Trial results

Webinar on the results and insights from the 5G-MOBIX Finland Trial Site
16 June 2022, 14:00 – 15:00 CET

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Recalling the trial setup

Remote driving user story storyboard

Step 1) Vehicle sends status messages and LIDAR stream to ROC using FI-MNO-05 and/or FI-MNO-06 from the beginning of the route.

Step 2) Vehicle faces obstacle and requests assistance from ROC and starts to also send video (live stream and pre-recorded) to ROC

Step 3) Remote human operator at ROC accepts new trajectory and vehicle manoeuvres around obstacle

Remote Operations Centre (ROC)

Fleet control server

Video streaming server

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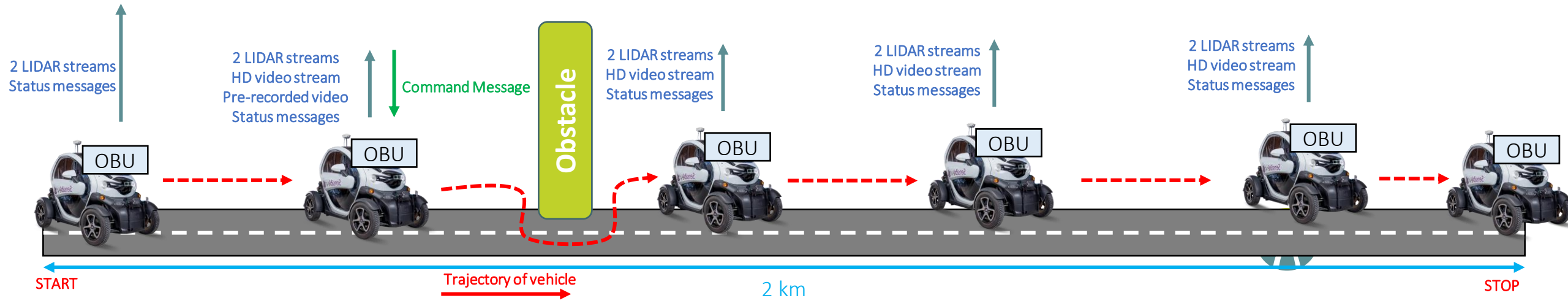
Step 4) vehicle connection to ROC maintained depending on single-SIM or multi-SIM OBU config

Step 5) Vehicle continues sending status message, LIDAR and video stream to ROC and terminates the traffic streams at the end of route

FI-MNO-05

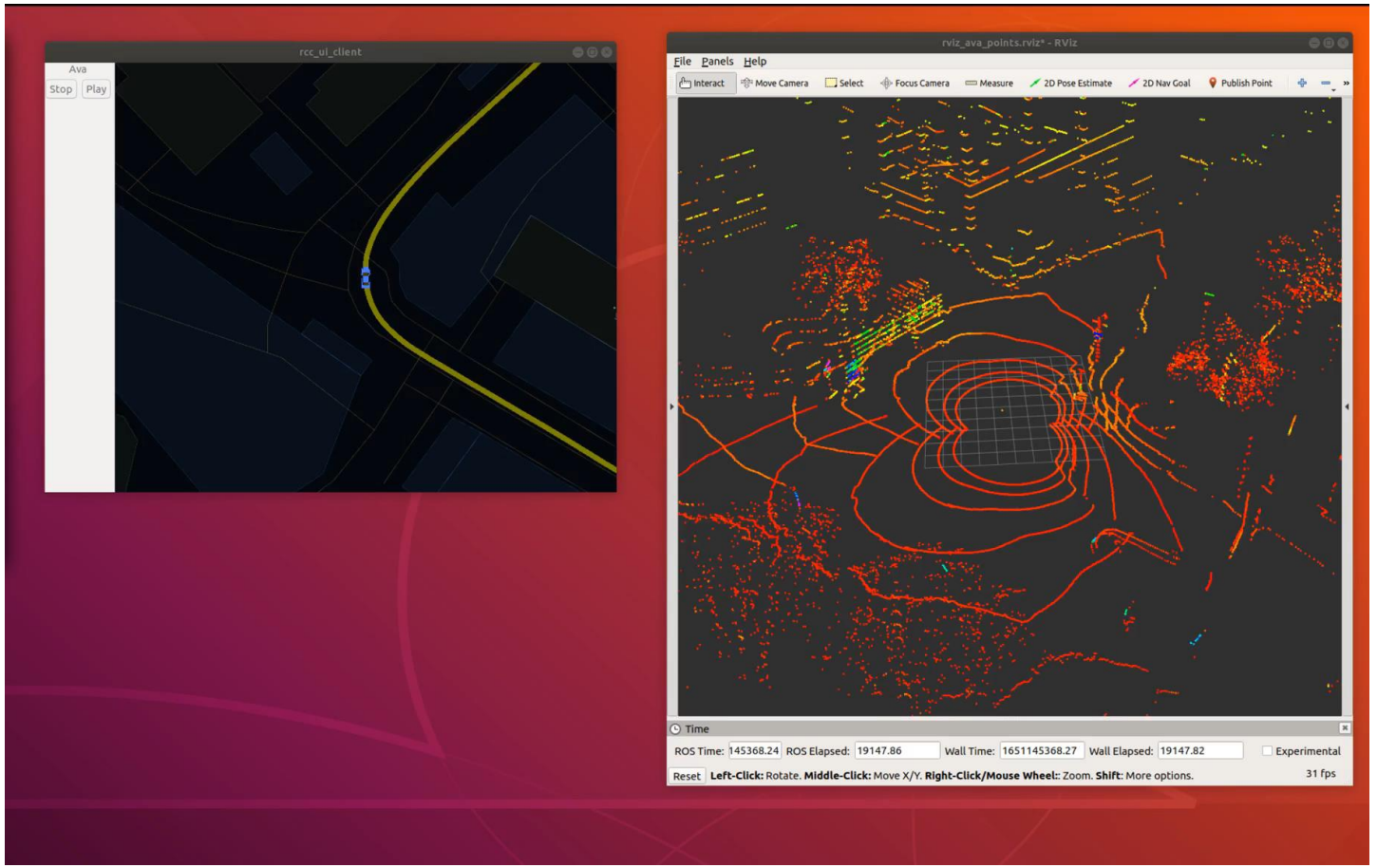
FI-MNO-06



Network impacts on remote driving

- Remote driving session outage
  - Lidar or video streams frozen or lost from remote human operator screen
  - Vehicle status (speed, location etc.) updates delayed or lost on map (*warping effect*)

- Vehicle manoeuvre delay after remote operator approves new trajectory
  - Also involves non-network factors! (e.g. oncoming vehicles on opposite lane)



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Specified test cases

Five test cases in trials of 25-28/04/2022

Singe-SIM (benchmark) vs multi-SIM (link selection or link aggregation)

Test Case (Short ID)	Network setup/usage	
FI-3.1, FI-3.2	FI-MNO-05 primary (priority) or FI-MNO-06 secondary	Multi-SIM (link selection)
FI-3.1, FI-3.2	FI-MNO-06 primary (priority) or FI-MNO-05 secondary	
FI-5.1, FI-5.2	FI-MNO-06 primary and FI-MNO-05 primary	Multi-SIM (link aggregation)
FI-6.1, FI-6.2	FI-MNO-05 primary	Single-SIM
FI-6.1, FI-6.2	FI-MNO-06 primary	

For example, FI-3.1 refers to test in FI-route-01 direction, while FI-3.2 is for FI-route-02 direction

Test Route Id	Test route name	Initial location id	End Location id	Figure	Description
FI_route_01	Otaniemi roads	FI_loc_01	FI_loc_02		From beginning of Maarintie to the end of Otakaari
FI_route_02	Otaniemi roads	FI_loc_02	FI_loc_01		From beginning of Otakaari to the end of Maarintie

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Selected evaluation results

Traffic flows and KPIs

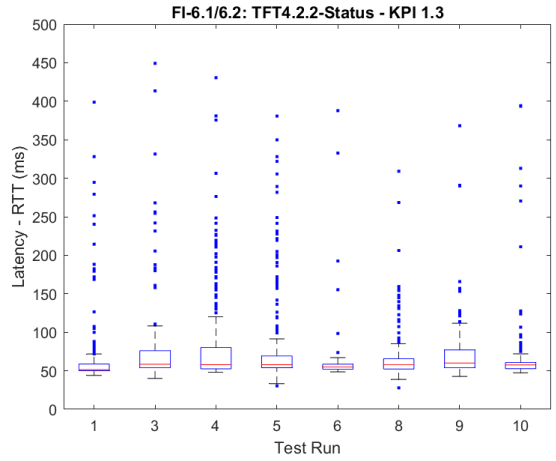
- **Traffic flows analysed**
  - TFT4.2.1-Sensor – LIDAR streams from vehicle to ROC
  - TFT4.2.2-Status – Status messages from vehicle to ROC
  - TFT4.2.3-Video – HD video streams from vehicle to ROC
  - TFT4.2.4-Command – Command messages from ROC to vehicle

- **KPIs of interest for different flows may include:**
  - KPI 1.1 User experienced data rate
  - KPI 1.3 End to end latency
  - KPI 1.6 Reliability (packet loss)
  - KPI 2.3 Mobility interruption time

Statistical analysis and results presentations

- Dimensions of results gathered from the field trials
  - 4 traffic flows
  - 1-3 KPIs per traffic flow
  - 5 test cases
  - 10-15 runs per test case

- This would produce about 40 results tables and accompanying stats
  - Select for analysis only KPIs that matter (e.g. throughput for *TFT4.2.2-Status* flow is not critical but latency is as shown in example table)
  - Present a consolidated view that compares across all test cases

KPI 1.3: End to end latency				
Target value	80 ms (≈160 ms RTT)			
Basic Descriptive Statistics	**# total samples**	**Mean**	**Median**	**Std. Deviation**
	3681	85	57	232
	Max	**Min**	**CI 95%**	**Percentile 95**
	9008	28	49 – 278	161
Extended Descriptive Statistics				
Evaluators comments				

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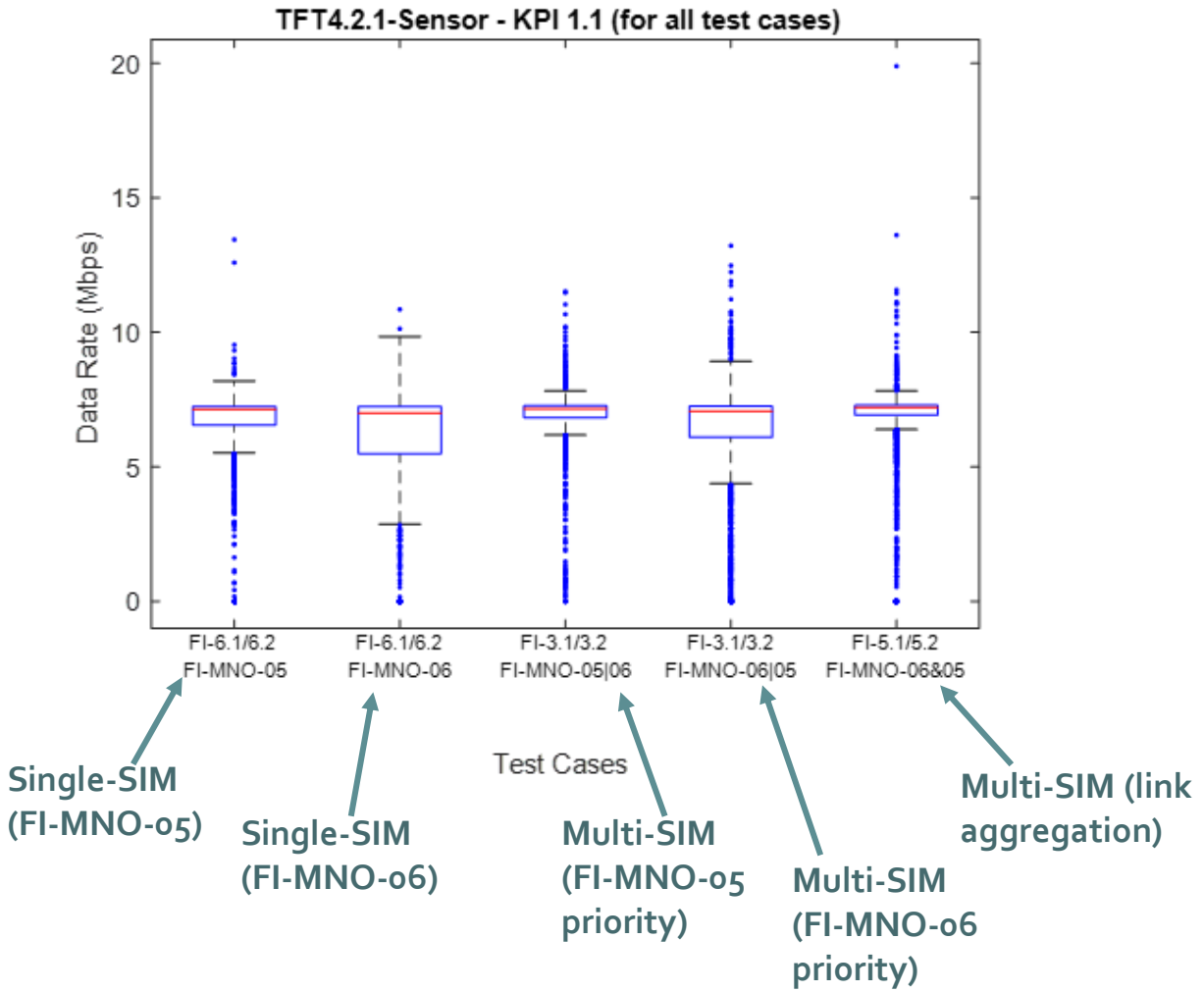
TFT4.2.1 Sensor (Lidar): KPI-1.1 Throughput

- TFT4.2.1 Sensor (Lidar)
  - UDP
  - CBR
  - 7.3 Mbps per LIDAR stream
- Noted observations
  - Improvements with both link selection and link aggregation modes
  - Improvements limited by prioritizing primary network (see FI-3.1/3.2 FI-MNO-06|05)



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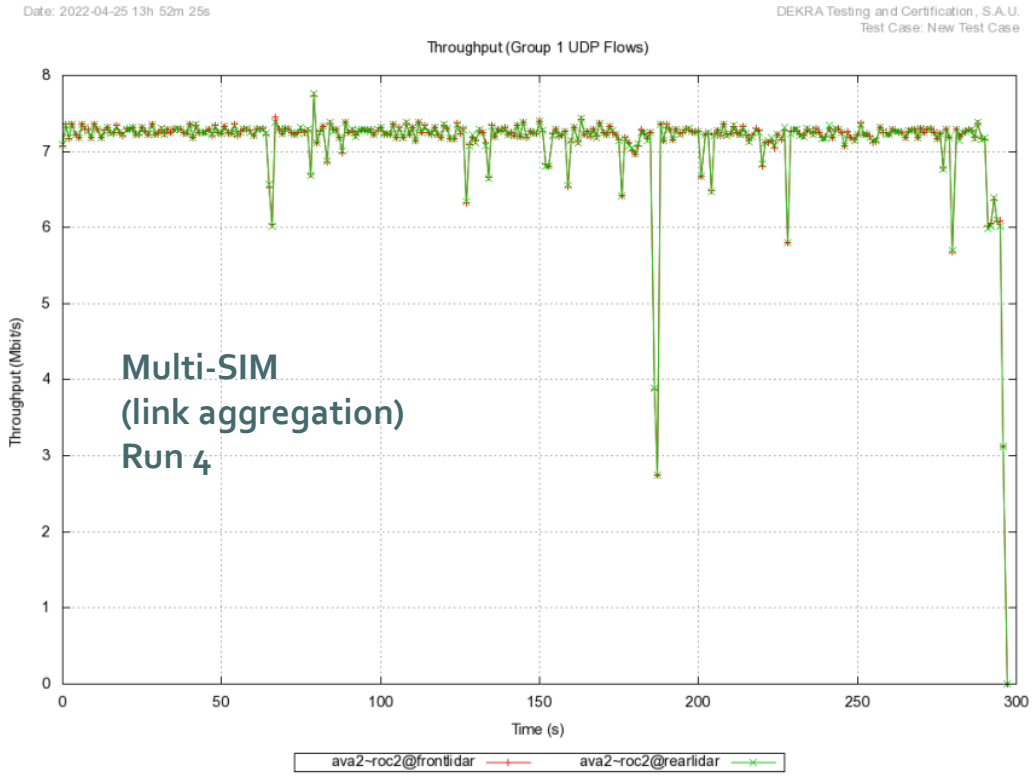
TFT4.2.1 Sensor (Lidar): KPI-1.1 Throughput

- Example KPI-1.1 result
- TFT4.2.1 Sensor (Lidar)
  - UDP, CBR, 7.3 Mbps per LIDAR stream



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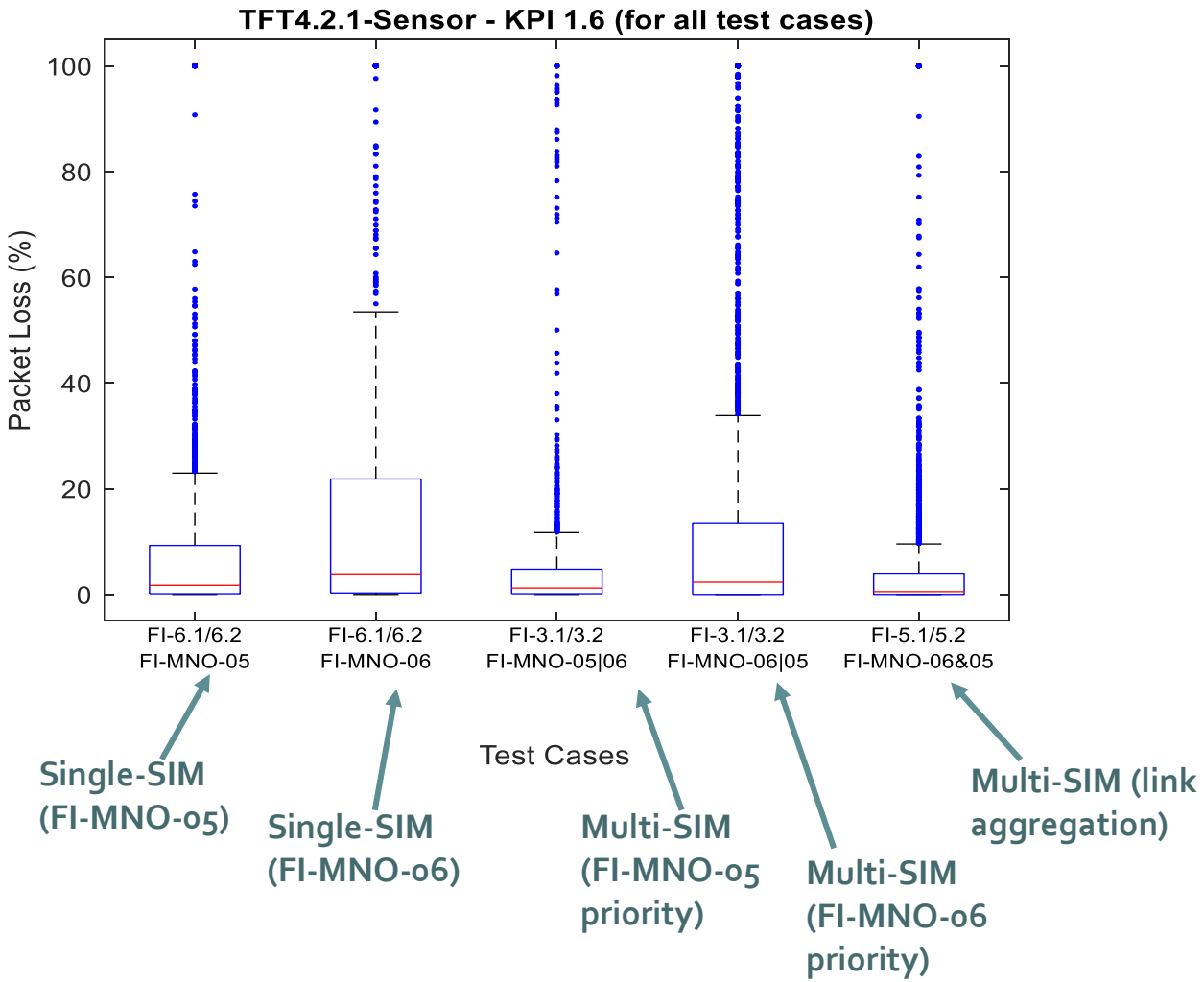
TFT4.2.1 Sensor (Lidar): KPI-1.6 Reliability

- TFT4.2.1 Sensor (Lidar)
  - UDP
  - CBR
  - 7.3 Mbps per LIDAR stream
- Noted observations
  - Improvements with both link selection and link aggregation modes
  - Improvements limited with prioritizing primary network (see FI-3.1/3.2 FI-MNO-06|05)



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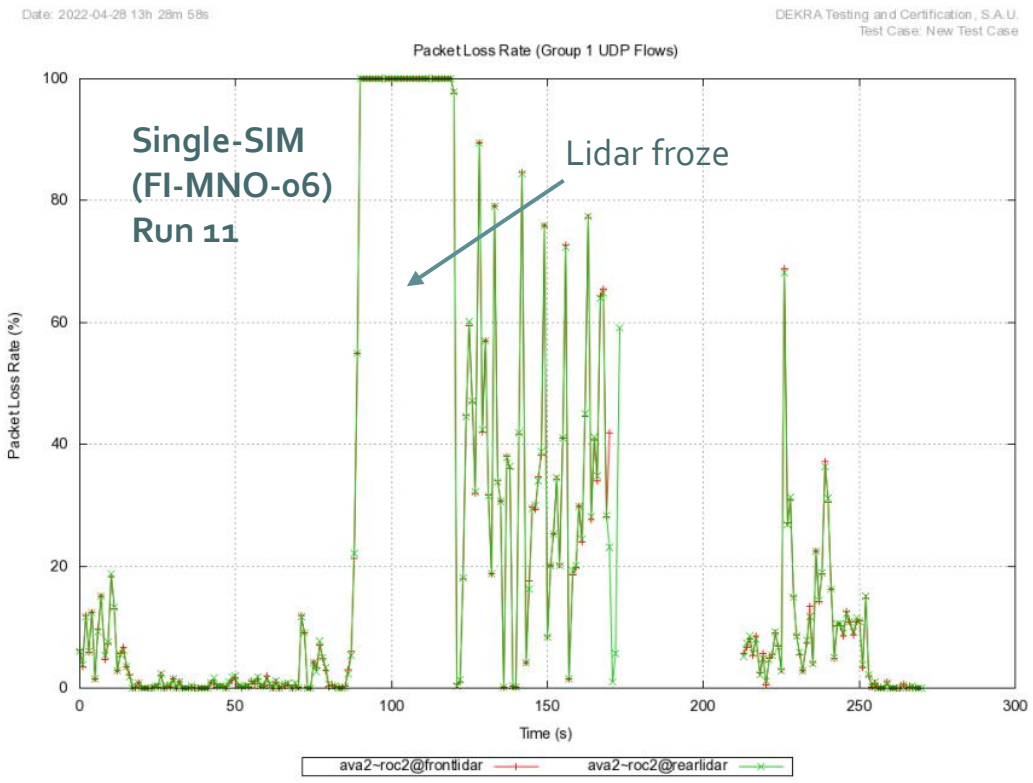
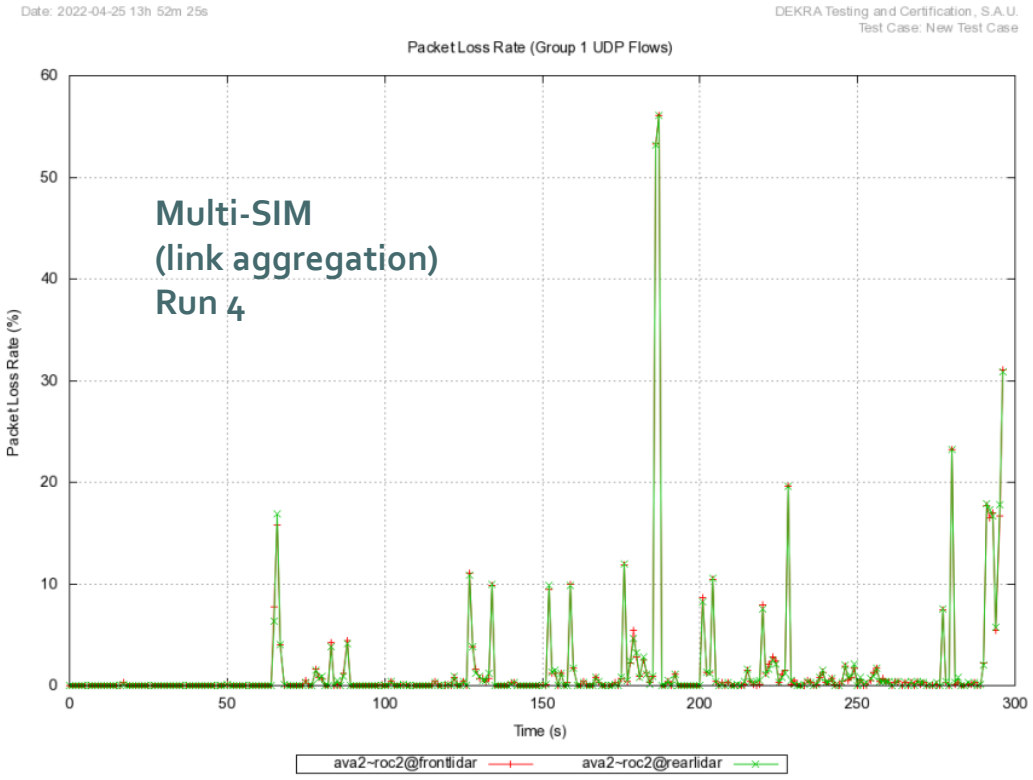
TFT4.2.1 Sensor (Lidar): KPI-1.6 Reliability

- Example KPI-1.1 result
- TFT4.2.1 Sensor (Lidar)
  - UDP, CBR, 7.3 Mbps per LIDAR stream





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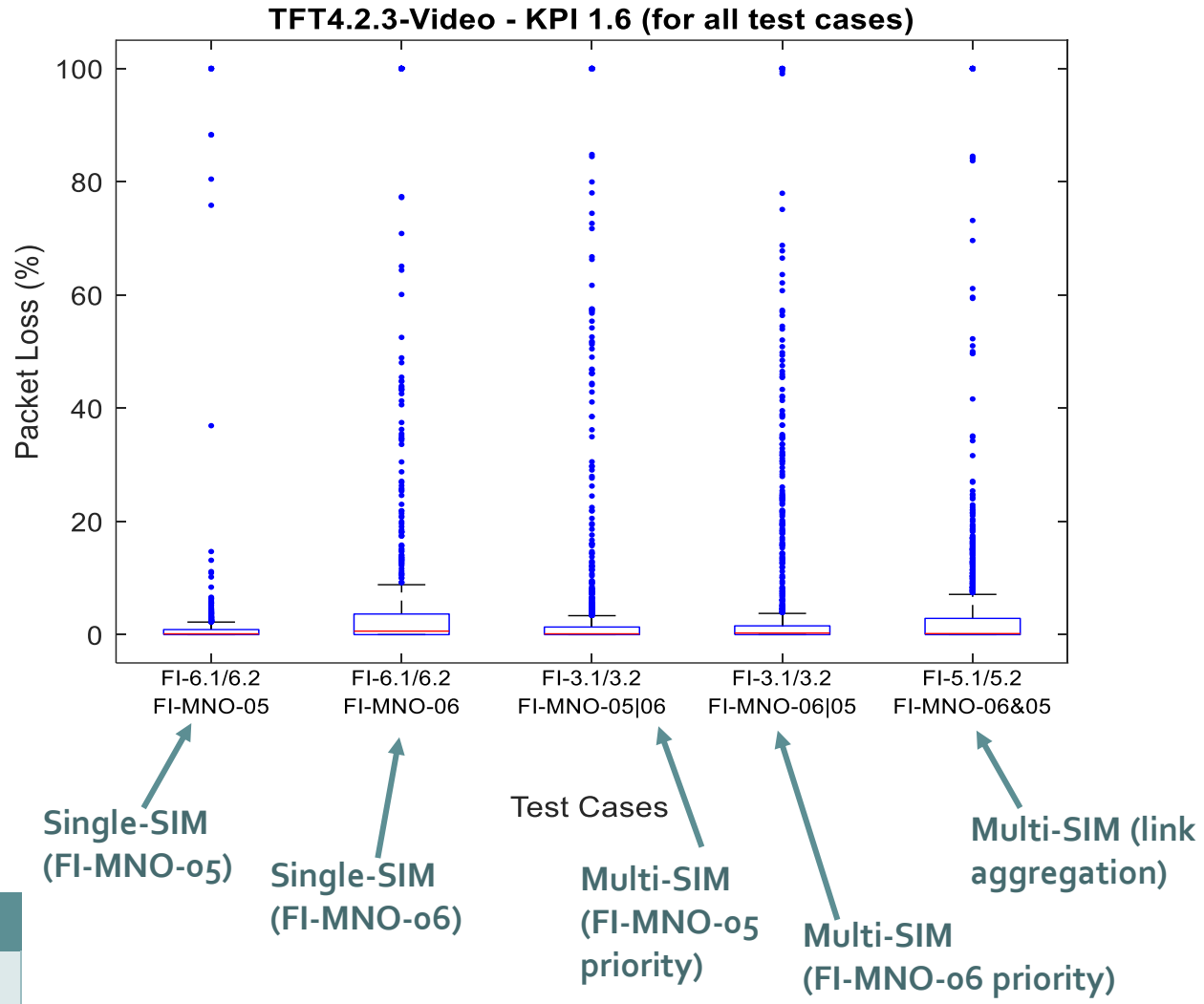
TFT4.2.3 Video: KPI-1.6 Reliability

- TFT4.2.3 Video
  - UDP
  - VBR
  - Around 6-8 Mbps
- Noted observations
  - Improvements of link selection/aggregation not as visible as in TFT 4.2.1 Sensor case (CBR)
  - Impairment less severe than the TFT 4.2.1 Sensor (Lidar) flow
  - Impact of rate adaptation of streaming protocol and encoders



KPI 1.6 Reliability (packet loss %)					
Test Cases →	FI-6.1/6.2 (FI-MNO-05)	FI-6.1/6.2 (FI-MNO-06)	FI-3.1/3.2 (FI-MNO-05|06)	FI-3.1/3.2 (FI-MNO-06|05)	FI-5.1/5.2 (FI-MNO-05&06)
Mean (Lidar)	10.05	21.73	5.14	14.89	6.8
Mean (Video)	1.84	9.83	4.32	4.12	4.46

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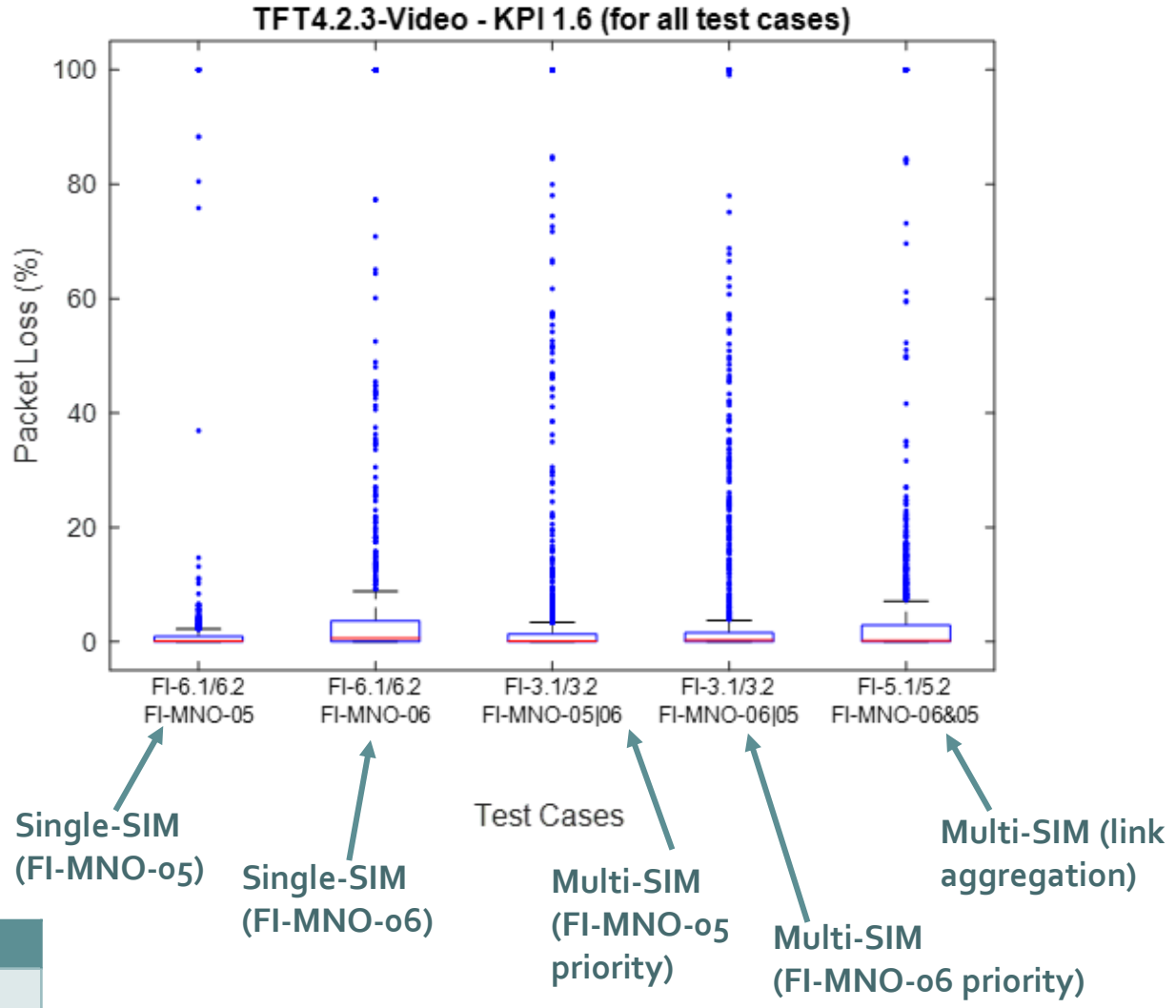
TFT4.2.2 Status: KPI-1.3 Latency

- TFT4.2.2 Status
  - TCP
  - Constantly generated data stream (100 kbit/s)
  - Target ≈160 ms RTT
- Noted observations
  - Generally acceptable performance
  - Frequent link (re-)selection may add latency (compared to single SIM case)
  - Note: In link selection mode, network changed about every 30 seconds (= every 300m, assuming average speed of 40 km/h)



KPI 1.6: End to end latency					
Tess Cases →	**FI-6.1/6.2 (FI-MNO-05)**	**FI-6.1/6.2 (FI-MNO-06)**	**FI-3.1/3.2 (FI-MNO-05|06)**	**FI-3.1/3.2 (FI-MNO-06|05)**	**FI-5.1/5.2 (FI-MNO-05&06)**
Mean	76.34	73.75	99.47	88.87	68.29

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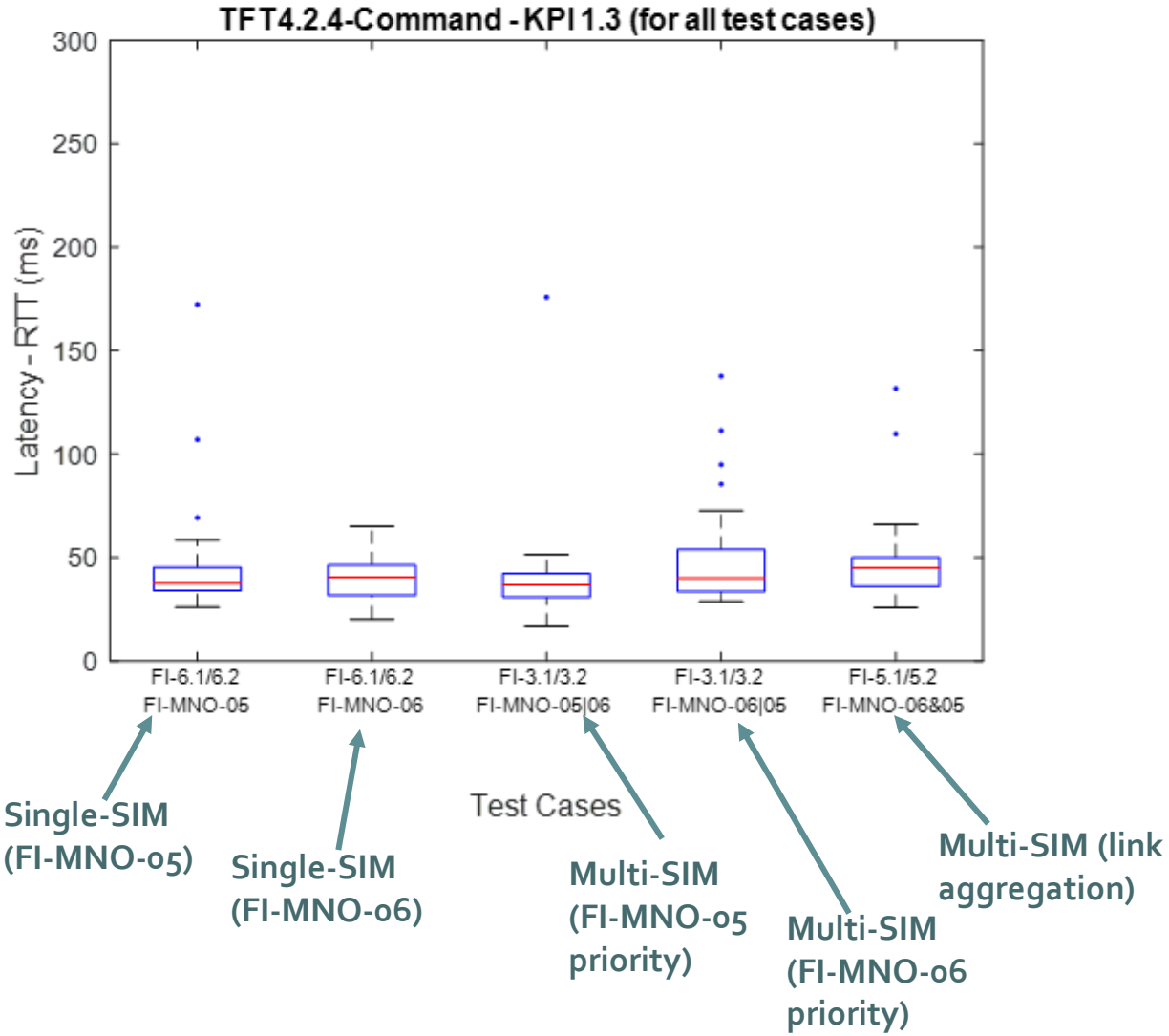
TFT4.2.4 Command KPI-1.3 (Latency)

- TFT4.2.4 Command
  - TCP
  - Episodic (only when remote request triggered from vehicle)
    - 1-4 packets per whole test run!
  - Target ≈160 ms RTT
- Noted observations
  - Acceptable performance in all cases
  - Least impacted by OBU configuration



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Conclusions

- This presentation summarized measurement results for the evaluation of the multi-SIM solutions for remote driving user story
- Overall results comparisons of the single-SIM vs multi-SIM solution highlighted the effectiveness of the latter solution in leveraging redundant networks for service continuity
- The next presentation will summarise the lessons and experiences acquired from these trials and future outlook

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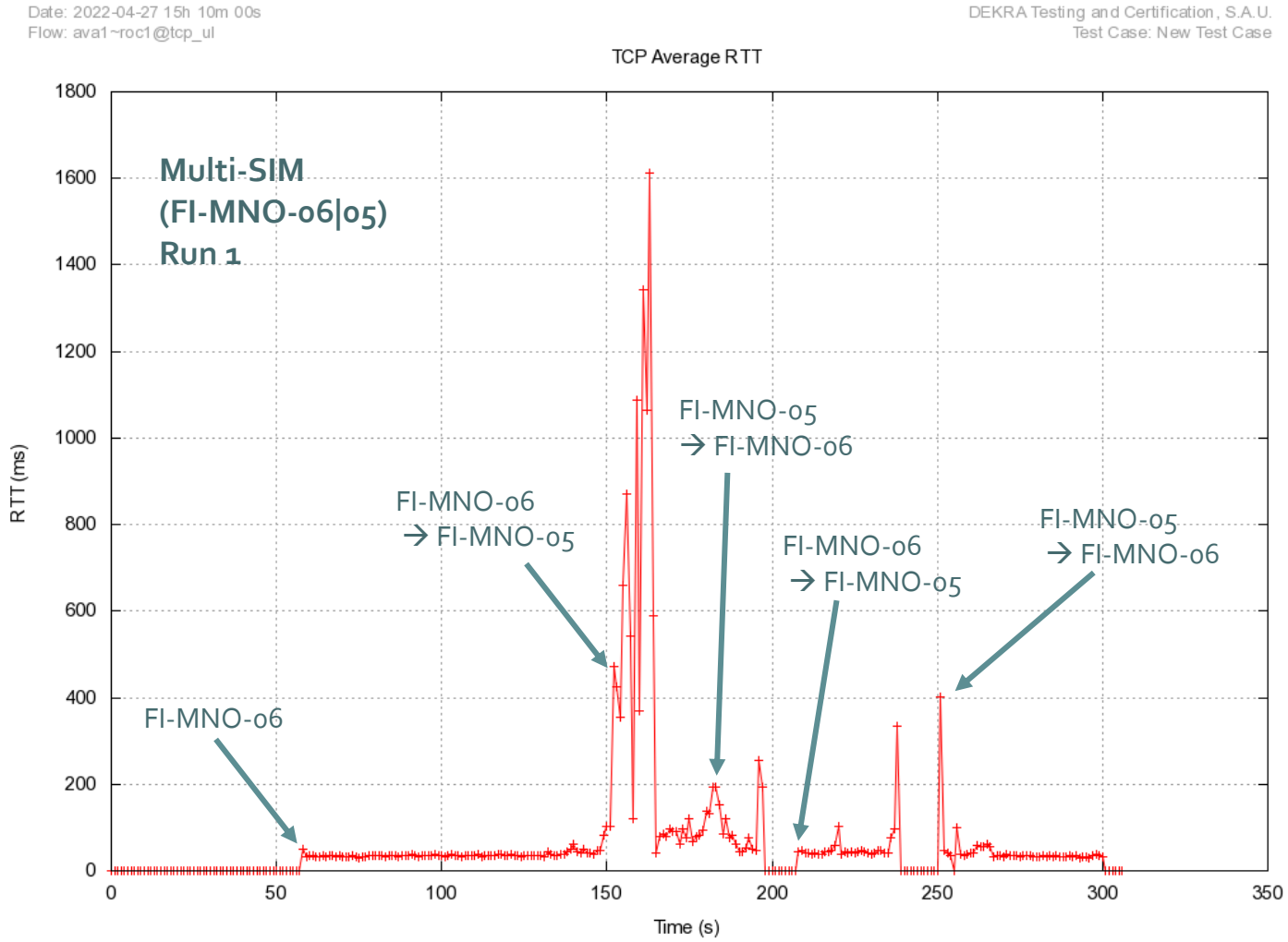
TFT4.2.2 Status: KPI-1.3 Latency

- TFT4.2.2 Status
  - TCP, Constantly generated data stream (100 kbit/s), Target ≈160 ms RTT



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