Evaluation of Mobile Connectivity when Aggregating Multiple Cellular Networks

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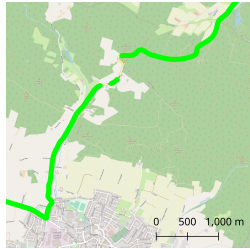Institute of Computer Science
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UNIVERSITÄT OSNABRÜCK

Motivation

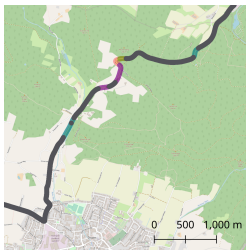(a) Telekom

(b) Vodafone

(c) O$_2$

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(b) Vodafone

(c) O₂

(d) Aggregated
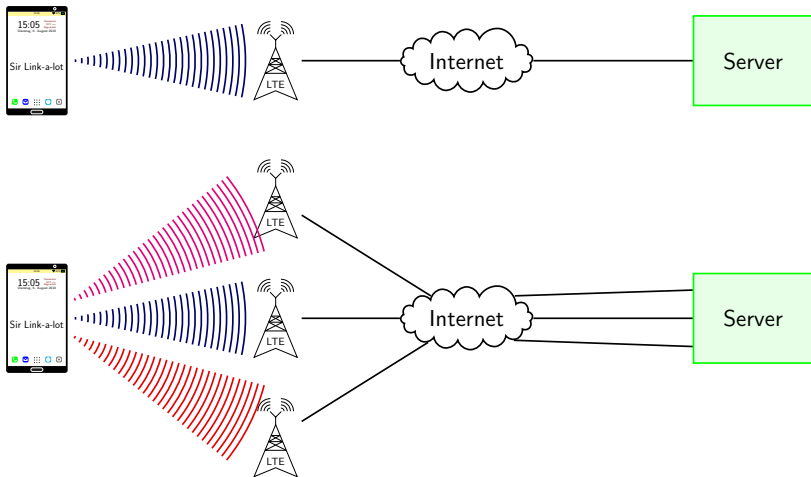
Possible option: Using multipath protocols such MPTCP

Literature overview

Related work:

- ▶ aggregation of LTE and WiFi

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New in this paper:
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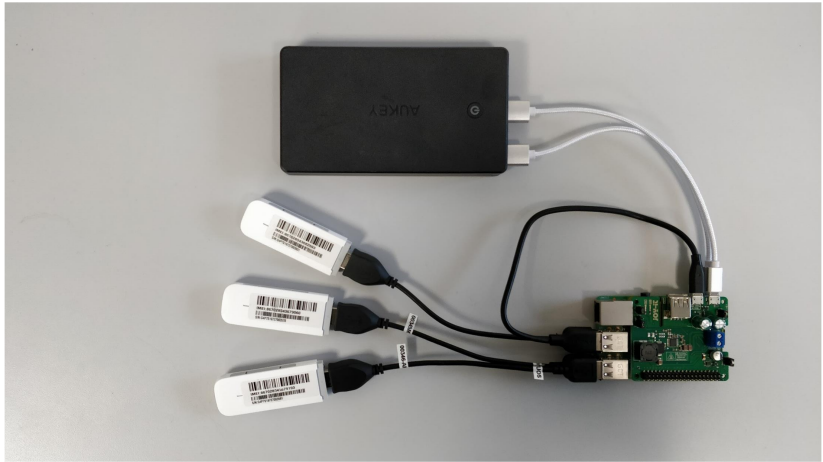
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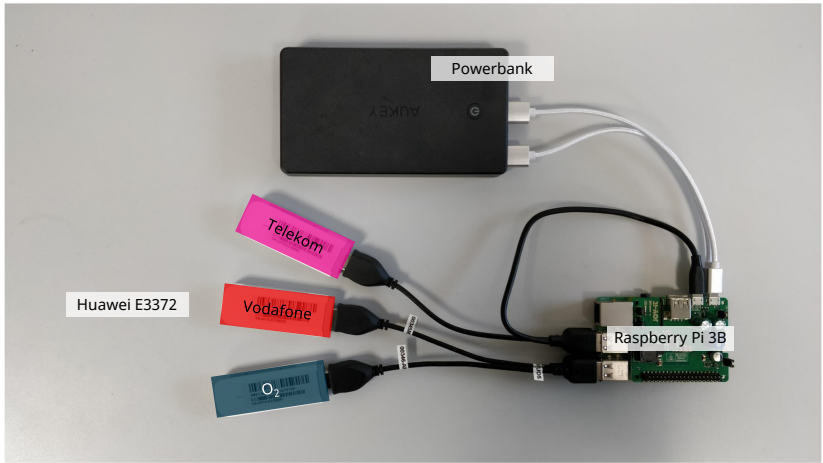- ▶ investigation of cellular network coverage

Figure: Measurement equipment

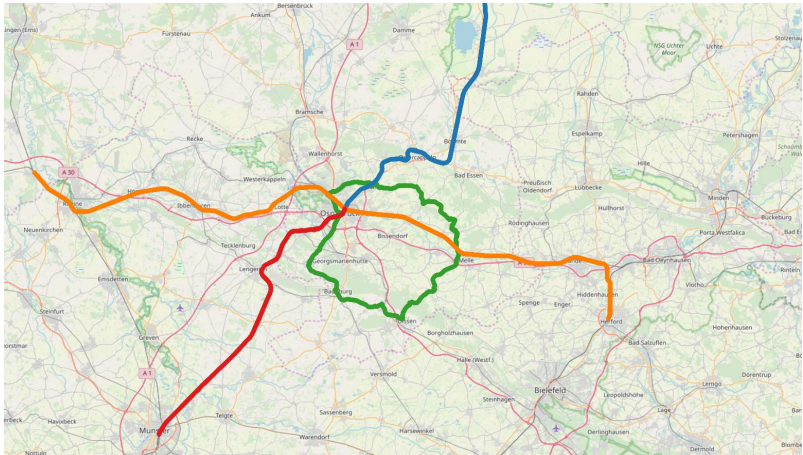Figure: Measurement equipment

Additionally used a GPS module for positioning

Figure: Map showing the measured routes

Measurements performed in December 2019

Combined packet loss traces

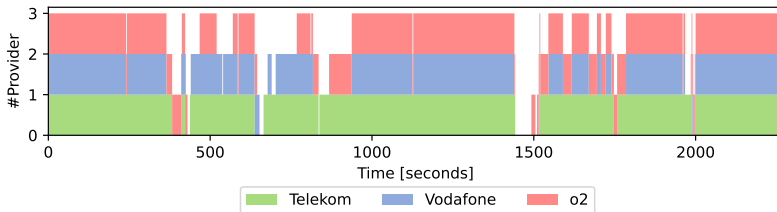Figure: Packet loss trace on the measurement OS-MS-1

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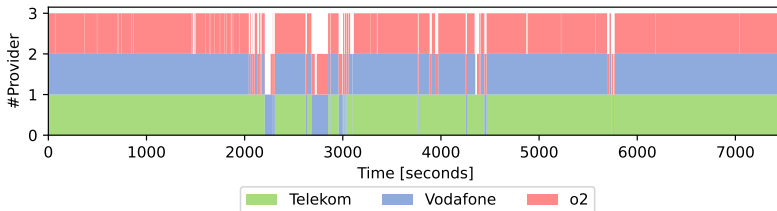
Packet loss rates

Table: Packet loss rates of different providers in [%].

	T	V	O	T+V	T+O	V+O	T+V+O	MPTCP
Safari-1	5.45	3.36	3.19	0.17	1.17	0.23	0.00	0.92
OS-HB-1	5.19	4.28	12.28	1.11	1.46	2.30	0.58	0.57
OS-HB-2	3.76	1.60	11.15	0.29	1.29	0.71	0.12	0.41
SB-HF-1	2.82	5.73	2.61	1.55	0.84	0.31	0.22	0.12
OS-MS-1	7.84	16.50	14.16	5.04	2.37	4.34	1.95	0.87
OS-MS-2	4.91	10.42	9.84	2.54	1.61	2.80	1.01	1.77

T=Telekom, V=Vodafone, O=O_2

Figure: Combined cellular standards for different measurements
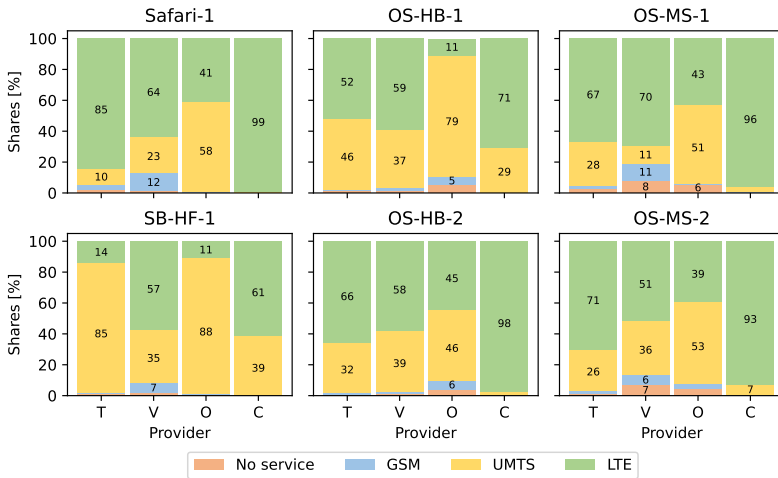
T=Telekom, V=Vodafone, O=O$_2$, C=Combined

Summary

- investigated mobile connectivity
- aggregated multiple cellular networks
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- theoretical gain differs from MPTCP scheduling results
- MPTCP gain benefits from retransmissions
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Cellular links with homogenous characteristics benefit from aggregation

Table: Description of all considered routes.

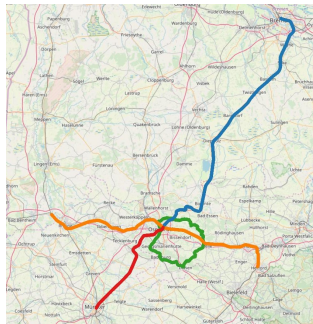| Name	Means of transport	Waypoints
Safari	car	Osnabrück→Belm→Wulften →Schledehausen→Melle →Dissen a.T.W.→Bad Iburg →Hagen a.T.W.→Osnabrück
OS-HB	train (RE9)	Osnabrück→Bremen→Osnabrück
SB-HF	train (RB61)	Osnabrück→Salzbergen→Osnabrück →Herford→Osnabrück
OS-MS	train (RB66)	Osnabrück→Münster→Osnabrück

Table: List of all measurements performed.

Name	Date	Duration	Route	Configuration modems
Safari-1	21Dec19	2hr5min	Safari	LTE, UMTS, GSM
OS-HB-1	22Dec19	2hr59min	OS-HB	LTE, UMTS, GSM
OS-HB-2	22Dec19	2hr56min	OS-HB	Automatic
SB-HF-1	23Dec19	3hr7min	SB-HF	LTE, UMTS, GSM
OS-MS-1	23Dec19	1hr25min	OS-MS	LTE, UMTS, GSM
OS-MS-2	23Dec19	1hr30min	OS-MS	LTE, UMTS, GSM

Figure: Sending of packets
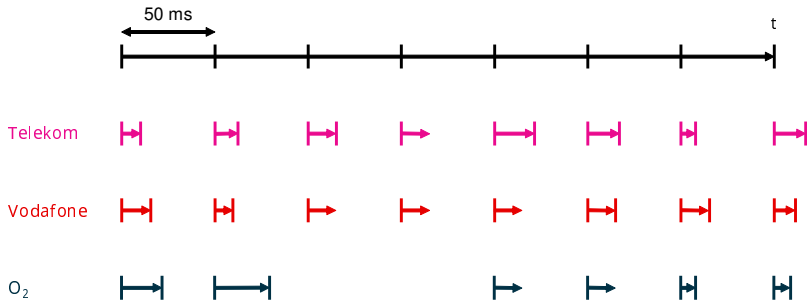
- ▶ Packets are sent through all links simultaneously using UDP
- ▶ Sending interval: 50 milliseconds
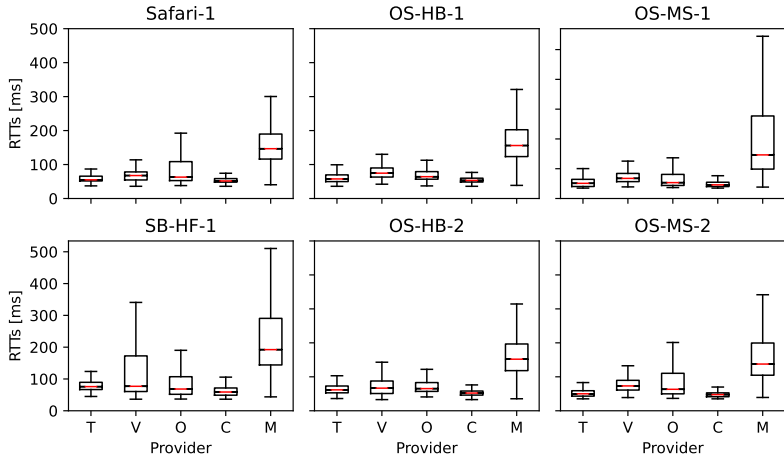- ▶ Echo server echos all packets

Figure: Round trip times for different measurements

T=Telekom, V=Vodafone, O=O$_2$, C=Combined, M=MPTCP

Table: Mean round trip times for different providers in [seconds].

	Telekom	Vodafone	O_2	Combined	MPTCP
Safari-1	0.23 ± 1.61	0.20 ± 1.08	0.12 ± 0.55	0.07 ± 0.13	2.46 ± 16.28
OS-HB-1	0.15 ± 0.67	0.25 ± 1.64	1.57 ± 8.33	0.07 ± 0.24	1.08 ± 5.24
OS-HB-2	0.15 ± 0.72	0.23 ± 1.34	1.71 ± 8.43	0.06 ± 0.12	0.67 ± 3.09
SB-HF-1	0.18 ± 0.96	0.45 ± 2.99	0.62 ± 3.47	0.10 ± 0.81	0.95 ± 3.85
OS-MS-1	0.23 ± 1.56	0.92 ± 3.68	0.91 ± 4.28	0.23 ± 1.49	9.81 ± 30.56
OS-MS-2	0.15 ± 1.18	0.98 ± 3.98	1.40 ± 5.52	0.28 ± 2.02	2.89 ± 10.89

Table: Packet loss in urban (U) versus rural (R) areas [%]

Region	Shares U	R	Telekom U	R	Vodafone U	R	O_2 U	R	Combined U	R
Safari-1	37	64	0.03	8.55	0.02	5.28	0.84	4.54	0.00	0.00
OS-HB-1	23	77	0.60	6.56	0.00	5.57	0.82	15.70	0.00	0.75
OS-HB-2	21	79	0.85	4.53	0.22	1.96	0.78	13.89	0.00	0.16
SB-HF-1	38	62	0.02	4.53	0.70	8.79	0.30	4.01	0.00	0.35
OS-MS-1	37	63	3.26	10.49	8.80	20.96	1.54	21.45	0.24	2.94
OS-MS-2	39	61	1.34	7.18	3.03	15.11	1.54	15.11	0.05	1.63