Using NorNet Edge to Measure Mobile Broadband Performance under Mobility

Džiugas Baltrūnas PhD Student & Research Engineer CRNA@Simula

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### Using NorNet Edge to Measure Mobile Broadband Performance under Mobility



#### **NNE deployment on trains**



#### Loss and delay measurements from train nodes



**Challenges and lessons learned** 

### Nornet Edge platform to measure MBB networks



More than 100 measurement nodes distributed across Norway Deployed in rural and urban areas, and on trains Dedicated 3G and LTE connections using USB modems Tools and server-side infrastructure for measurements

### NNE@mobile: deployment on trains

- 17 nodes were (re)deployed since 2014
- **Currently 5 nodes online**
- Typically with four 3G/LTE USB modems
- Covering Oslo-Stavanger, Oslo-Bergen and Oslo-Trondheim-Bodø routes
- **Continuous RTT+loss measurements**
- Collection of metadata (RAT, RRC, RSSI, etc.)
- **GPS+speed data from NSB**



Using NNE platform for mobile loss and RTT measurements

|                  |                | t <sub>1</sub><br>t <sub>2</sub><br>RTT = t<br>SS =1 if t <sub>1</sub> | t <sub>1</sub> + t <sub>2</sub><br>+ t <sub>2</sub> > 60s | Control Control   Control Control |
|------------------|----------------|--|---|---|
|                  | 1 min          |  | 1 min   |   |
| Conn#1           | LTE            | LTE LTE  |   |   |
| Conn#2           | <b>3G-DCH</b>  | 3G-DCH   | 3G-FACH   |   |
| Conn#3           | <b>3G-FACH</b> | Mixed-RRC  | 3G-FACH   |   |
| Conn#4           | Mixed-RRC      | 3G-DCH   | 3G-DCH  |   |
| Conn#5           | 2G             | 2G   | Mixed-RAT   |   |
| Conn#6 Mixed-RAT |                | 3G-FACH  | 3G-DCH  |   |

Sending 20-byte UDP packets every second from all available connections

Aggregating data and metadata into 5-minute or 1-minute bins

Calculating AVG/MAX RTTs and loss rate for every connection and bin

# Observed high variation in RTTs in 2G, under mobility and during the inter-RAT handovers



Normal delays are O(100ms) in 2G and O(10ms) in 3G / LTE

- Inter-RAT handovers cause high delays and variation
- 2G likely faces infrastructure challenges
- Much higher variation under mobility
- Maximum RTTs can be several seconds, especially when mobile

## Observing *triangle events*: excessive monotonically decreasing consecutive delays that last for several seconds



A sequence of at least two packets, the first having RTT > 2 s followed by a sequence of packets with each RTT decreasing ~1 s

### Loss rates are much higher under mobility



Loss percentage

## Most loss under mobility happens in periods with RAT changes or glitches



- 70% packet loss happens in periods with varying RAT
- 40-50% lossy periods with varying RAT end up in connection reset
- In some networks, loss during cell changes is high

Mobile measurement data demands extensive postprocessing and filtering prior to making conclusions

| 3G    | <b>4G</b> | <b>3G</b> | Con   | No<br>nection | 3G    | 3 | G     | 3G |  |
|-------|-----------|-----------|-------|---------------|-------|---|-------|----|--|
| $b_1$ | $b_2$     |           | $b_3$ | $b_4$         | $b_5$ |   | $b_6$ |    |  |

Connections go up and down periodically: measuring uptime is non-trivial Significant fraction of loss is just a pre-mortem phase of a connection

Coverage holes have to be distinguished from temporary degraded service

- Data binning leads to multiple mixed (RAT, RRC) categories
- **RAT upgrades might never happen**
- High number of filters has to be imposed on the data

### Keeping a reasonable number of operational mobile nodes and mobile broadband connections is hard



Fluctuations in current due to poor and varying radio signals Indirect cause of power supply failures and SD card corruption USB modems are not always stable and require intervention Connection management involves an interplay from UE, OS and PPP One unresponsive modem might slow down a single-core CPU Mobile broadband performance under mobility can be severe and capturing user experience is challenging



High delays and their variability under mobility

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- Significantly higher packet loss compared to stationary scenario
- High RTTs and loss rates mainly during handovers
- Measurement dataset needs extensive post-processing and filtering

Questions?

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