The EECC, satcom and ARTES

1. In 2021, an **ARTES Future Preparation** study completed the investigation of the impact of upcoming cyber regulations on satellite communications. This study also considered the **European Electronic Communications Code the "EECC"** from a cyber perspective.

2. The EECC extends rules to electronic communication service providers that were not regulated before. Member States have until **21 December 2020** to transpose the EECC into legislation in their own country.

3. The EECC requires that "***The adequate broadband internet access service shall be capable of delivering the bandwidth necessary for supporting at least the minimum set of services set out in Annex V.***"

Satellite networks and the EECC

For the purposes of this Directive, the following definitions apply:

Article 2

(1) 'electronic communications network' means transmission systems, whether or not based on a permanent infrastructure or centralised administration capacity, and, where applicable, switching or routing equipment and other resources, including network elements which are not active, which permit the conveyance of signals by wire, radio, optical or other electromagnetic means, including satellite networks, fixed (circuit- and packet-switched, including internet) and mobile networks, electricity cable systems, to the extent that they are used for the purpose of transmitting signals, networks used for radio and television broadcasting, and cable television networks, irrespective of the type of information conveyed;

2. National regulatory authorities in coordination with other competent authorities shall specify, taking utmost account of BEREC guidelines, the quality of service parameters to be measured, the applicable measurement methods, and the content, form and manner of the information to be published, including possible quality certification mechanisms. Where appropriate, the parameters, definitions and measurement methods set out in Annex X shall be used.

Article 104

By 21 June 2020, in order to contribute to a consistent application of this paragraph and of Annex X, BEREC shall, after consulting stakeholders and in close cooperation with the Commission, adopt guidelines detailing the relevant quality of service parameters, including parameters relevant for end-users with disabilities, the applicable measurement methods, the content and format of publication of the information, and quality certification mechanisms.

Annex X defines **how** to measure and verify the SLA's of service providers, but imposes **limited absolute performance figures**.

This is done on purpose – to allow competition based on different SLA's

A number of guidelines published – refining **which** Quality of Service parameters to measure, and **how**.

Measurement campaign supported by ARTES

1. A number of countries investigating the use of satellite networks and EECC

2. At the request of DLR, a measurement campaign was initiated to assess current satellite internet performance

3. The most flexible implementation mechanism proved to be ARTES AT 5G METEOR/5G MakerSpace ARTES MakerSpaces 5GMETEORS

4. It was recommended to include Starlink as part of measurements – as it became available in 1Q 2021 in a number of European countries

Computer Science 7
Computer Networks and
Communication Systems

FRIEDRICH-ALEXANDER
UNIVERSITÄT
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TECHNISCHE FAKULTÄT

5. Implemented by Computer Networks and Communication Systems group, Friedrich-Alexander-Universität Erlangen-Nürnberg, University of Erlangen, Germany

Computer Science 7
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TECHNISCHE FAKULTÄT

Satellite Internet Performance Measurements

Jörg Deutschmann, Kai-Steffen Hielscher, Reinhard German

joerg.deutschmann@fau.de

2021-06-21

Supported by esa and DLR

Motivation: Internet is essential

- European Electronic Communications Code (EECC)
  https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02018L1972-20181217

Annex V *minimum set of services which the adequate broadband Internet access service [...] shall be capable of*

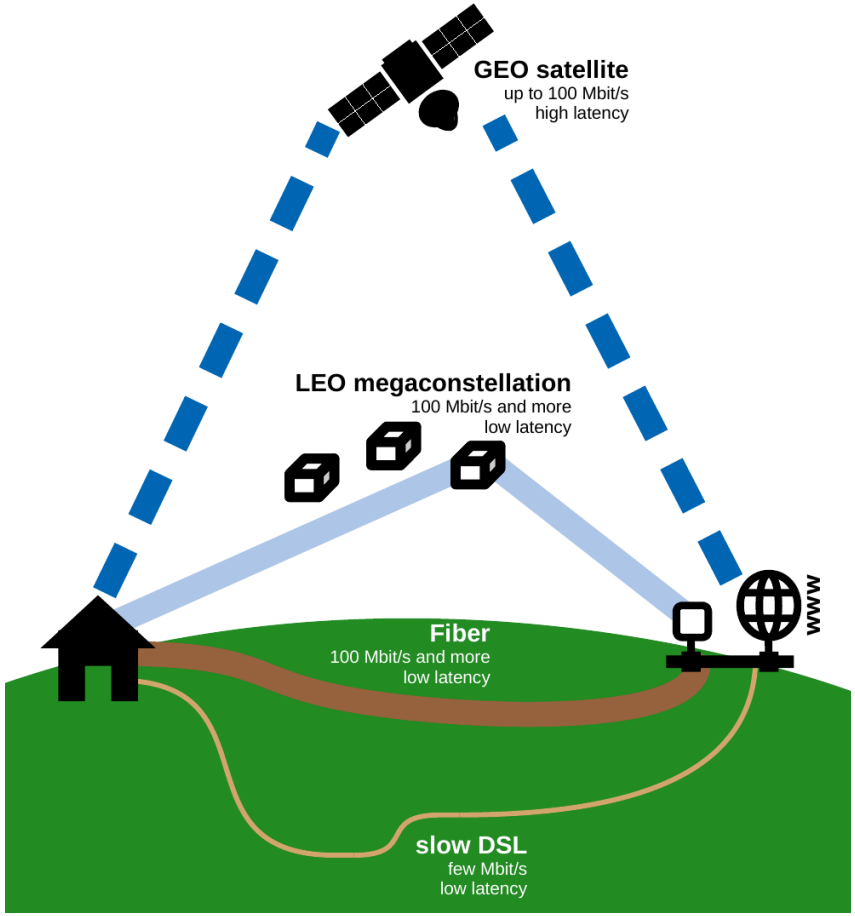
- E-mail
- search engines [...]
- basic training and education online tools
- online newspapers or news
- buying or ordering goods or services online
- job searching and job searching tools
- professional networking
- internet banking
- eGovernment service use
- social media and instant messaging
- calls and video calls (standard quality)

- Body of European Regulators for Electronic Communications (BEREC) Guidelines detailing Quality of Service Parameters
  https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9043-berec-guidelines-detailing-quality-of-service-parameters

- Voice: Call set-up time; Unsuccessful call rate; Speech transmission quality; [...]
- Mobile: [...]
- Customer service: [...]
- Internet: Data transfer speed; Web page loading time; Latency; Jitter; Packet loss rate

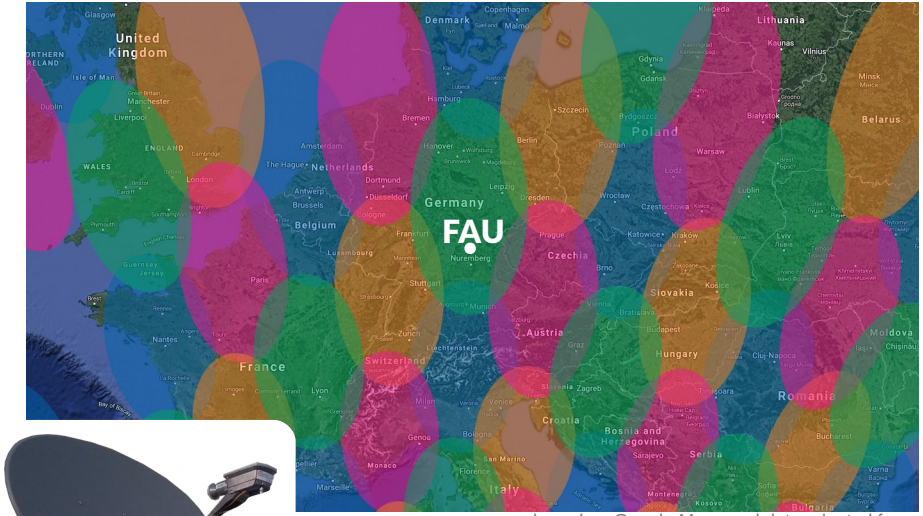
Motivation

- Comparison of different Internet access technologies
  - Geostationary satellite access (GEO)
    (impact of high latency?)
  - Low earth orbit (LEO) megaconstellations
    (Starlink)
  - DSL and LTE as reference
- Test multiple applications and multiple providers



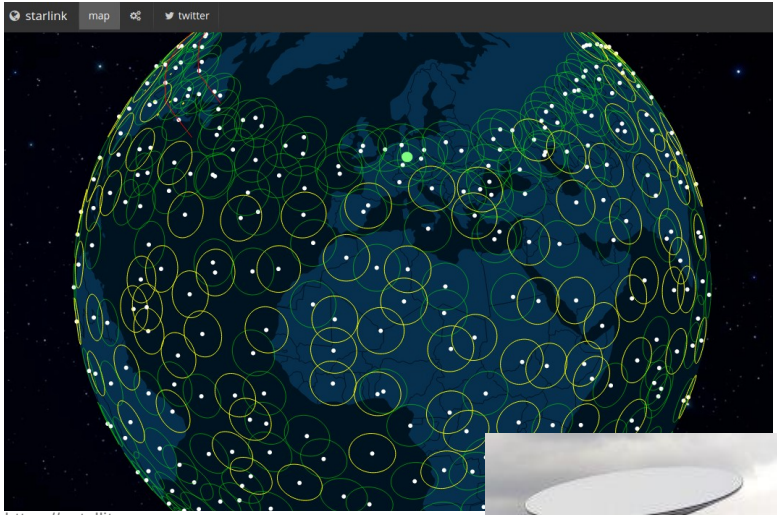
Basics – Internet via Satellite

Geostationary satellite with spot-beams and parabolic antenna



based on Google Maps and data adapted from
https://www.satsig.net/tooway/satellite-dish-pointing-ka-sat-tooway-europe.htm

Low earth orbit megaconstellation with phased array antenna



https://satellitemap.space

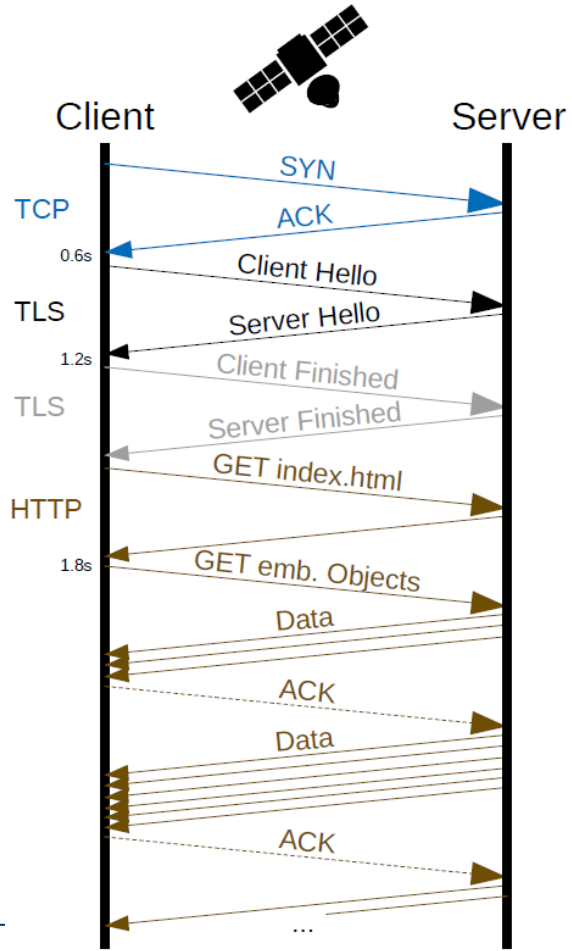
- Shared medium: users share resources/capacity
  (GEO, LEO, LTE, DOCSIS/cable)

Basics

- Real-time protocols (e.g., voice): UDP

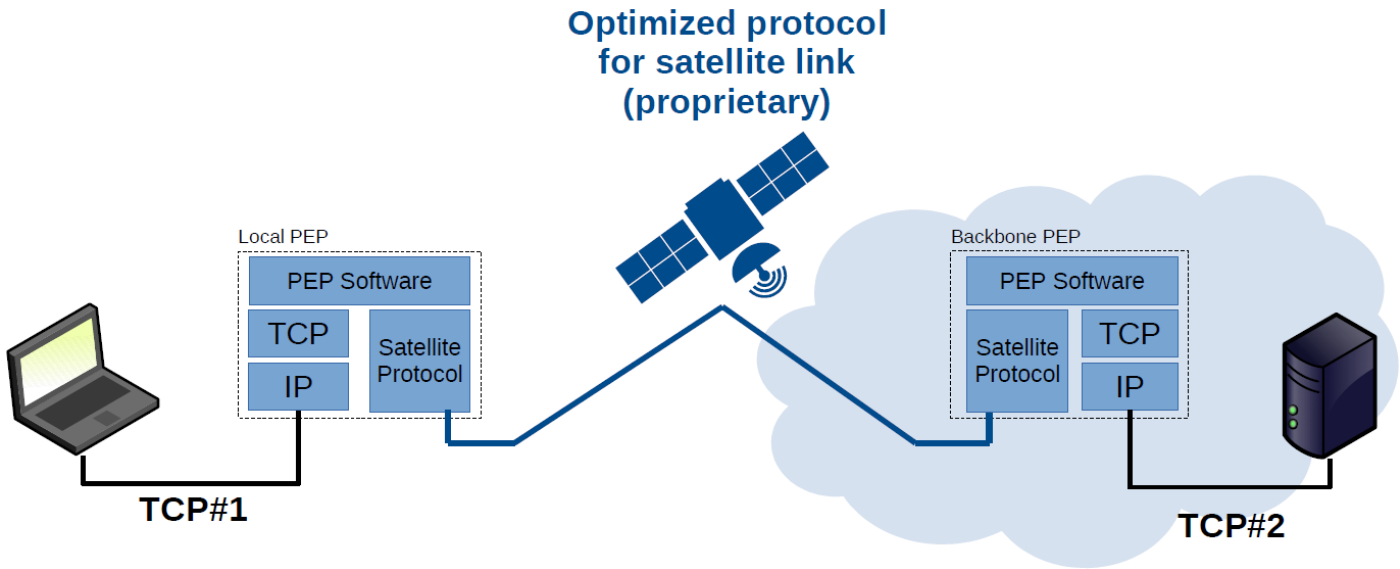
- Web protocols: HTTP/TLS/TCP
  - handshakes
  - flow and congestion control
    (slow start)
  - retransmissions and
    head-of-line blocking

  → multiple Round Trip Times (RTTs)
  (time from sender to receiver and back)



Basics

- Geostationary satellite networks:
  Performance Enhancing Proxies (PEPs)
  - improves TCP performance (Split TCP)
  - not applicable when typical VPN software (OpenVPN, Wireguard, IPsec, ...) is used
  - PEPs are a *necessary evil*

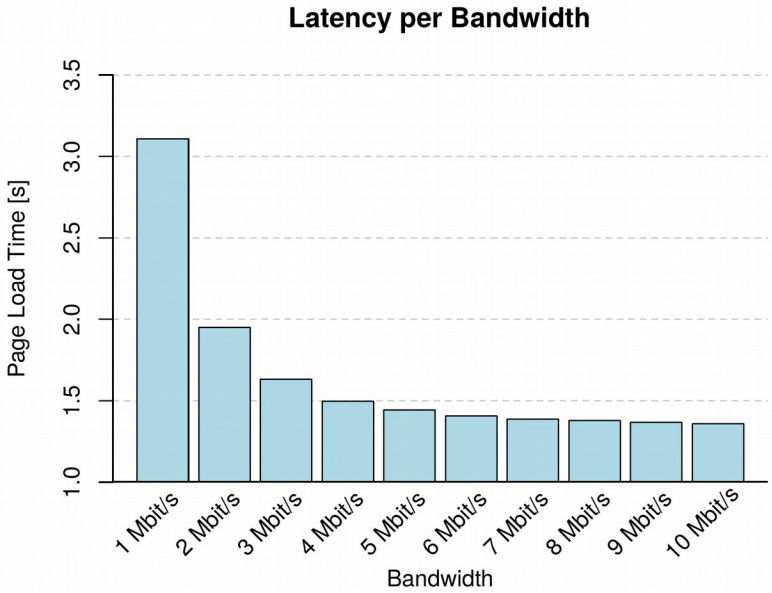


Basics (spoiler alert)

- Why more bandwidth doesn‘t matter (much)
  - Web browsing: Page Load Time

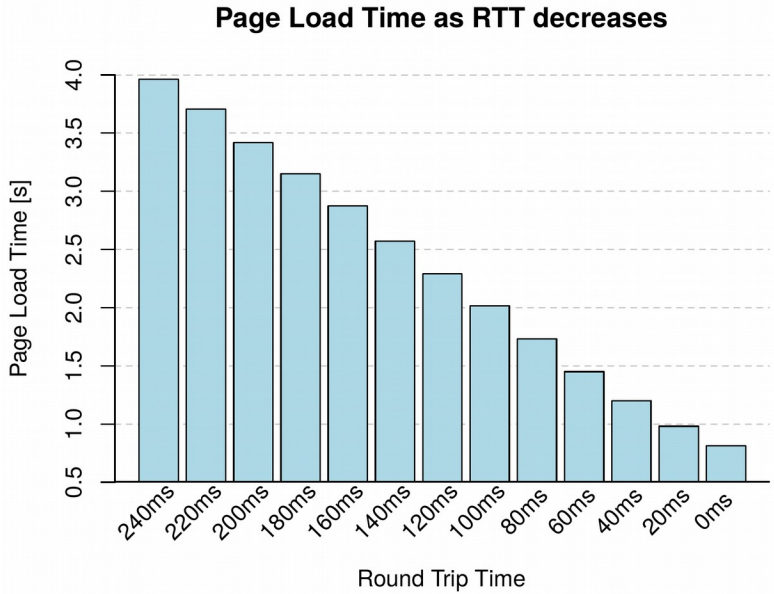
Mike Belshe, Google (2010)
www.belshe.com/2010/05/24/more-bandwidth-doesnt-matter-much

Test #1: Vary the Bandwidth



60ms RTT, 0% packet loss

Test #2: Vary the Round Trip Time



5 Mbit/s, 0% packet loss

Outline

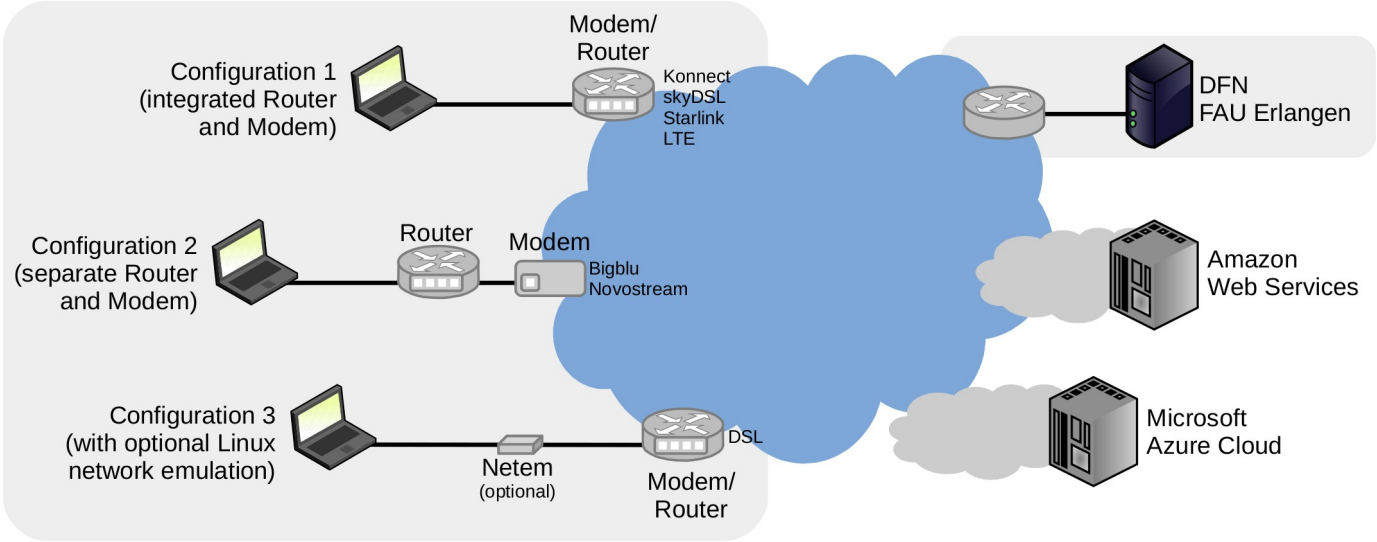
- Introduction
- Provider overview, Test setup, Test overview
- Evaluation of basic metrics
  - Latency (Round Trip Time)
  - Packet Loss
  - Data rate (Goodput)
- Evaluation of applications
  - Windows File Sharing
  - Web browsing
  - Video streaming
  - Voice over IP
- Summary and Outlook

Provider overview

Tech.	Shared Medium		Provider Service Level Agreement (SLA)	Download (= forward link)	Upload (= return link)
GEO	yes		Konnect Zen (Eutelsat Konnect) 7.2° East	50 Mbit/s	5 Mbit/s
			skyDSL2+ (Eutelsat KA-SAT) 9° East	50 Mbit/s	6 Mbit/s
			Bigblu Konnect Bronze DE (Eutelsat KA-SAT) 9° East	16 Mbit/s	3 Mbit/s
			Novostream Astra Connect L+ (Astra) 28.2° East	20 Mbit/s	2 Mbit/s
LEO	yes		SpaceX Starlink (Beta)	-	-
DSL	no		o2 DSL Max flat	50 Mbit/s	10 Mbit/s
LTE	yes		Congstar Homespot 100	50 Mbit/s	25 Mbit/s

Test setup

- Black-box testing
- Typical end-user topology
  - one computer per Internet access
    (hardware located at FAU Erlangen, Germany)
  - different servers to avoid backbone bottlenecks
    (one server located at FAU Erlangen plus two cloud services)



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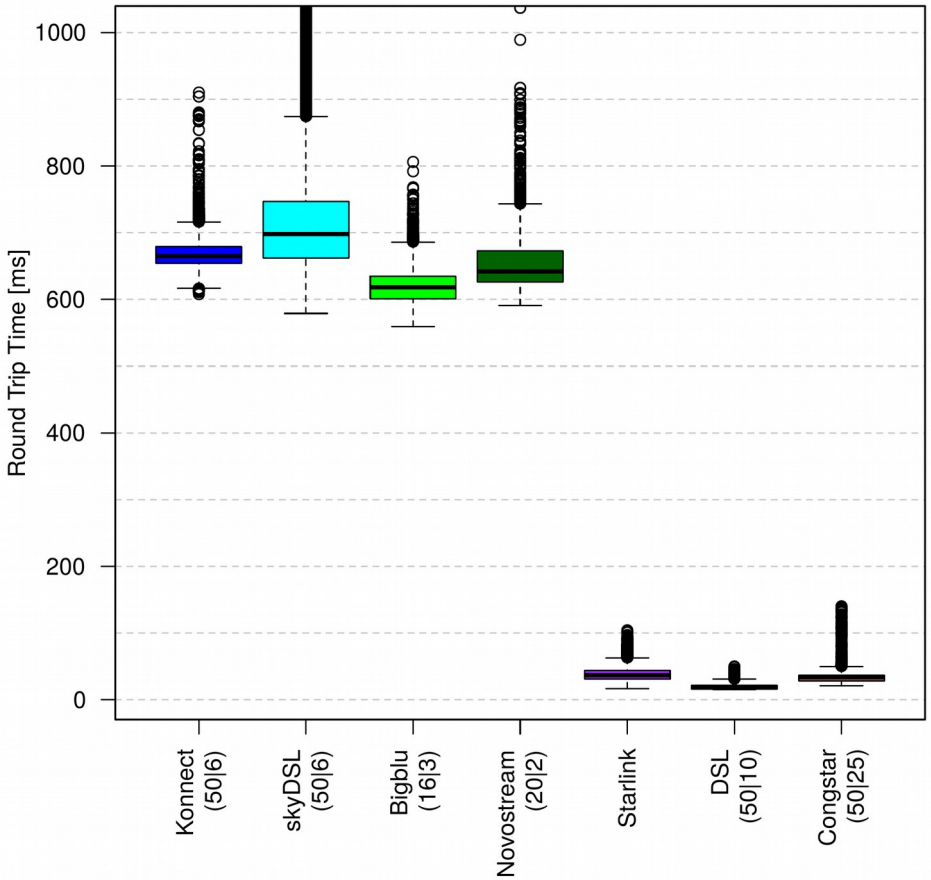
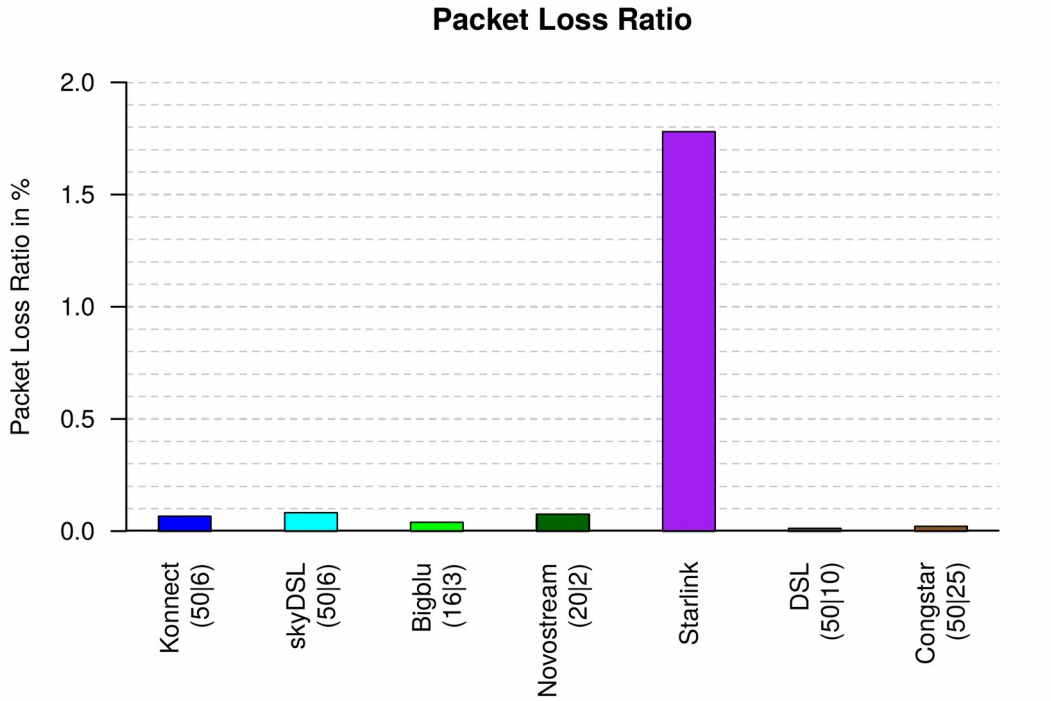
Round Trip Times (UDP packets with different sizes and send intervals)

- GEO: high latency and jitter
  (reason for jitter might be radio resource allocation and/or backbone network)
- Starlink comparable with terrestrial access links
- Differences between Starlink and terrestrial links not relevant for everyday use



Packet loss (UDP packets with different sizes and send intervals)

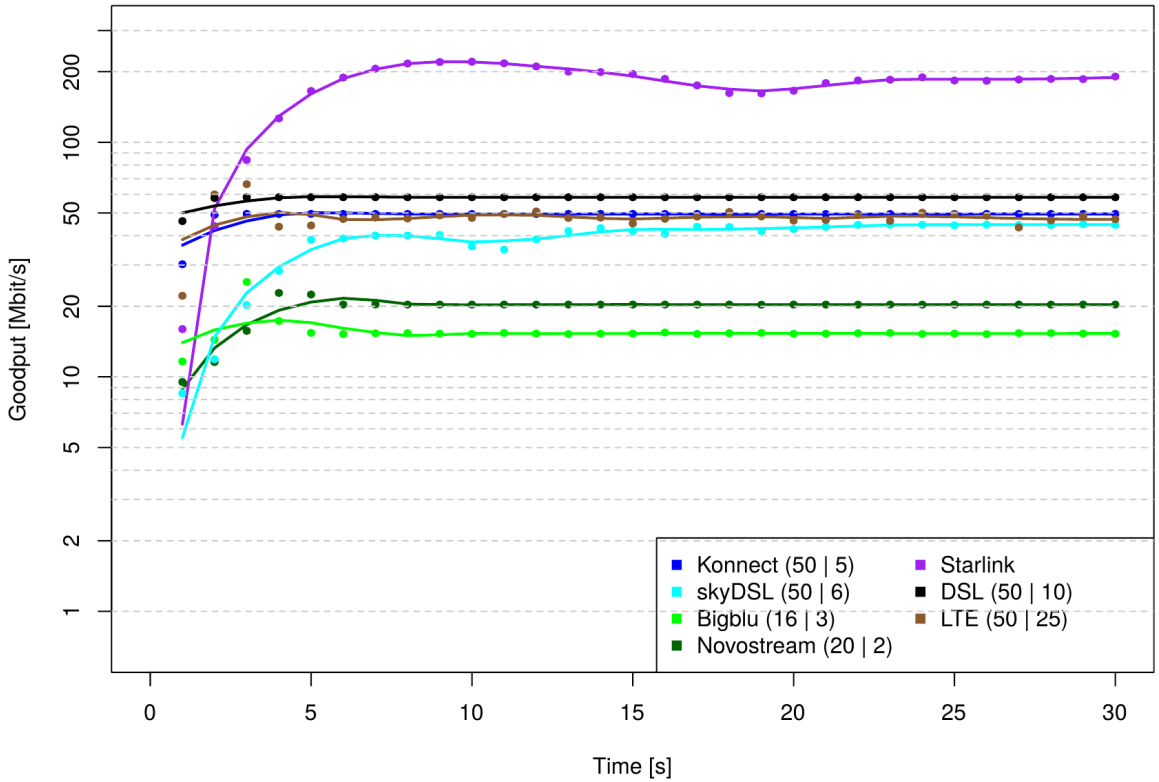
- Very low packet loss for GEO, DSL, and LTE
- Noticeable, but still acceptable packet loss with Starlink
  (needs further evaluation in future measurements)



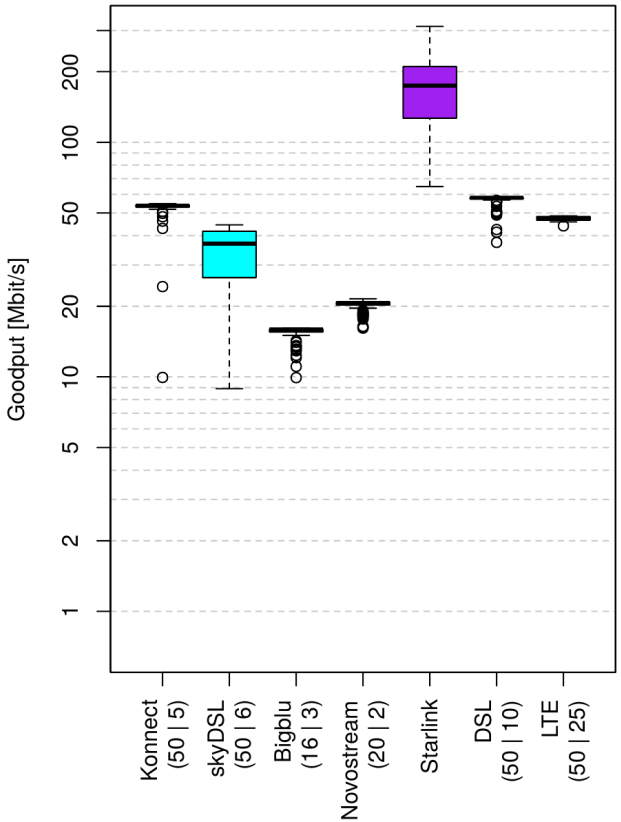
Bulk Data Transfer (iperf3, single flow, download, **without VPN**)

- How does a single TCP connection perform?

Download data rate in 1-second intervals, 100 iterations, without VPN



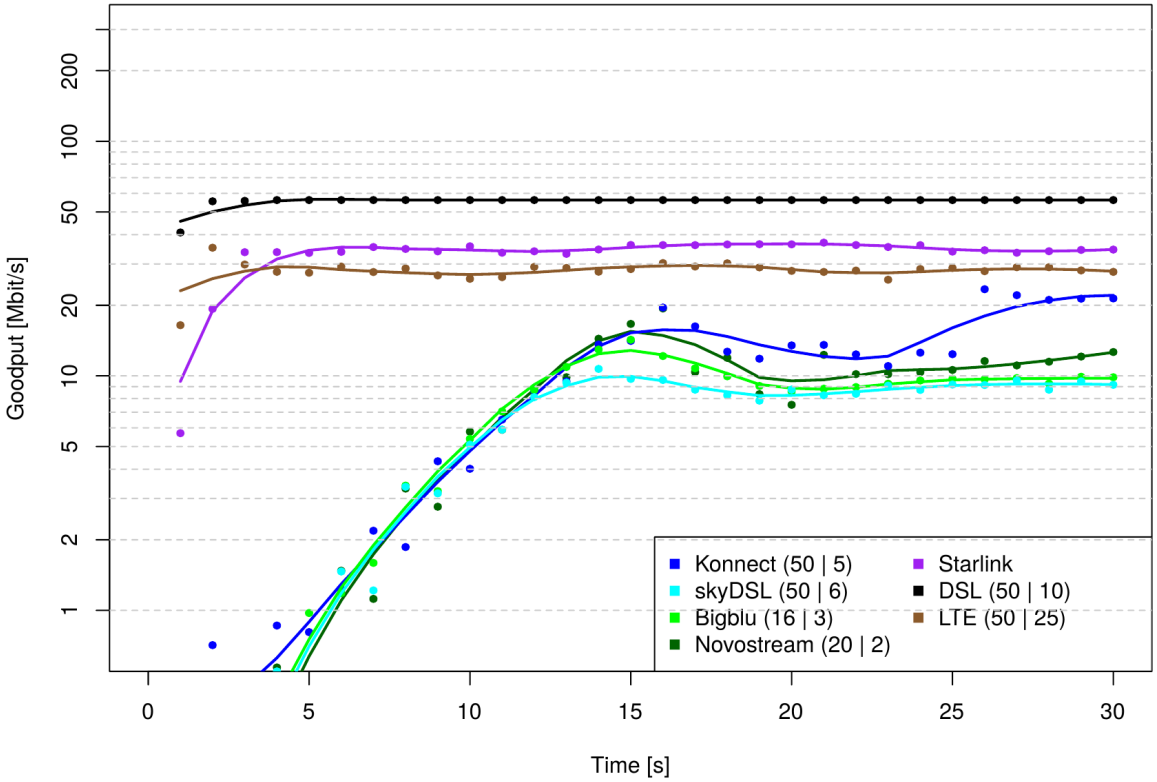
Overall data rate (0s to 30s)



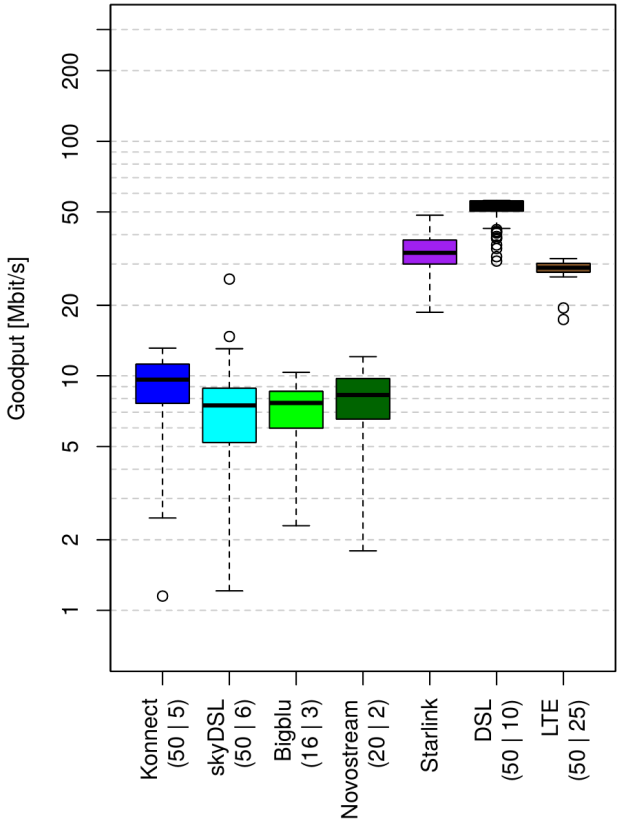
Bulk Data Transfer (iperf3, single flow, download, **with OpenVPN**)

- How does a single TCP connection perform?

Download data rate in 1-second intervals, 100 iterations, OpenVPN



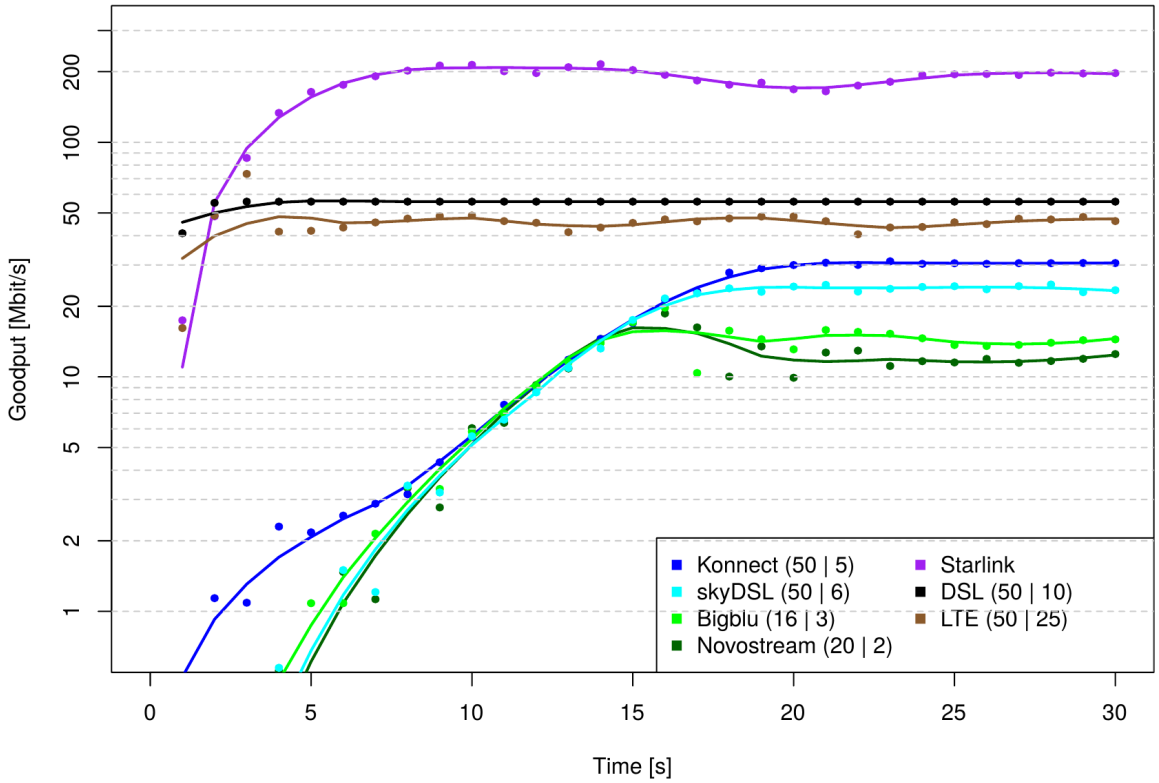
Overall data rate (0s to 30s)



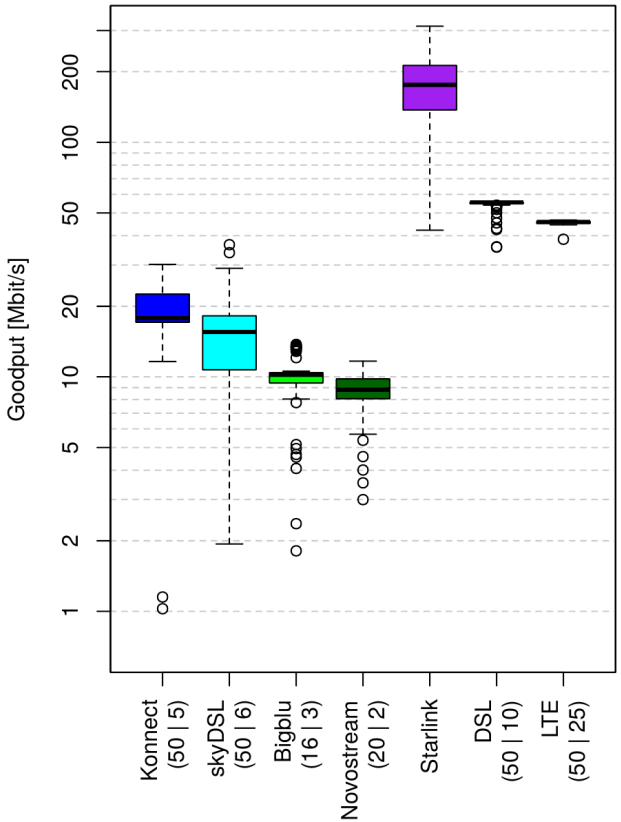
Bulk Data Transfer (`iperf3`, single flow, download, **with Wireguard**)

- How does a single TCP connection perform?

Download data rate in 1-second intervals, 100 iterations, Wireguard

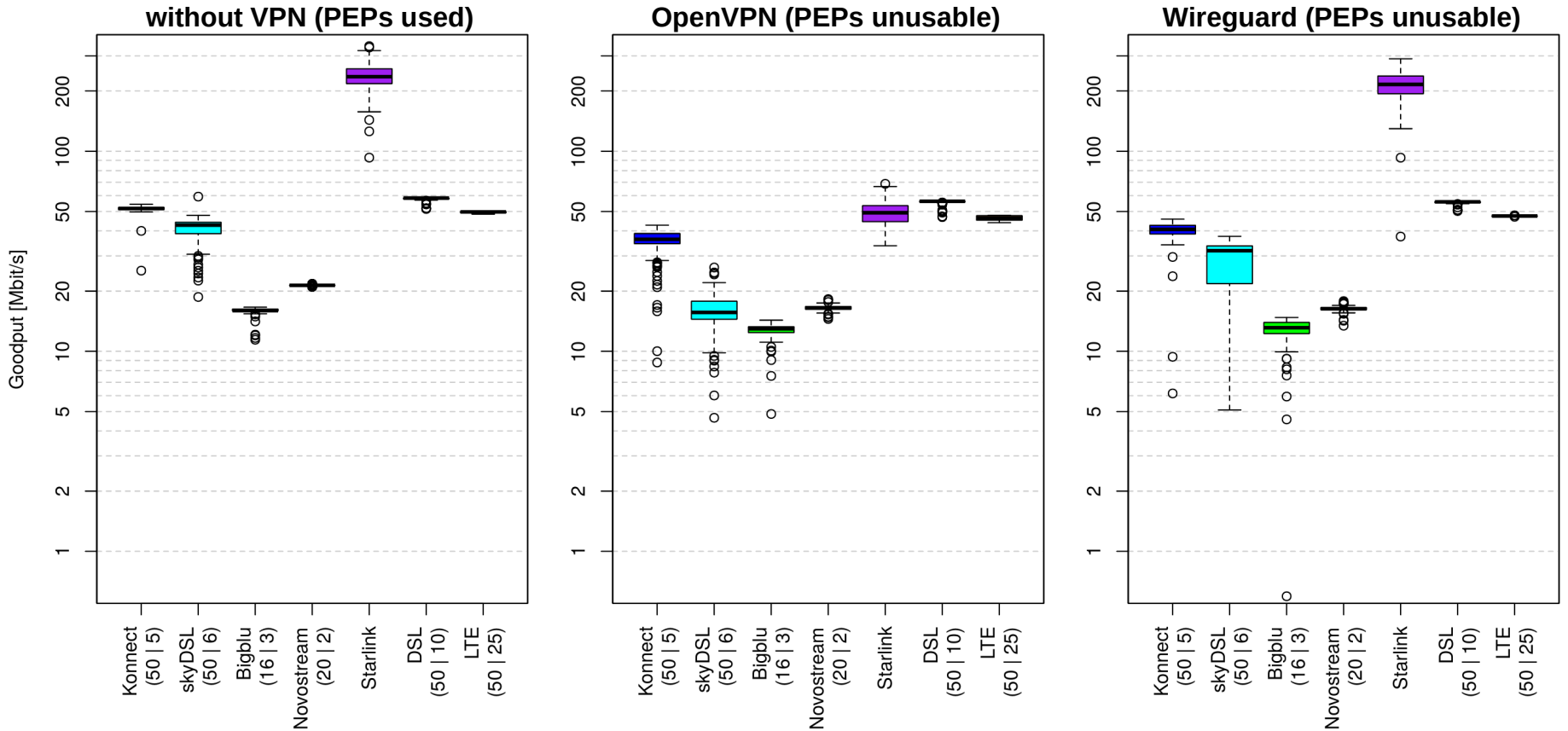


Overall data rate (0s to 30s)



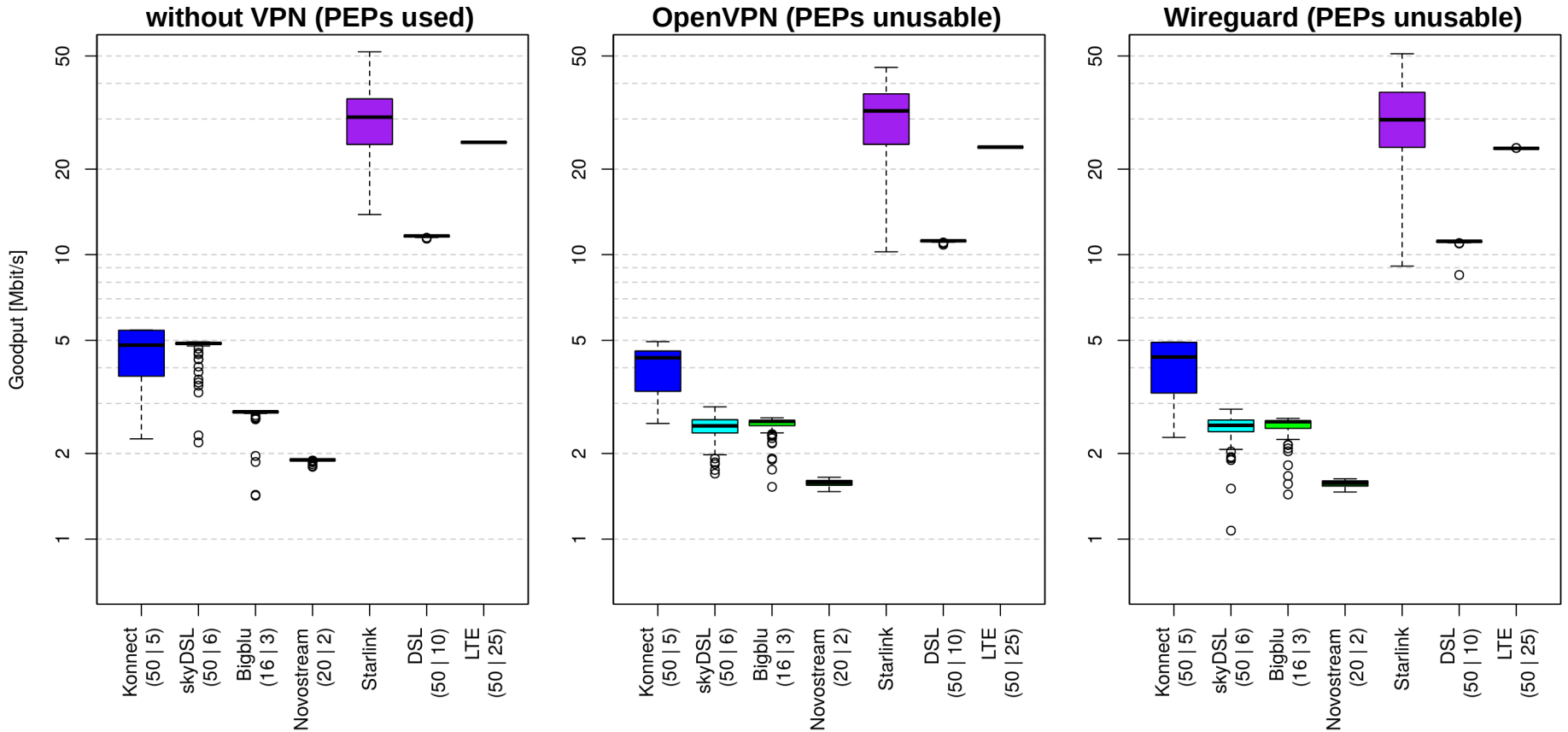
Bulk Data Transfer (`iperf3`, **10 flows**, **download**, overall data rate from 0s to 30s)

- How much can we get out of the access link?



Bulk Data Transfer (`iperf3`, **10 flows**, **upload**, overall data rate from 0s to 30s)

- How much can we get out of the access link?



Bulk Data Transfer – Summary

	download speeds	upload speeds	reaches adver-tised speeds	VPNs, single flow	VPNs, multiple flows
GEO	high	moderate	yes (with PEPs)	severe impact	some impact (still slow startup)
LEO DSL LTE	high	high	yes	little impact (except OpenVPN and high data rates)	little impact (except OpenVPN and high data rates)

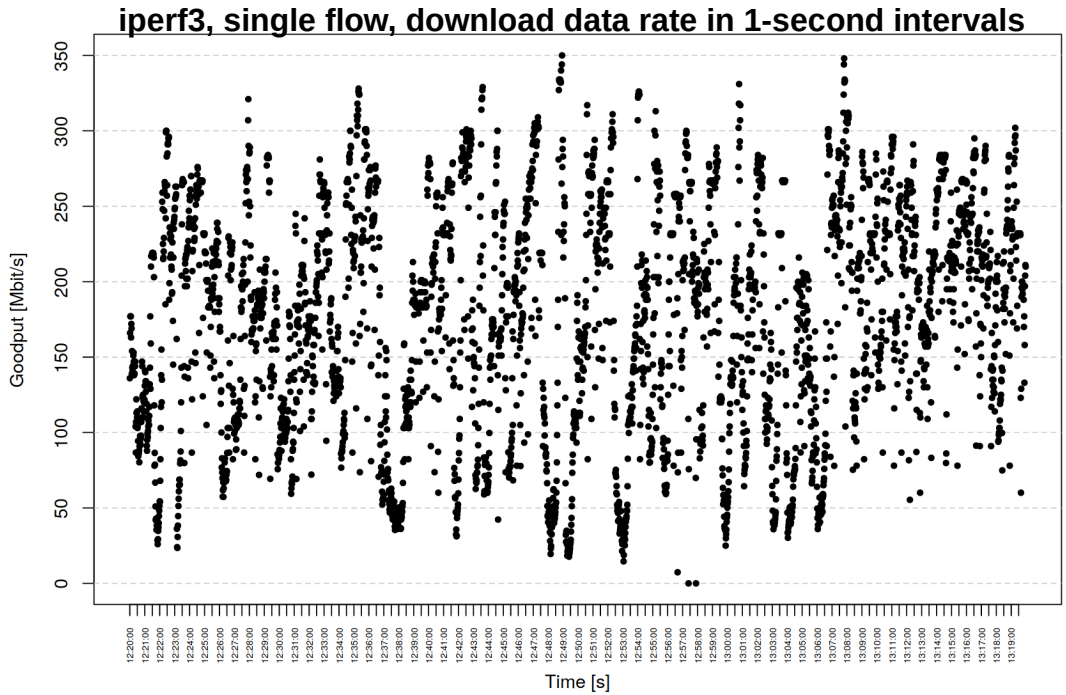
- Geostationary satellite Internet access and VPNs
  - PEPs are not applicable → poor TCP performance
  - Use higher-layer secure web protocols instead of VPNs?
- Starlink has high data rates and works well with VPNs
- Wireguard better than OpenVPN (especially for high data rates)

Time-dependent and weather-dependent performance

- GEO
  - Measurements in February 2021
    (skyDSL not yet included at that time)
    - heavy snowfall: outages with Konnect/Eutelsat and Novostream/Astra
    - reduced data rates at peak times (~7 p.m. to ~10 p.m.) with Bigblu/Eutelsat
  - No significant time-dependent performance issues in further measurements

Time-dependent and weather-dependent performance

- LEO Starlink (not available during winter season)
  - Thermal shutdown not observed (yet)
  - Varying data rates in general



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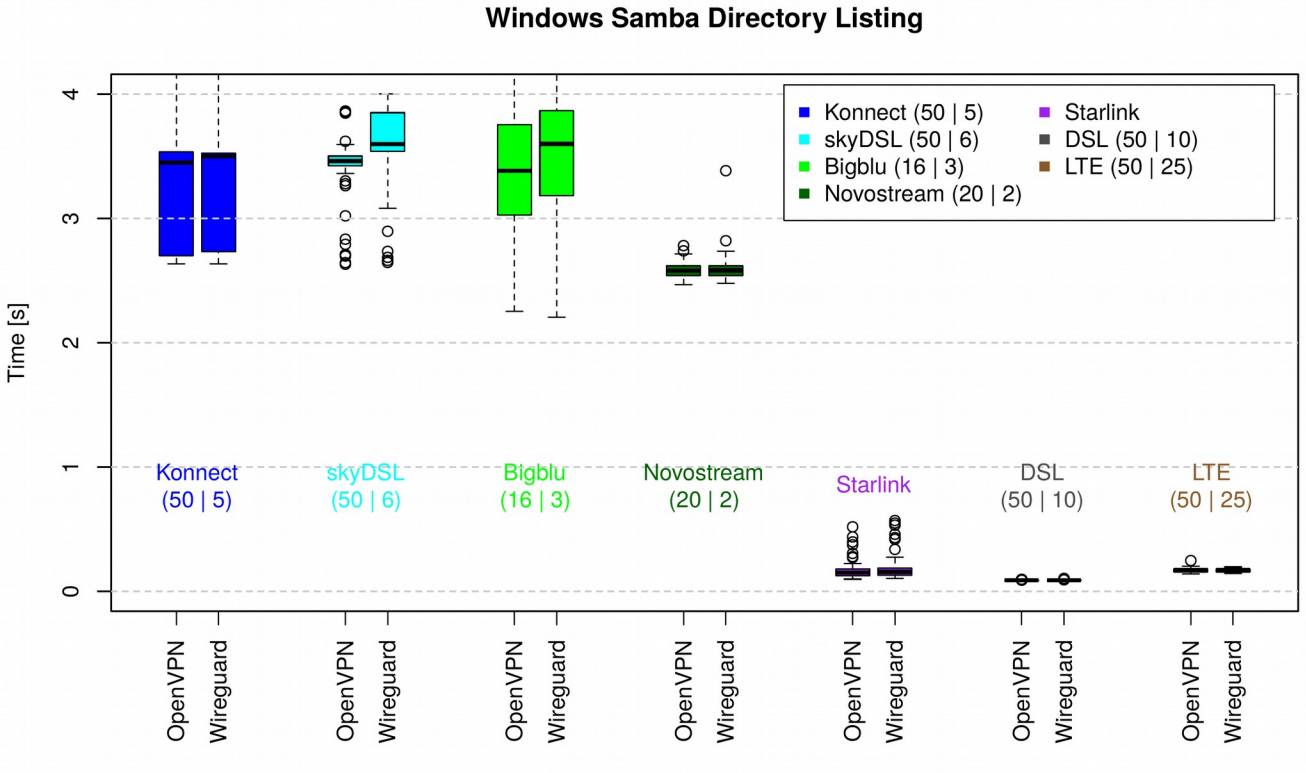
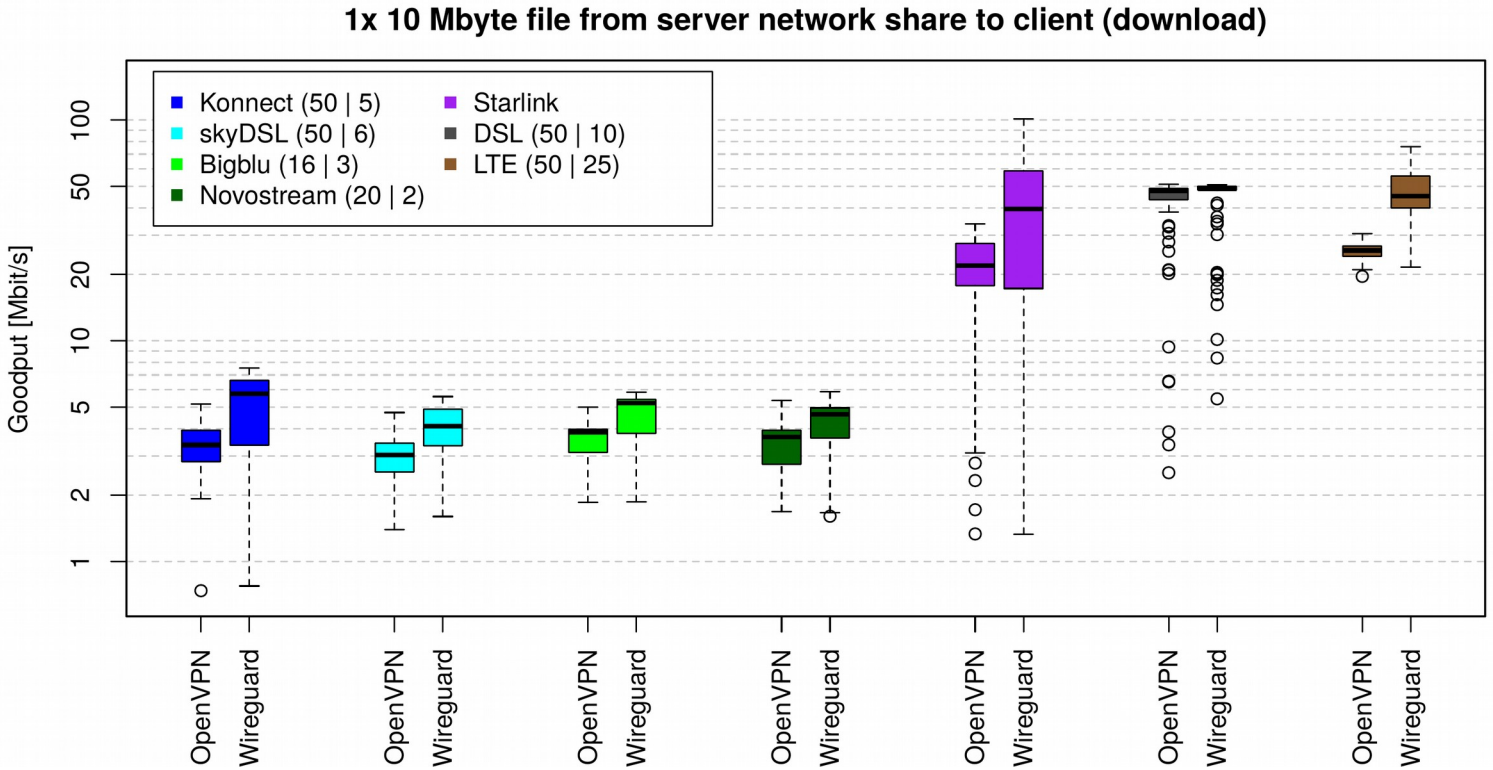
Windows File Sharing: Directory Listing

- How long does it take to open a directory on a network share?



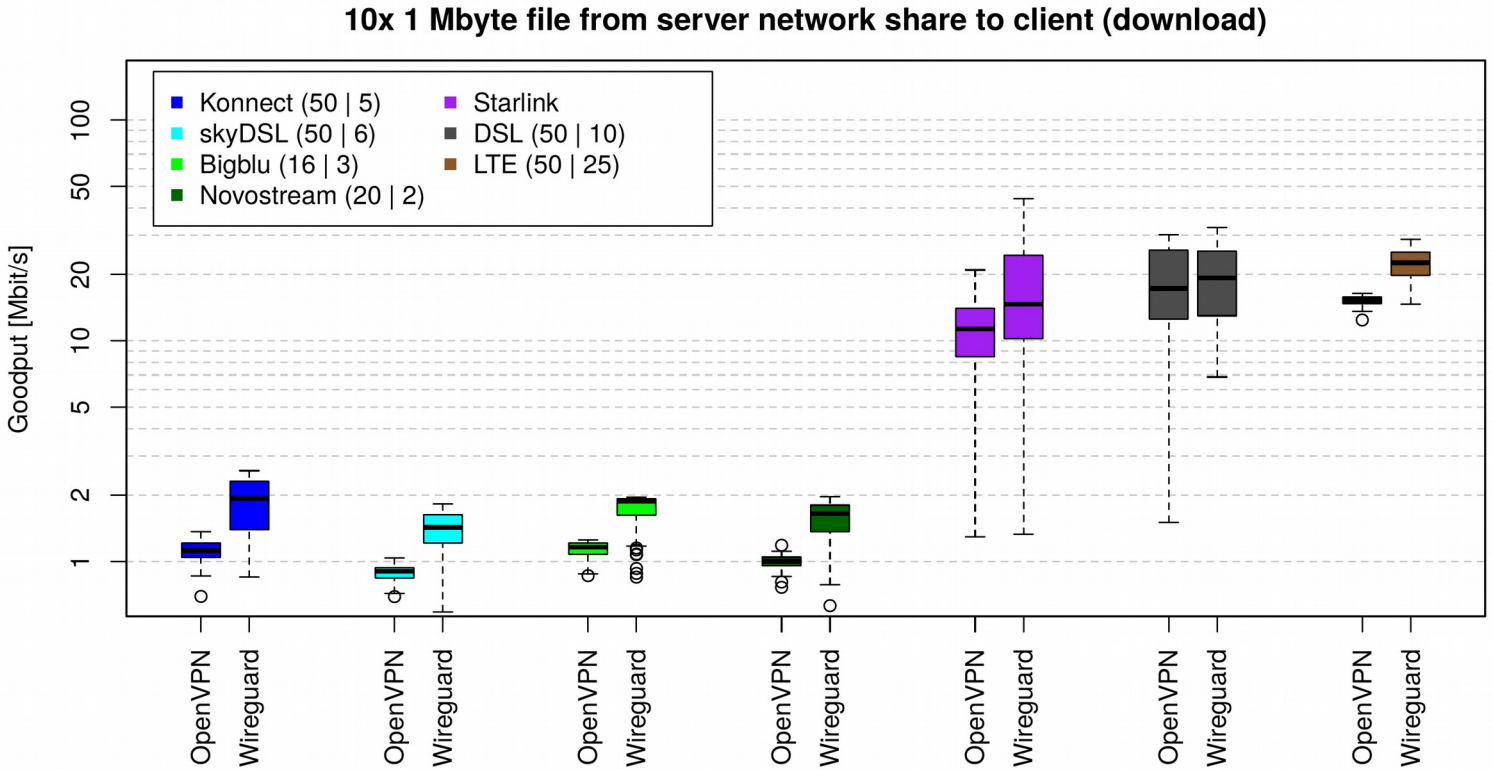
Windows File Sharing: File Copying

- How fast is a single large file copied?



Windows File Sharing: File Copying

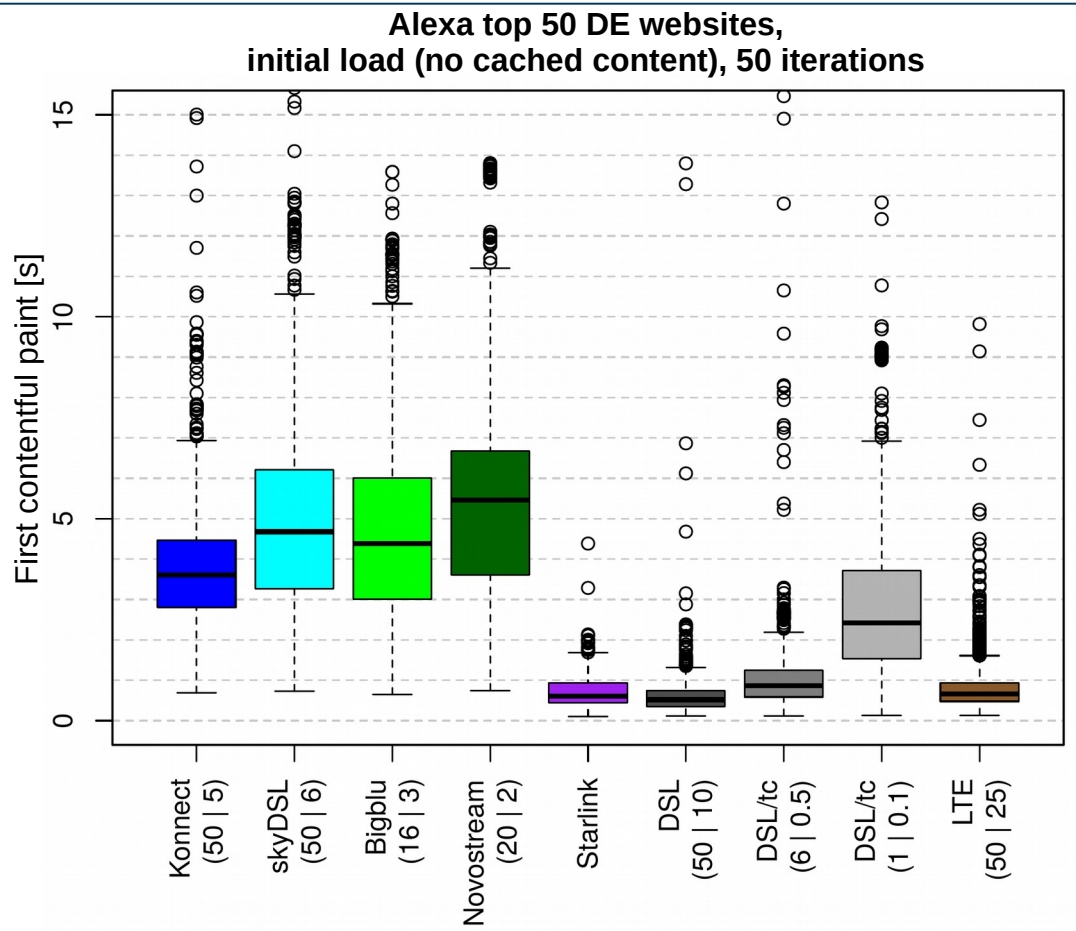
- How fast are multiple small files copied?
  (files are copied sequentially → additional RTTs)



Web browsing (`browsertime 11.6.1`)

Screencast
https://www7content.cs.fau.de/~deutschmann/eecc

- Two additional setups with throttled DSL
  (Linux tc network emulation)
  - 6 Mbit/s down, 0.5 Mbit/s up
  - 1 Mbit/s down, 0.1 Mbit/s up
- Metrics
  - First contentful paint
  - Visual complete 85%
  - Page Load Time



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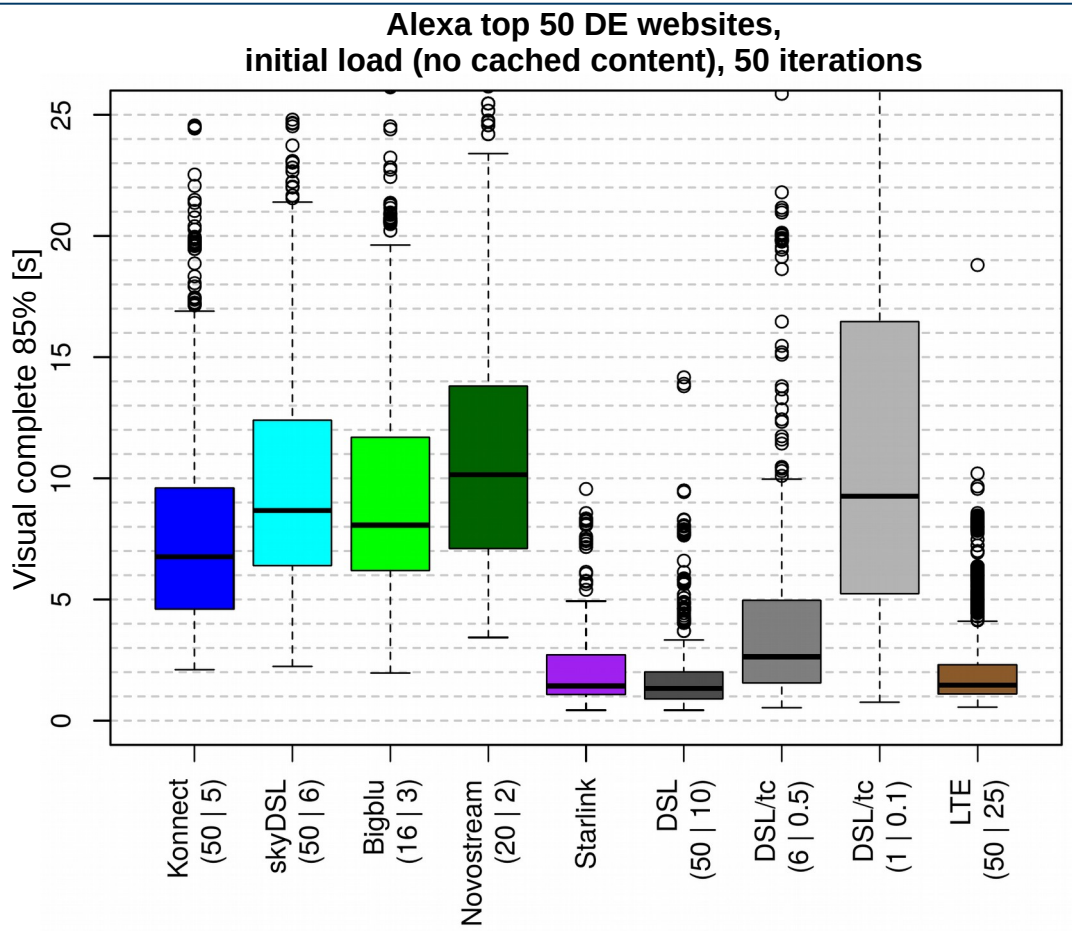

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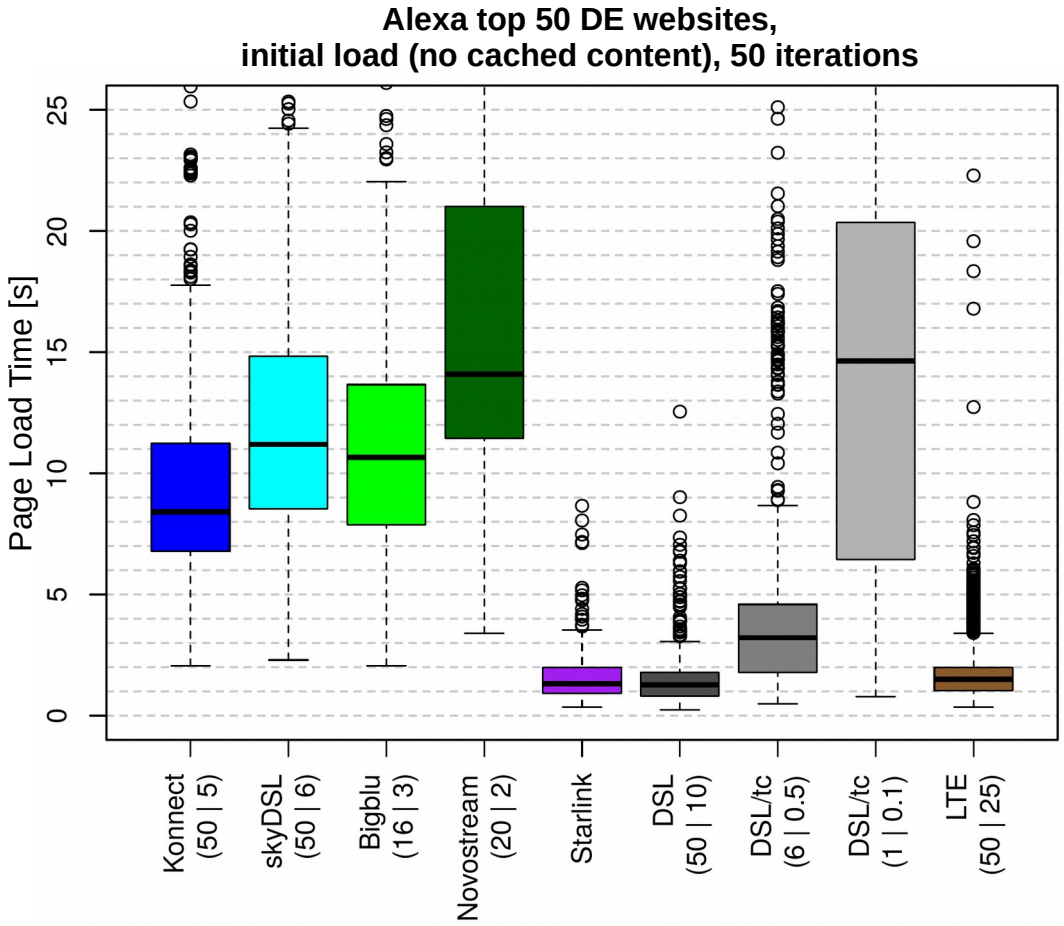

Further measurements (not shown in detail)

- HTTP File Download
  - results comparable to Bulk Data Transfer
- Video streaming (Youtube)

4K (3840x2160)	WQHD (2560x1440)
• skyDSL (50 | 6) • Novostream (20 | 2) • Starlink • DSL (50 | 10) • LTE (50 | 25)	• Konnect (50 | 5) • Bigblu (16 | 3)

- Novostream: barely achieves 4K streaming
- Konnect: data rate limitation for chosen SLA
- Bigblu: 16 Mbit/s insufficient for 4K streaming

- Voice over IP
  - connection setup time comparable to Round Trip Times
  - very good speech quality, packet loss has almost no impact
    (Mean Opinion Score obtained with ViSQOL)
  - impact of delay on Quality of Experience not quantifiable
    (according to ITU-T Recommendation G.114 delays between 300ms and 400ms results in *some users dissatisfied*)

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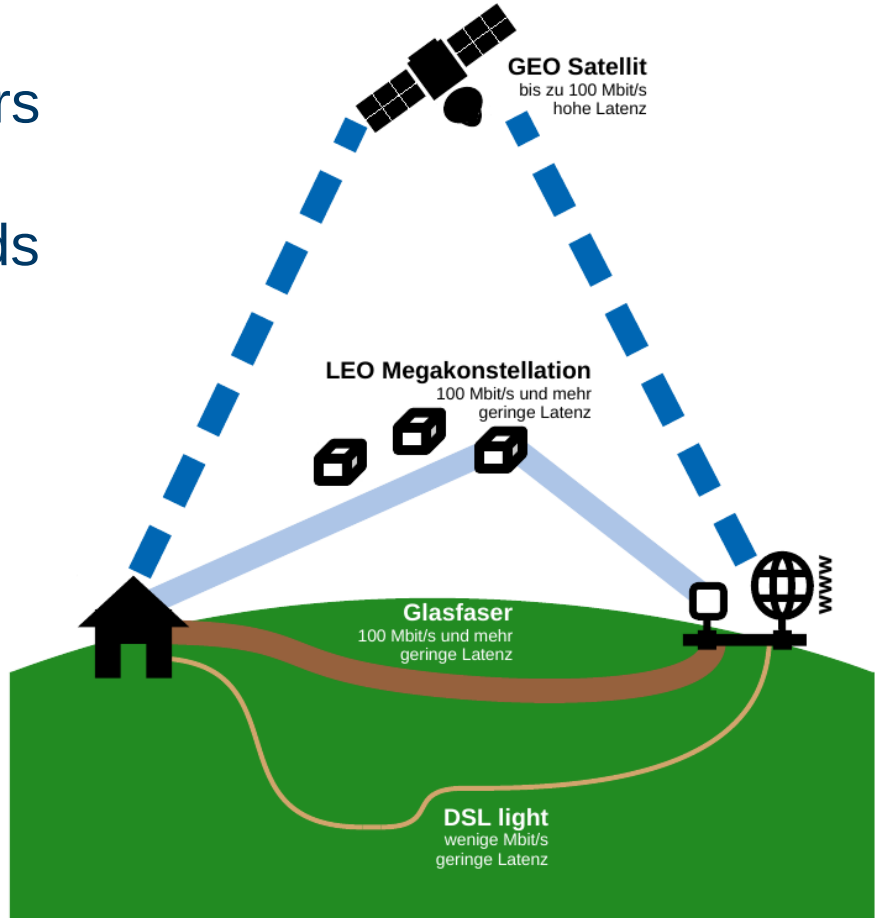
Summary

- Evaluation of multiple applications and multiple providers
- Geostationary satellites
  - impact of high latency depends on application
    (VPNs being problematic)
- Starlink with high data rates and low latency
  - comparable to terrestrial Internet access links
  - long-term evaluation required
    https://starlinkstatus.space



Summary

- Rating of access technologies based on QoS results

	Data rate download	Data rate upload	Latency	Web browsing	Voice, Video conf.	File download	Video streaming	Home office VPN
GEO	●●●○	●●○○	●○○○	●●◐○	●●◐○	●●●○	●●●◐	●◐○○
LEO	●●●◐	●●●○	●●●○	●●●◐	●●●◐	●●●◐	●●●◐	●●●◐
Fiber	●●●●	●●●●	●●●●	●●●●	●●●●	●●●●	●●●●	●●●●
slow DSL	●○○○	●○○○	●●●○	●○○○	●●○○	●○○○	●○○○	●○○○

Outlook

- Further evaluations
  - more detailed evaluation of individual applications
  - evaluation of video conferencing (no out of the box tools)
  - long-term measurements (especially LEO megaconstellations)
- New protocol developments: QUIC – RFC 9000 (May 2021)
  - novel transport layer protocol supported by major Internet technology companies (Google, Facebook, Mozilla, CDNs, ...)
  - encrypted transport layer headers
    → PEPs cannot be applied anymore (as with VPNs)
  - for GEO both a problem (PEPs not applicable, performance degradation) and a chance (PEPs not needed, new features like 0-RTT)

Literature

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