Application Level Performance Measurements of Multi-Connectivity Options in Cellular Networks for Vehicular Scenarios

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Measurement Setup

Introduction

Measurement of real-world performance (throughput, latency, reliability) of multi-connectivity options:

- Single-Input Single-Output (SISO) vs.
 Multiple-Input Multiple-Output (MIMO) antenna setup
- Singlepath vs. Multipath TCP (MPTCP)
- Vehicular scenario in rural and urban environments

TG Receiver at vehicle side

Setup in vehicle:

SISO:

• x86 Mini PC with MPTCP kernel

Measurement Setup

Setup in Server:

- AWS E2 instance
- MPTCP kernel

ITG Server

at cloud side

- Traffic generation and measuremt:
- Traffic generator D-ITG
- Constant bit rate downlink traffic 120 Mbit/s
- Last 125 ms interval from 3 s TCP flow is used

MIMO vs. SISO throughput

- For comparison, measurements are grouped by regions of 178 m x 178 m
- Throughput is measured using lperf3
- Average improvement of 1.72 times from 11 Mbit/s to 18 Mbit/s

The figures show the throughput averaged per tile:



MIMO vs. SISO Reliability

- Our MIMO setup decreases packet loss frequency from $4.5\mathrm{e}{-3}$ to $1.1\mathrm{e}{-3}$
- Large delays occur at regions with poor network coverage and handover probability

packet loss
1 of 3 packets lost
2 of 3 packets lost

MIMO:

Congestion Control

- Mean throughput increases from 45 to 64 Mbit/s
- Similar traffic pattern per geolocation
- TCP BBR shows a more balanced usage of paths







MIMO vs. SISO latency

- Round trip time (RTT) measurements using ping
- $P[\mathsf{RTT} > 100 \ ms] \approx 0.1$
- MIMO reduces large delays
- The figure shows the cumulative distribution function of the measured RTTs

MPTCP Throughput

- About 30 Mbit/s throughput for each provider
- 57 Mbit/s aggregated throughput
- MPTCP cannot exploit paths fully





Measurements per provider MPTCP Cubic:





Conclusion of our Measurement

- MIMO increases the throughput significantly, factor 1.72
- MIMO reduces latency, packet loss,
- handovers, network deregistration events
- MPTCP increases the aggregated throughput
- MPTCP cannot exploit paths fully
- MPTCP utilization can be increased by selection of BBR as congestion control

Measurements per provider MPTCP BBR:

