network change responses → lower RTT, lower throughput (TCP BBR)
- Difficult to detect connection breakdown at lower layers
  - By default, high timer values monitor connection breakdown >20 s
  - Mobile network configuration - active influencing of TCP disconnections

TCP in The Mobile Network

- Bandwidth Delay Product: *TP x RTT*
  - Increasing of CWND – more data „in flight“
    - If a problem occurs, drops and forwards, RTT grows
  - Increasing the number of concurrent connections - increasing transmission overhead
    - With a large number of flows, there is a risk of overflowing the buffers of intermediate network elements, which leads to packet dropping → synchronization of TCP algorithms
    - If there are signal problems, the simultaneous establishment of a large number of TCP connections increases the time without data transmission → synchronization of TCP algorithms

TCP in The Mobile Network

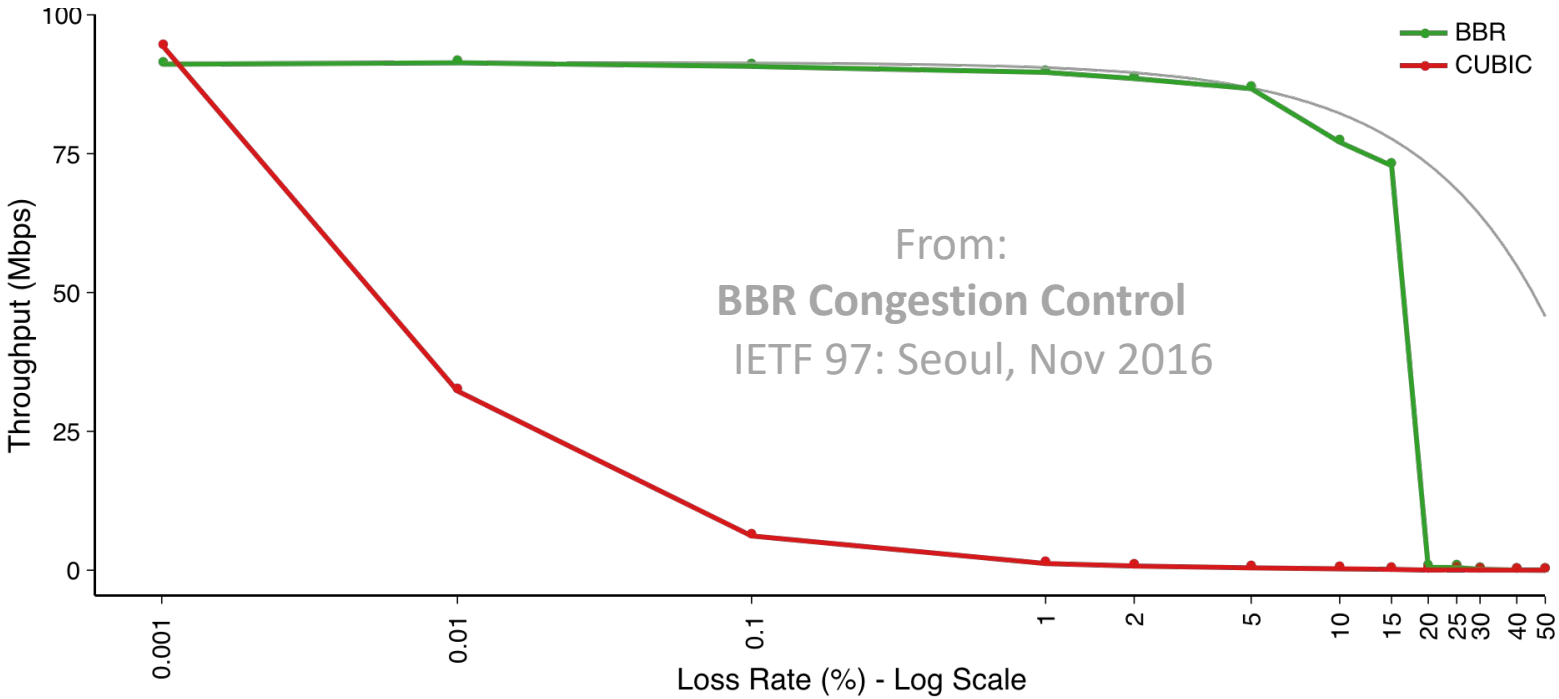
- TCP algorithms
  - TCP Cubic
    - **Where:** The most common algorithm – Windows 7 and newer, Linux
    - **How:** Transmission control is based on loss and regulation of the amount of data in the network is according to the cubic function
    - **Impact:** Ability to utilize high-capacity transmission paths with higher RTT. When a large CWND (greater than 128 KB) is used, it behaves "like UDP" on networks with higher RTT (hundreds of ms). It is able to significantly reduce competitive traffic.

TCP in The Mobile Network

- TCP algorithms
  - TCP BBR
    - **Where:** On the rise - Some Linux distributions
    - **How:** Transmission control is based on periodic RTT control and subsequent optimization of CWND settings
    - **Impact:** Ability to utilize high-capacity transmission paths with diverse RTT. Among other available TCP algorithms, it has the lowest latency. It does not take the load of the transmission path to such an extreme as TCP Cubic does, the resulting throughput is several percent lower than TCP Cubic.

Influence of Error Rate on TCP

Cubic vs. BBR – theory



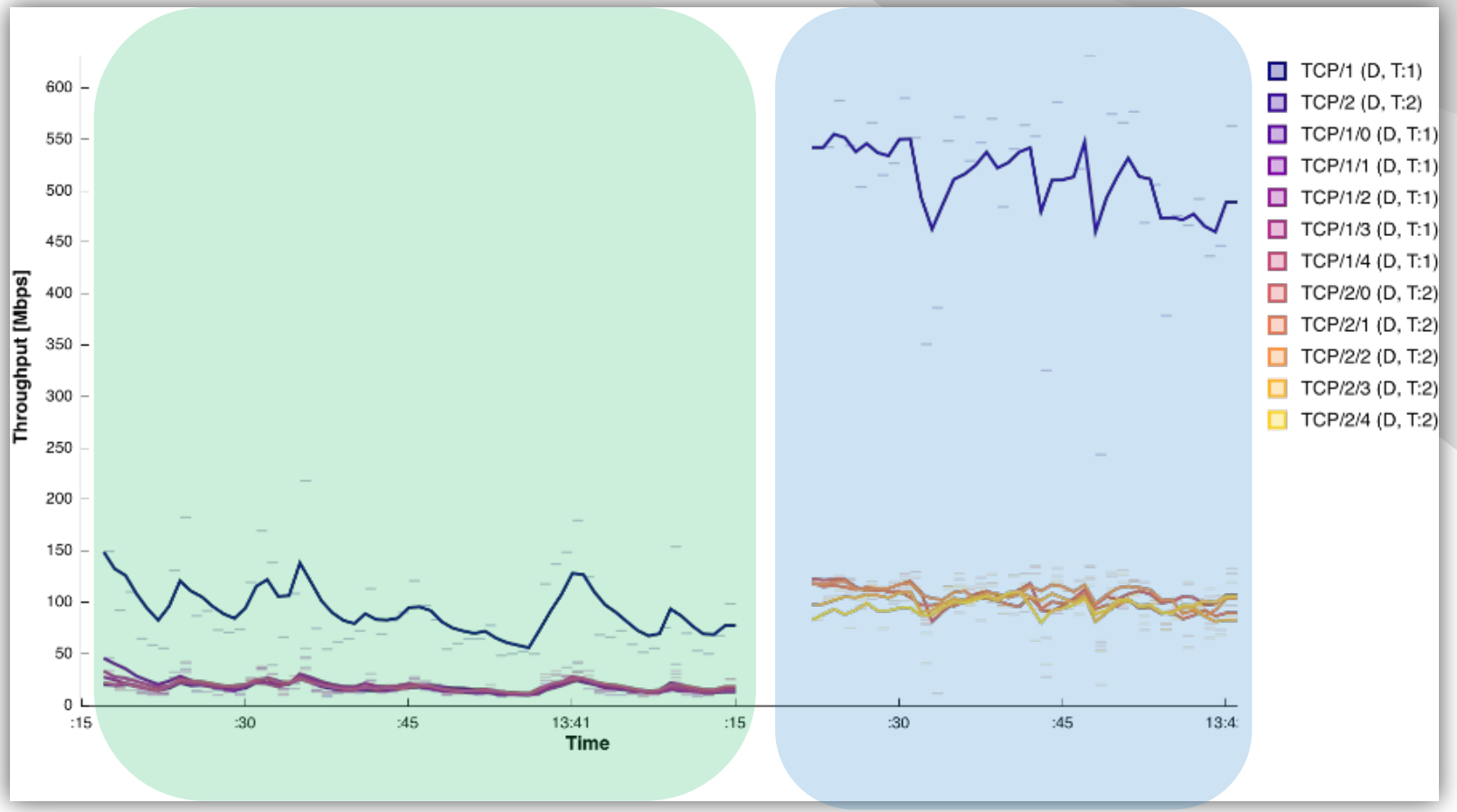
BBR vs CUBIC: synthetic bulk TCP test with 1 flow, bottleneck_bw 100Mbps, RTT 100ms

Influence of Error Rate on TCP

Cubic vs. BBR – RTT approx **12 ms**

Cubic

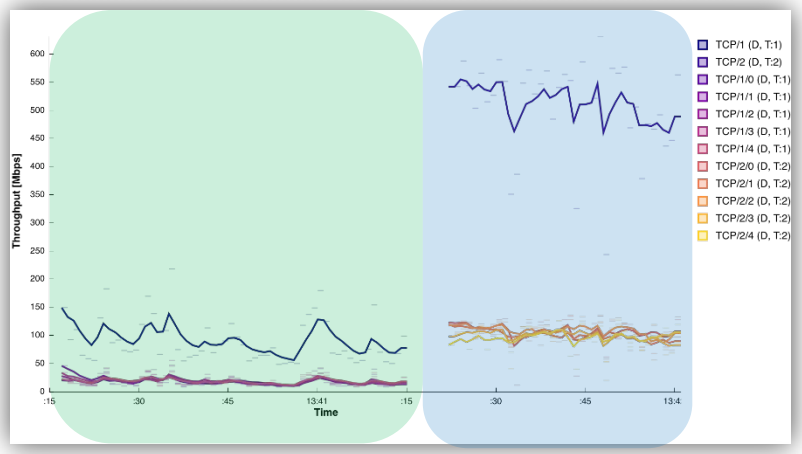
BBR

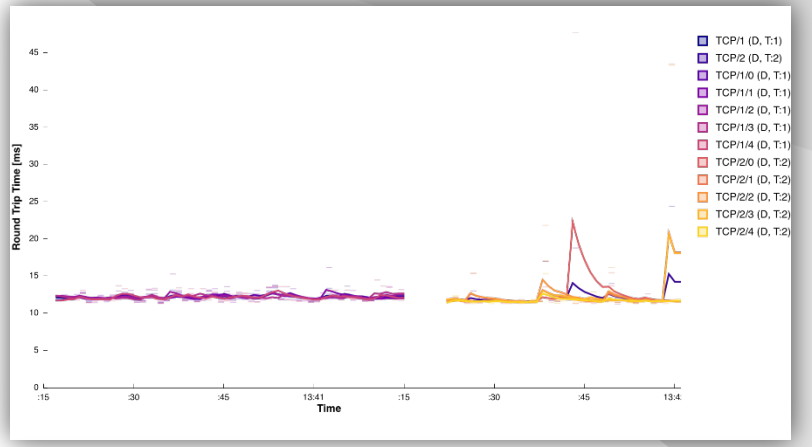


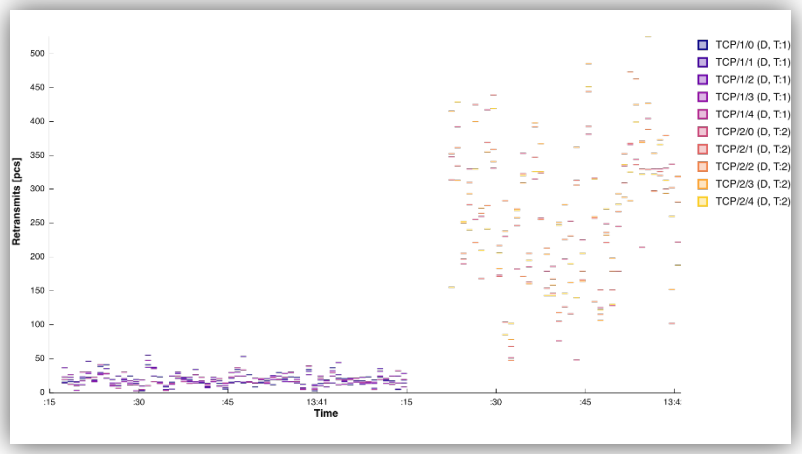
Influence of Error Rate on TCP

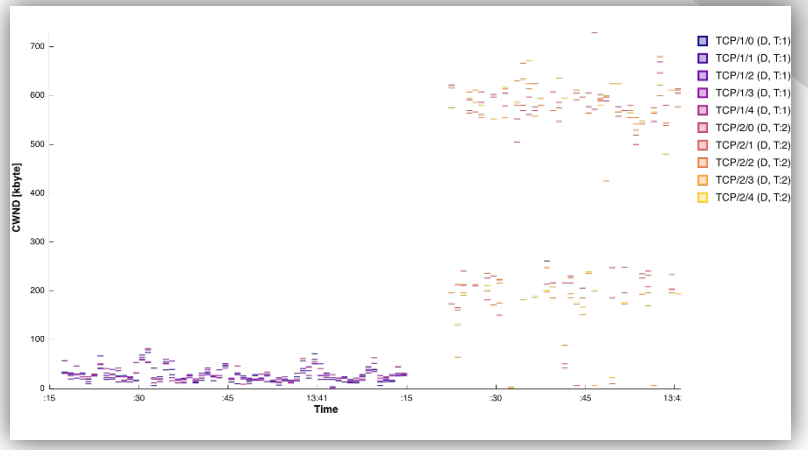
Cubic vs. BBR – RTT approx **12 ms**

Cubic BBR





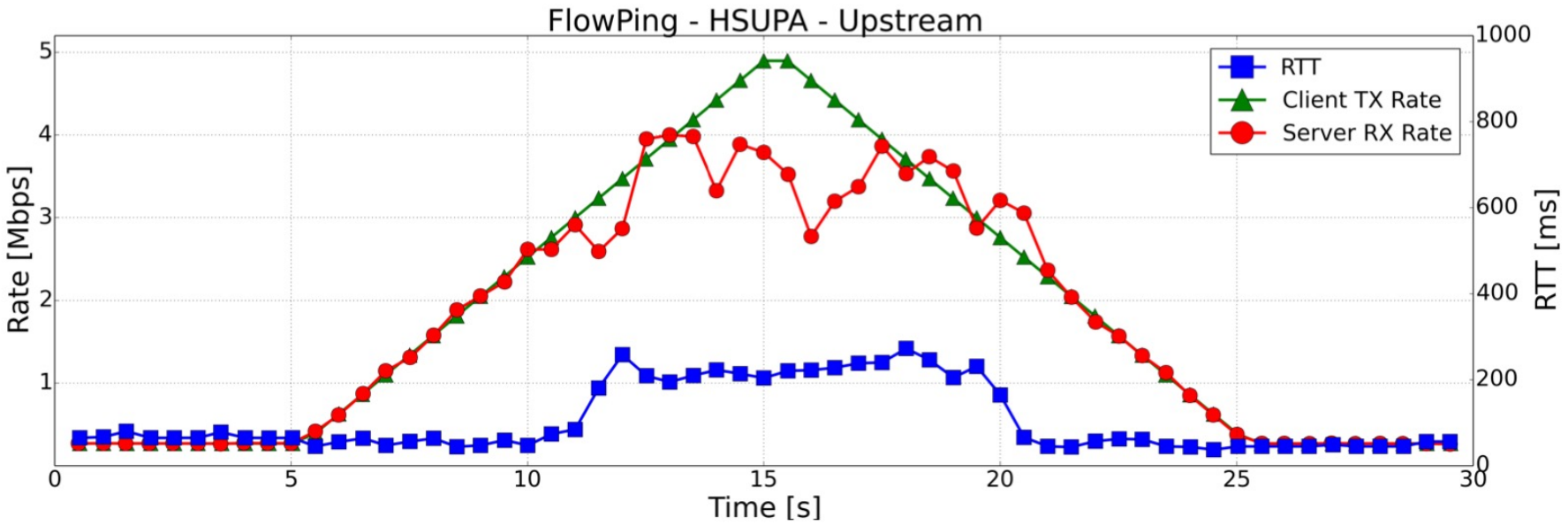




Aspects of UDP Measurement in The Mobile Network

- Basic characteristic
  - Lower overhead compared to TCP
  - No delivery feedback
  - Ability to flood the network (multiple times)
  - Emulation of higher layer protocol behavior
- Measurement
  - Fixed data flow
    - Packet size, packet sending interval
  - Variable data flow
    - Packet size and packet sending interval depending on time
    - Emulation of various network situations
  - With feedback
    - TCP emulation using UDP (Flowping)

Aspects of UDP Measurement in The Mobile Network

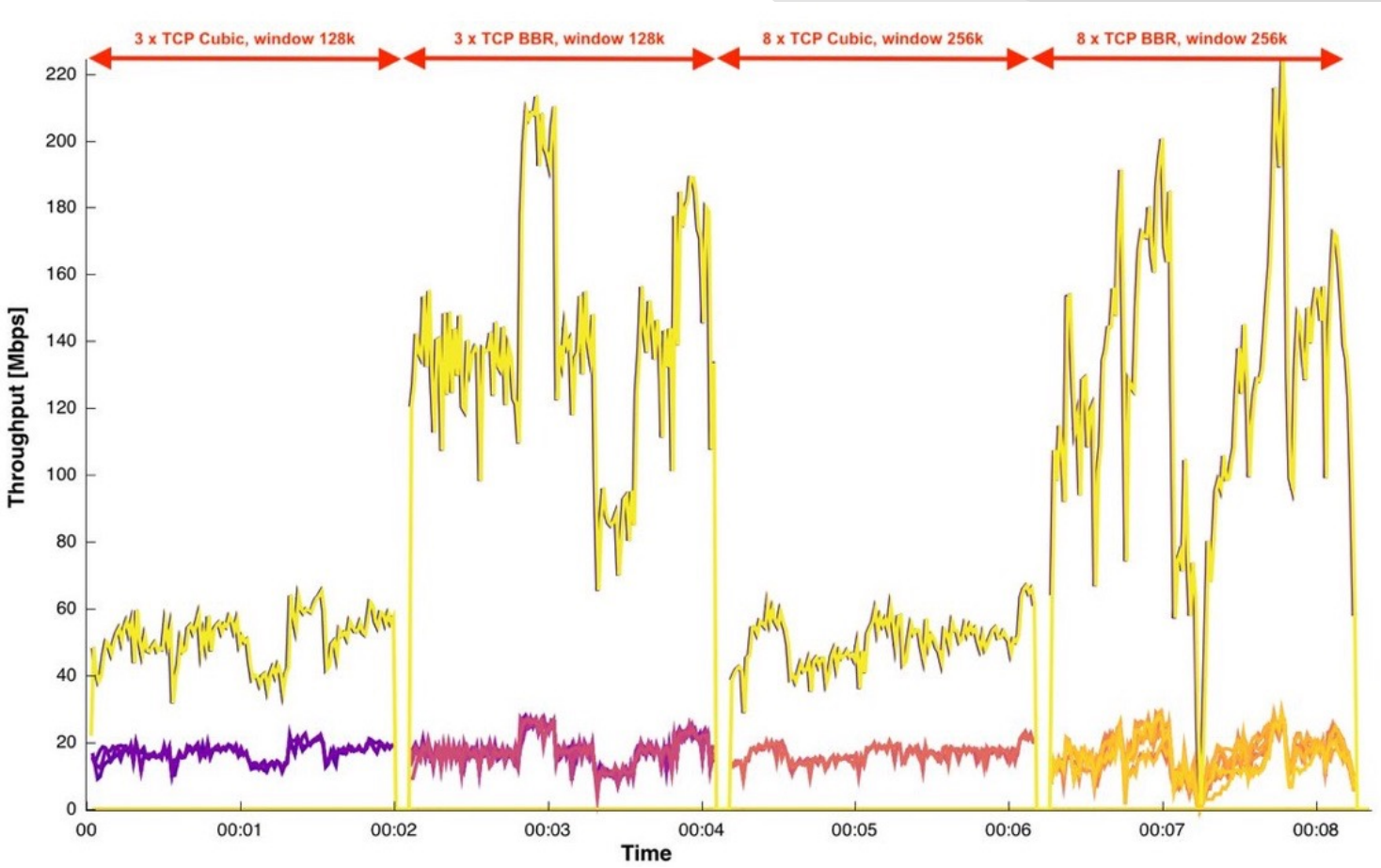


Iperf UDP vs. Flowping

- Iperf UDP
  - Data flow generator
  - Data transfer regardless of the other side response
  - Low computational complexity - the ability to generate higher data flows
  - Measurement outputs:
    - Bitrate for the selected data flow
    - Packet loss
- Flowping
  - “ping“ with the ability of defining the generated data stream
  - Precise packet generation → higher computational complexity
  - Measurement outputs:
    - Bitrate for a defined data flow
    - Packet loss
    - RTT
    - Jitter

Starlink

- Throughput [Mbit/s]



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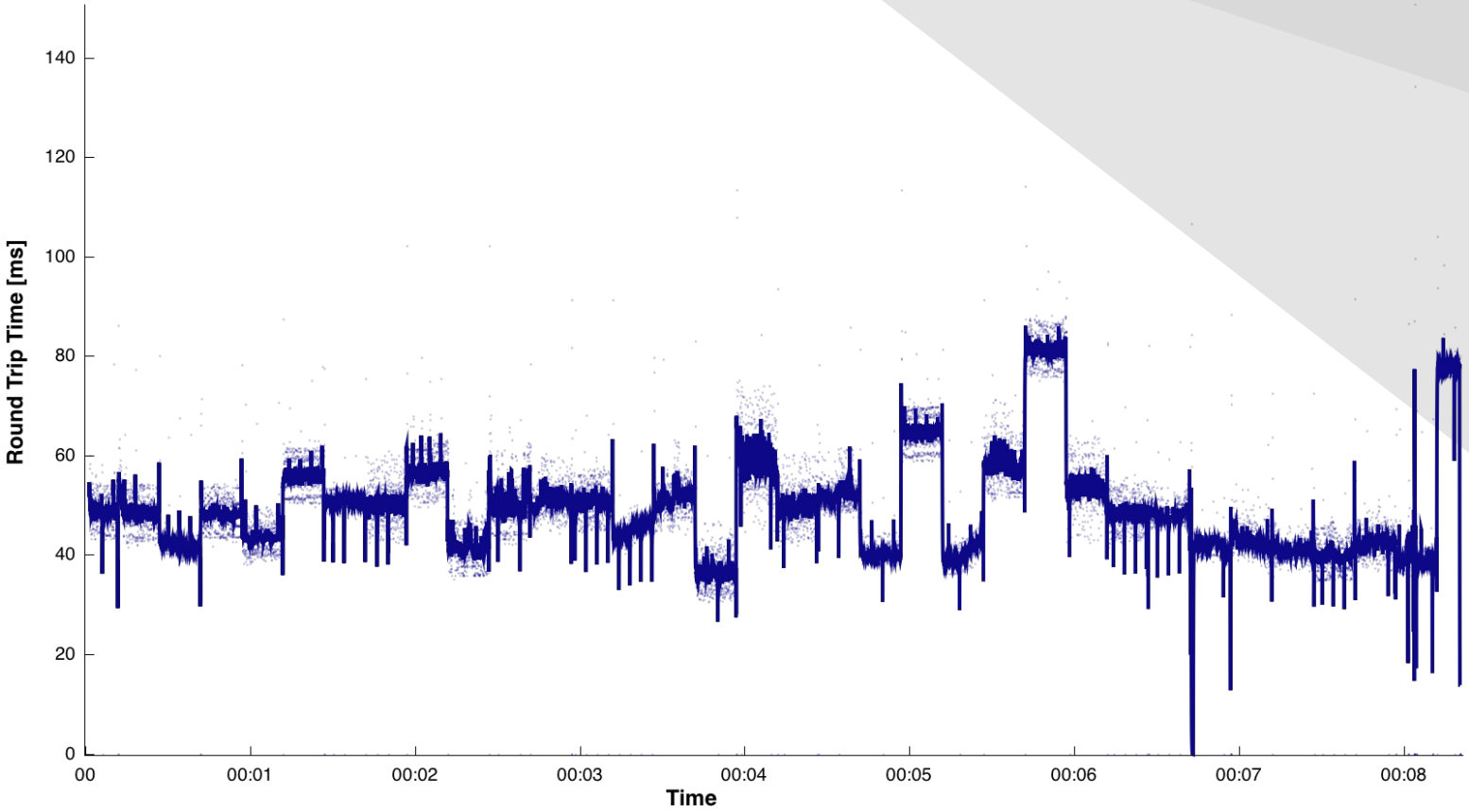
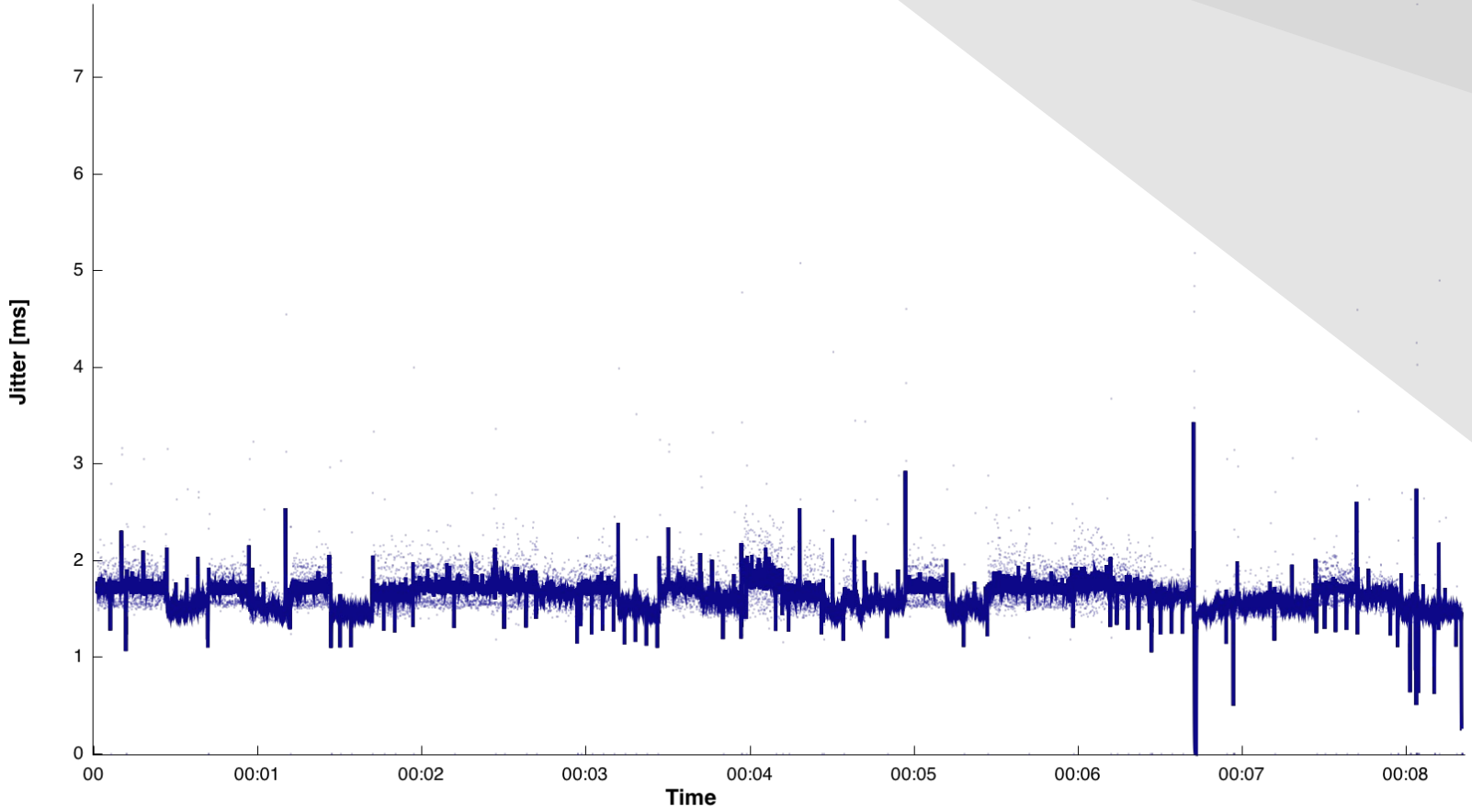
- Round trip time (RTT) [ms]



Starlink

- Jitter [ms]



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