

CanalLink: Empirical Analysis of Cellular and LEO Satellite Networks in Inland Maritime Waterways

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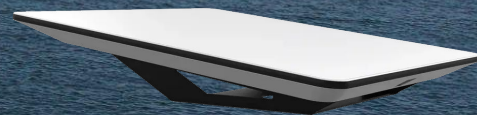




5G Routers



MS Wavelab

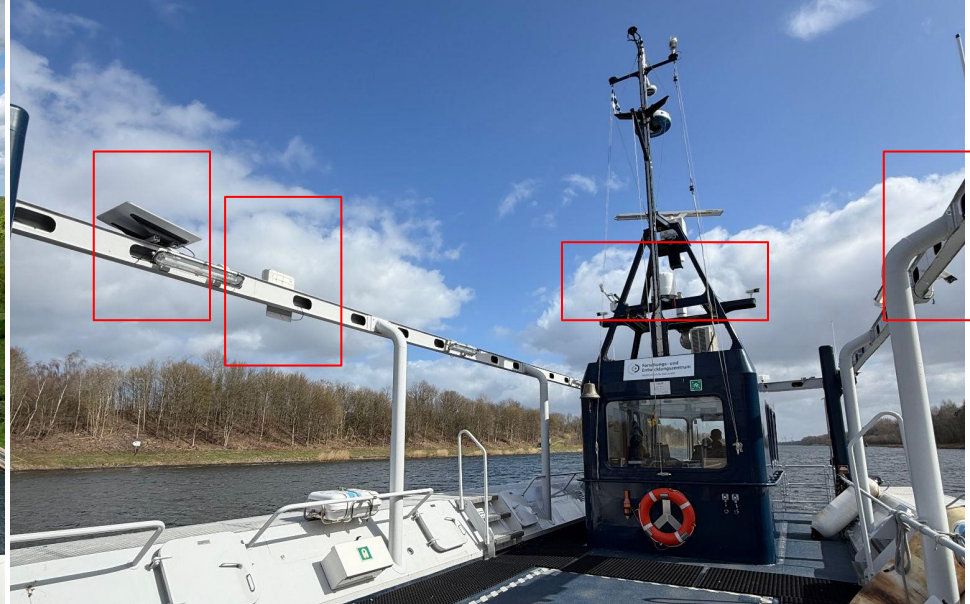


Starlink Dish

ADDIX



Limited Cellular Coverage



Large Objects



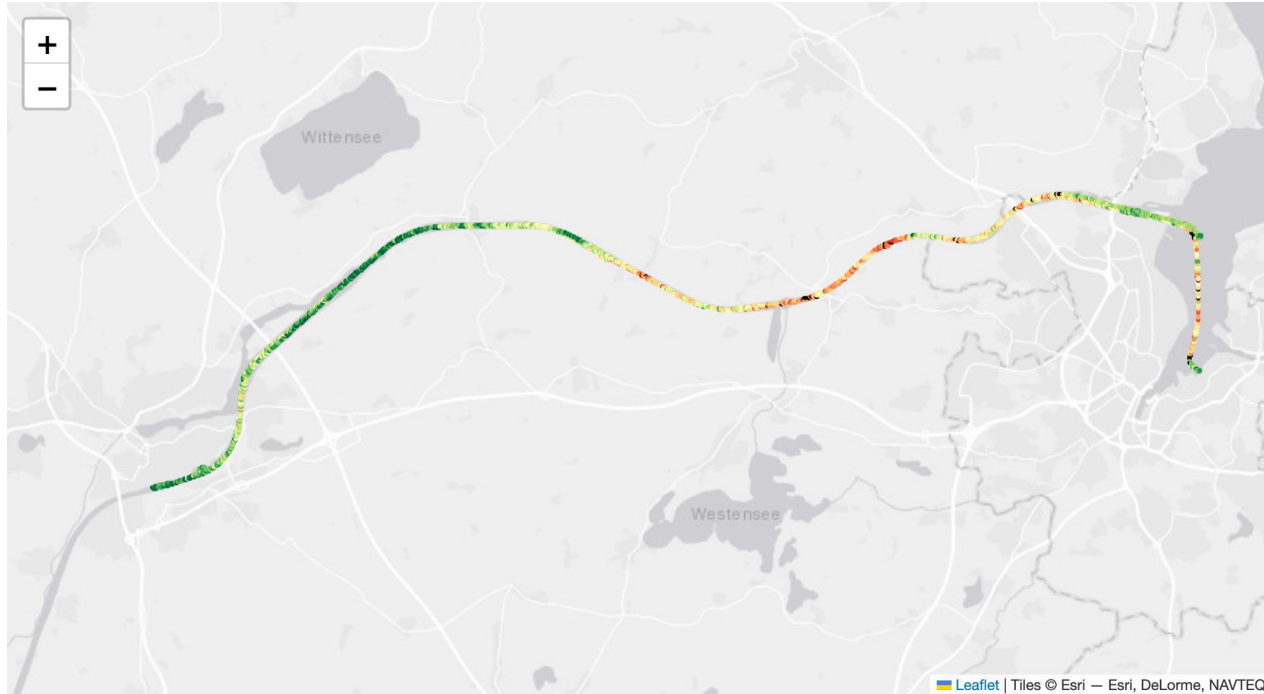
Bridges

Contributions

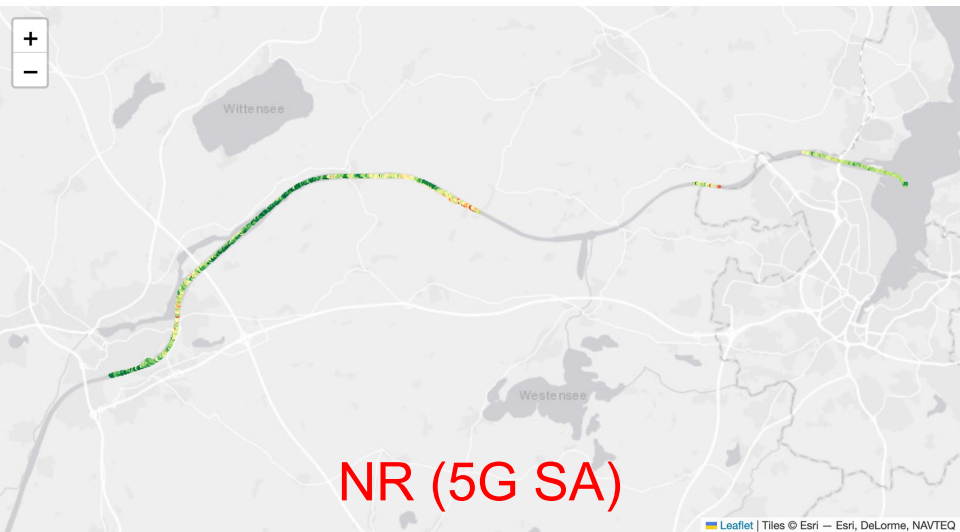
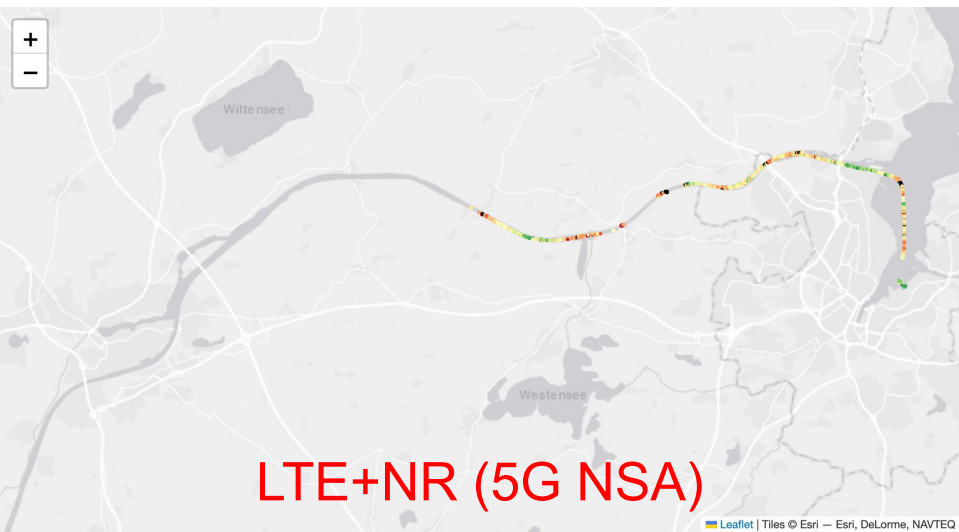
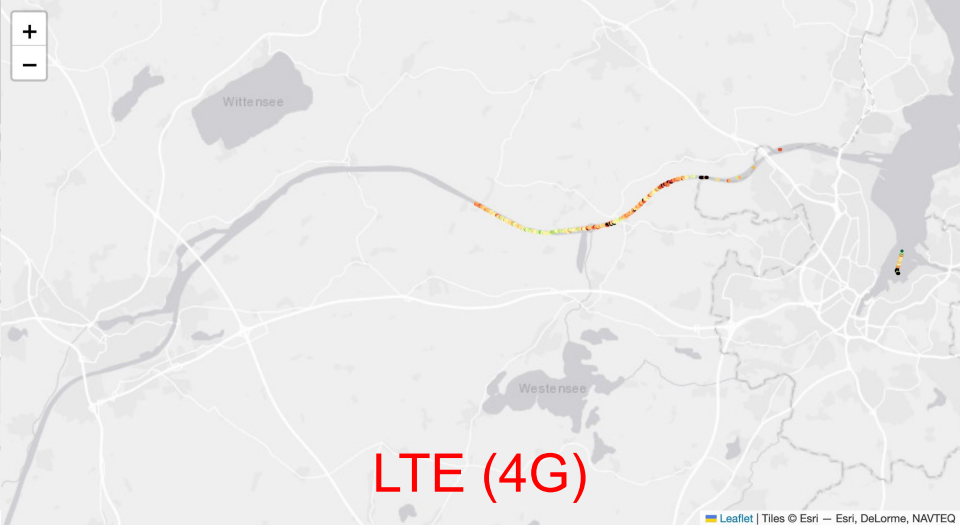
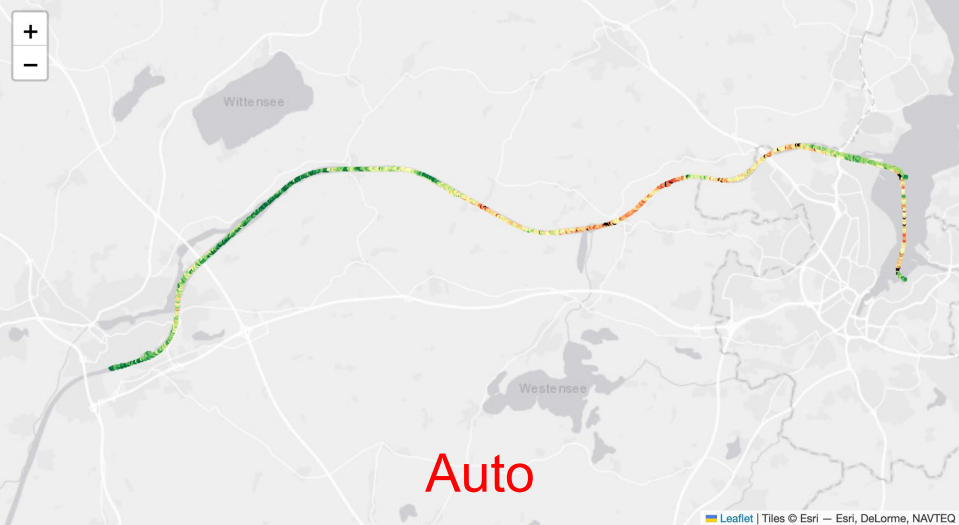
- We introduce CanalLink, a Starlink and 5G dataset collected for inland maritime waterway connectivity.
- We analyze the CanalLink dataset in terms of real-time video streaming and data streaming KPIs.
- We discuss potential studies enabled by CanalLink, such as multi-link aware proactive link switching.



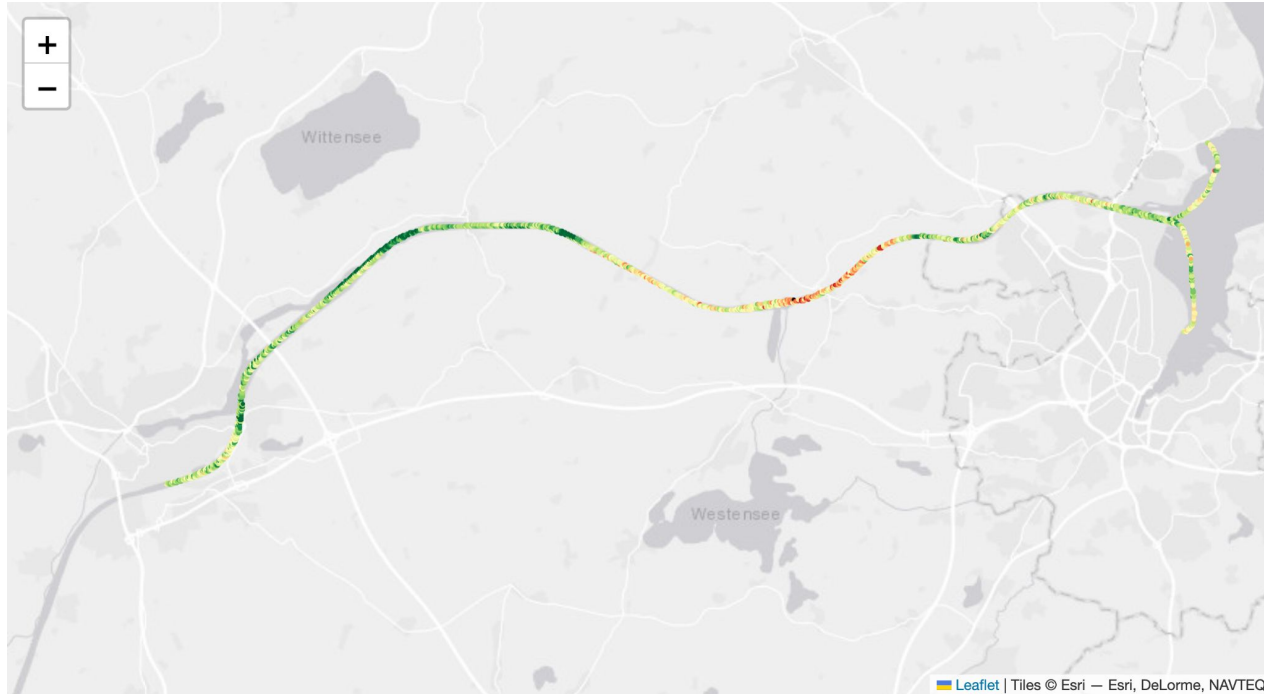
Data Collection Campaign



Measurement region in the Kiel Canal on the 7th of November, 2024.
We plot the CQI coverage of one 5G router using operator #1.
Color range: green is high and red is low.



Data Collection Campaign



Measurement region in the Kiel Canal on the 6th of May, 2025

We plot the CQI coverage of one 5G router using operator #1 with full 5G SA coverage.

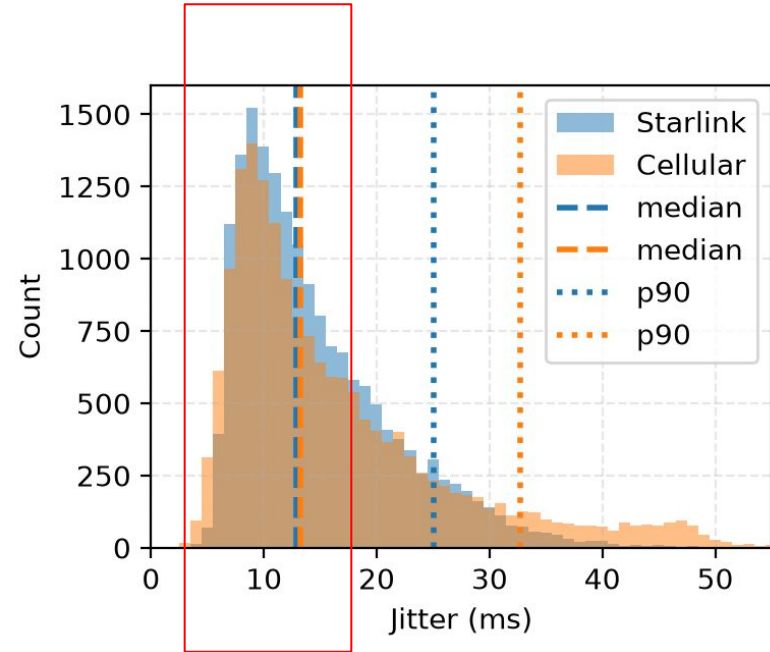
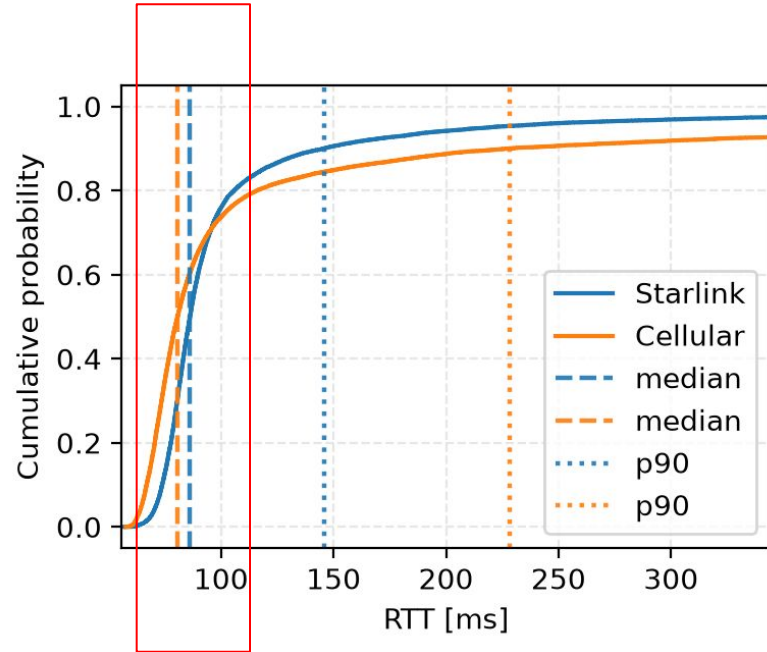
Color range: green is high and red is low.

Data Collection Campaign

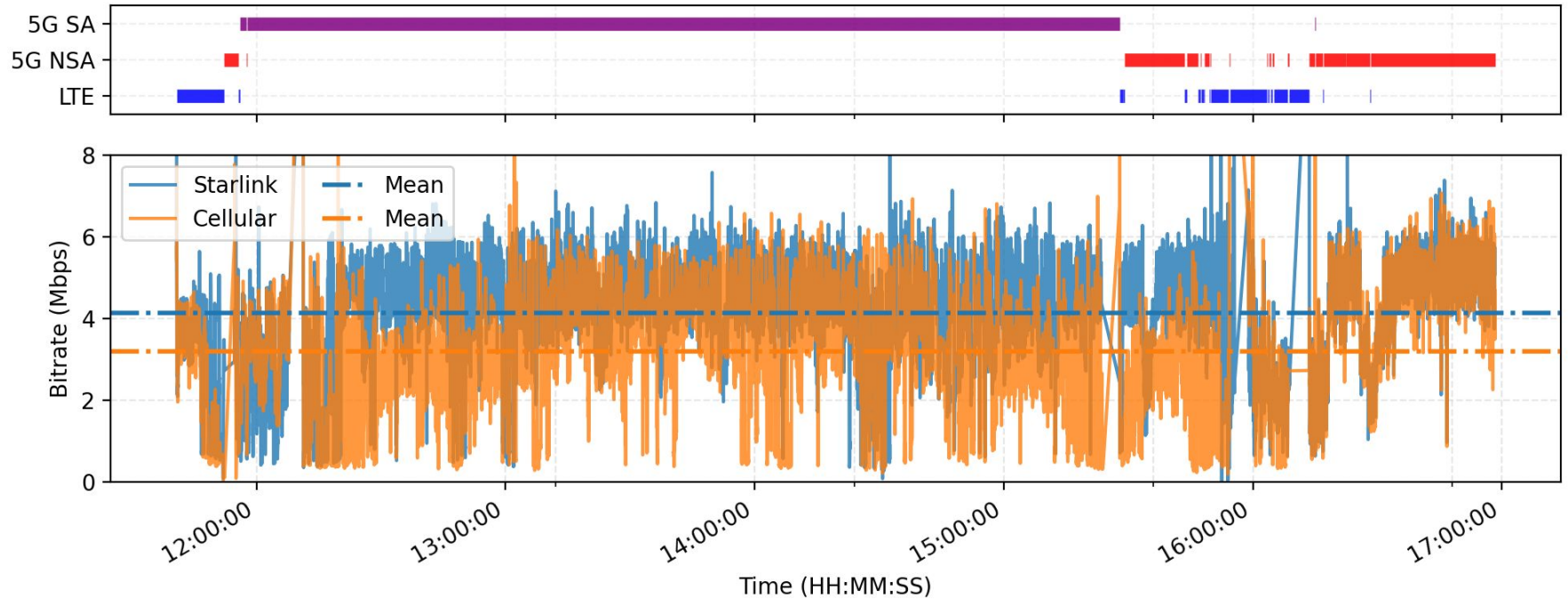
- Starlink Flat High Performance Dish
 - MikroTik Chateau 5G routers
 - Operator #1 with 5G Standalone
 - Operator #2 with 5G Non-Standalone
 - 2 days of data collection
 - November 2024
 - May 2025
 - Over a million collected data points
- 5G modem
 - Signal strength, Frequency, GNSS
 - Starlink dish
 - PoP ping, SNR state, obstruction state, GNSS
 - TWAMP
 - Latency, Jitter, Packet Loss
 - WebRTC
 - RTT, Jitter, Packet Loss, NACK, PLI, GNSS
 - Weather
 - Temperature, Wind, Precipitation

Data Analysis

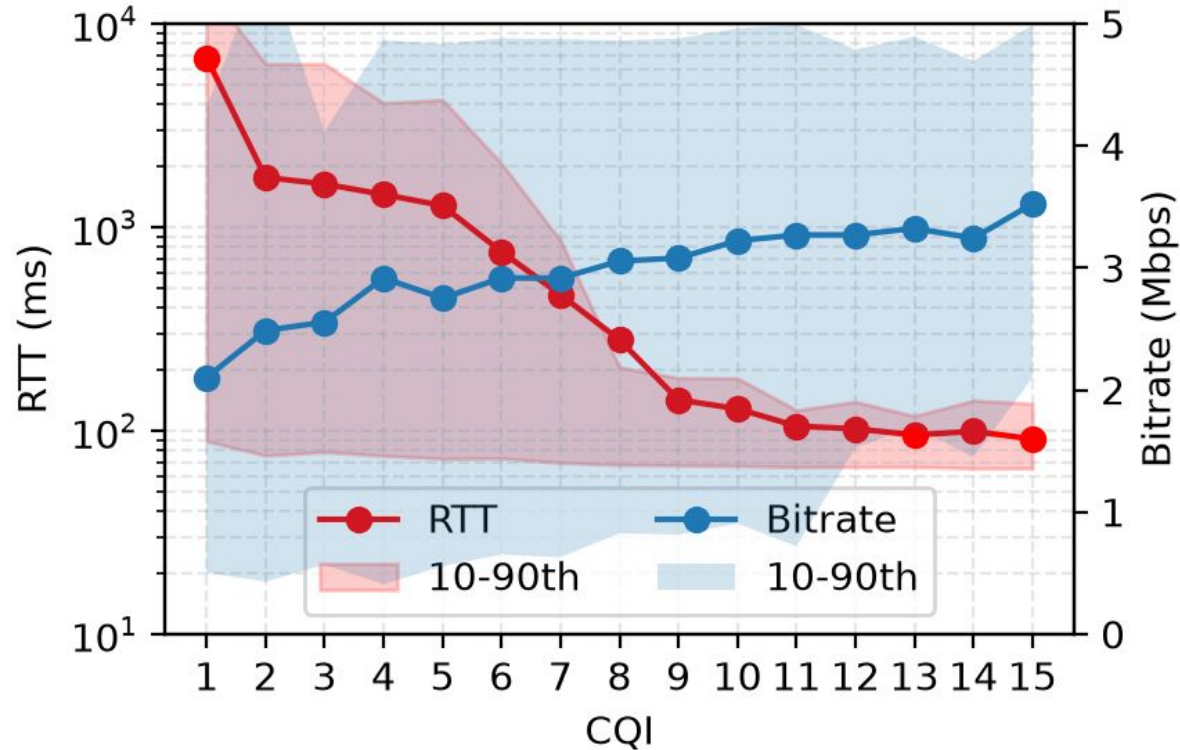
Real-time Video Streaming - Latency & Jitter



Real-time Video Streaming - Bitrate

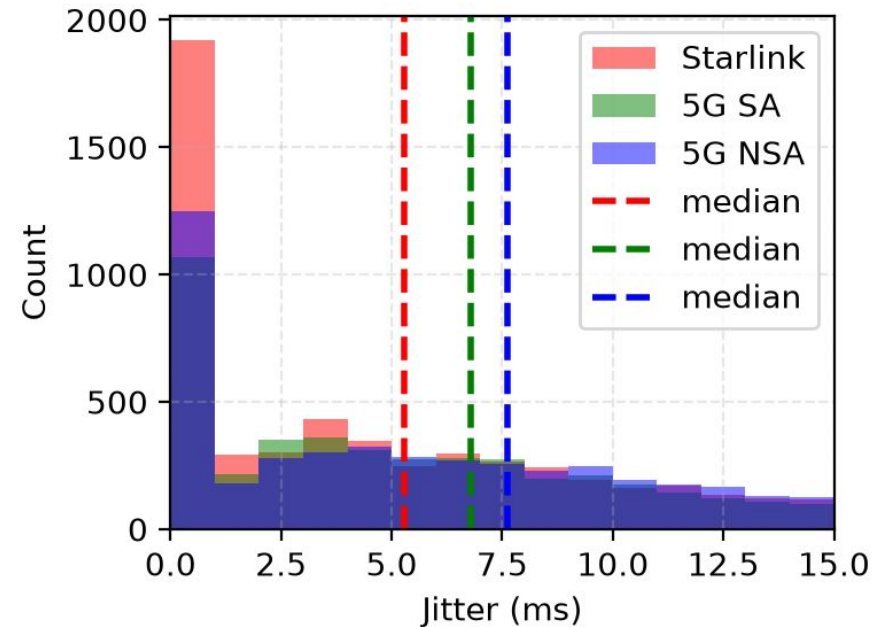
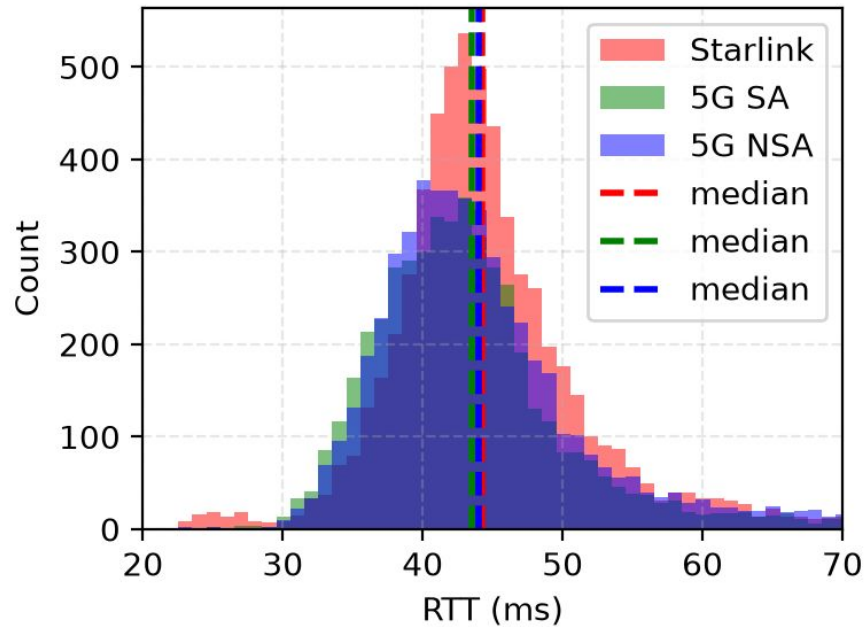


Real-time Video Streaming - CQI vs RTT/Bitrate

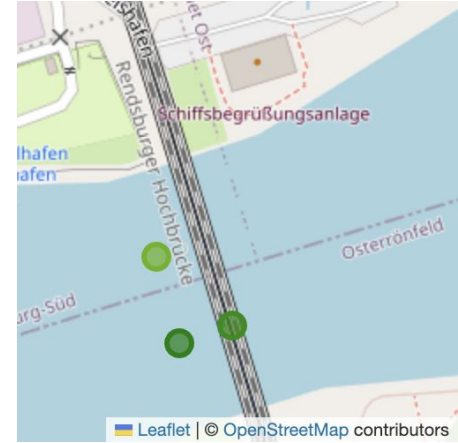
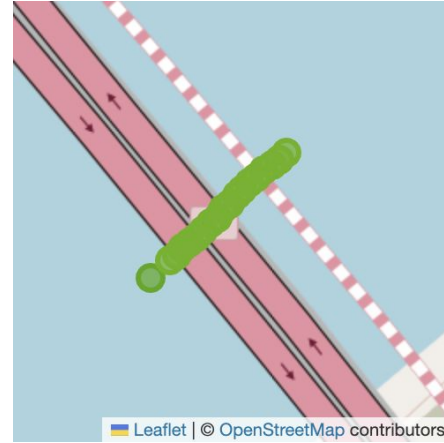
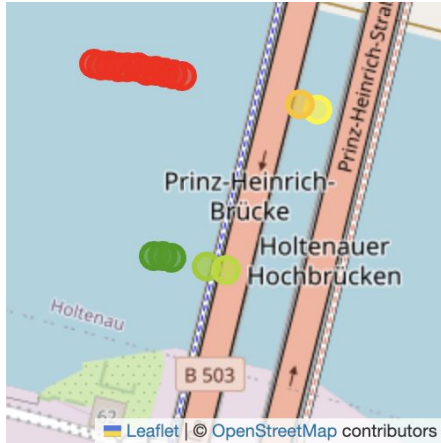


+ RSRP, SINR, Band, Channel Width, ..

Real-time Data Streaming - Latency & Jitter



Impact of obstruction on signal and latency



The impact of obstruction on SNR

Starlink reports low SNR below a threshold while passing under bridges, causing latency spikes in the LEO link.

Green to red regions: minimal to maximal latency increase.

Potential Studies enabled by CanalLink

- Video Streaming
 - Real-time rate control of WebRTC video streams in 5G networks: Improving quality of experience with deep reinforcement learning [16]
 - RTT, jitter, bitrate drops, NACK, PLI, ..
- Bandwidth Prediction
 - Bandseer: Bandwidth prediction for cellular networks [22]
 - Capaware: Capacity-aware uplink bandwidth prediction for cellular networks [23]
 - RSRP, SINR, CQI, Band, Handover, ..
- Proactive link selection and load balancing
 - e.g., 5G+5G, or 5G+LEO
 - **Challenges** with L1 info from Starlink → 3GPP Release 17 devices with RSRP, SINR, CQI, ..

Conclusion and Summary

- We collect CanaLink, a Starlink and 5G dataset for coastal maritime connectivity research.
- We analyze and show the usefulness of the dataset.
- Available as open source
 - <https://github.com/ds-kiel/CanaLink>

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