ITU Asia-Pacific CoE Training

Broadband Quality of Service - End User Experience

Sessions 10&11: Implementing End User Broadband Quality of Service

27-30 October, 2015

Bangkok, Thailand

- Objective: This Session will present practical case studies on broadband quality of service implementation for service providers and / or regulators

Current Issues

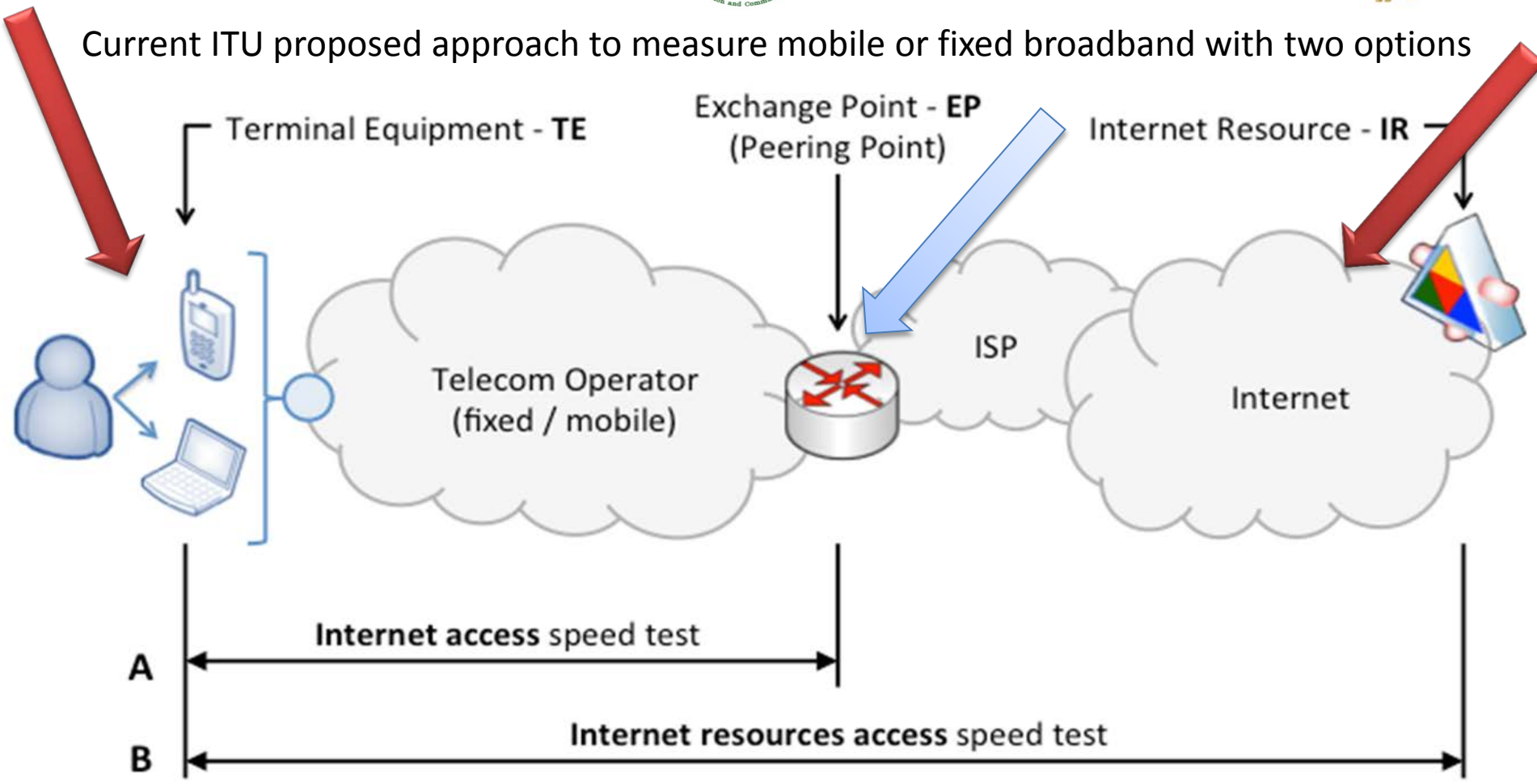
- lack of standardized measurement framework
  - test results achieved by one method vary from results achieved by another method
- lack of standardized measurement procedure
  - random measurements can be used during testing
  - the testing algorithm is not specified
- insufficient accuracy
  - some of existing methods make several attempts at different times of measurement
  - the measurement time period is not specified
  - busy-hour are excluded
- different approaches for collecting testing results
  - processing of measured values assumes dropping some measurement results (sometimes up to 40%)

Best Practice

- Measurement approaches are categorized as follows:

- End-user Application Measurement (EAM)
  - Daily use of an end-user's computer or mobile phone is employed for measurement with an application or browser under the user's control
- End-user Device Measurement (EDM)
  - Tests are done by specific devices which are installed by end users for measurement, but they are separated from the daily use of computers and mobile phones thus controlled remotely by the project, and
- Project Self Measurement (PSM)
  - The project itself installs or allocates and controls a device or computer to do tests.

Current ITU proposed approach to measure mobile or fixed broadband with two options

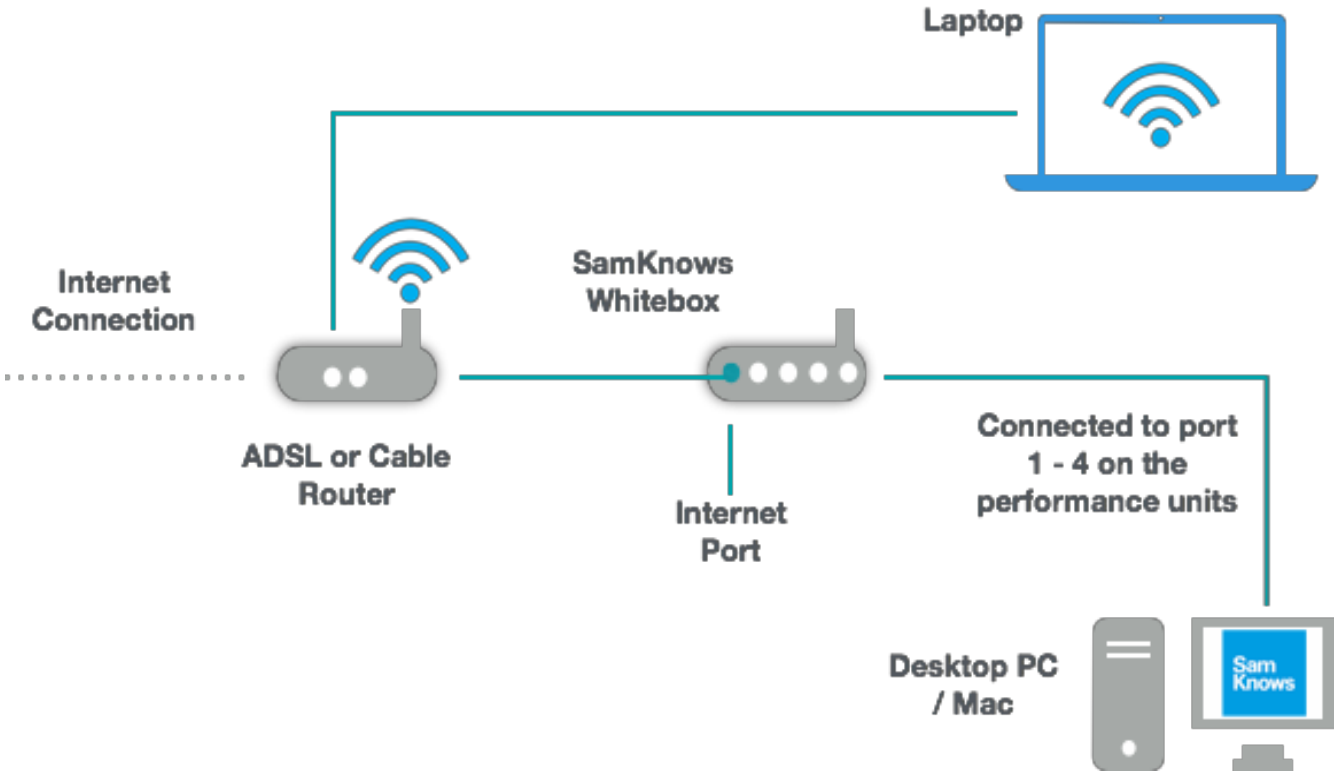


http://www.itu.int/en/ITU-T/C-I/Pages/IM/Internet-speed.aspx

Quality of Broadband Services in the EU

- Report October 2014
- xDSL, FTTx, Cable
- SamKnows
  - “Whiteboxes”
- 3G, LTE not investigated

SamKnows probe location



- In terms of tests, SamKnows monitors the following indicators in this study:
  - Web browsing
  - Voice over IP
  - Download speed
  - Upload speed
  - UDP latency
  - UDP packet loss
  - DNS resolution
  - Video streaming

- The SamKnows Performance monitoring framework is a distributed network of Whiteboxes in actual consumers' homes, and is used to accurately measure the performance of fixed line broadband connections based on real-world usage.
- These are controlled by a cluster of servers, which host the test scheduler and the reporting database. The data is collated on the reporting platform and accessed via a reporting interface and secure FTP. The framework also includes a series of speed-test servers, which the nodes call upon according to the test schedule.

SamKnows Technical Objectives	SamKnows Solution
1. Must not change during the Monitoring Period.	The pulling data process is automatic and consistent throughout the monitoring period.
2. Must be accurate and reliable.	Based on independent testing, the hardware solution is reliable.
3. Must not interrupt or unduly degrade the consumer's use of their broadband connection.	The volume of data does not interfere with the broadband experience as tests are not run when a panelist is using their connection.
4. Must not allow collected data to be distorted by any use of the broadband connection by other applications on the host PC and other devices in the home.	The hardware solution does not interfere with the PC and is not dependent on PC. Its only dependence is that the router needs to be switched on as well as the Whitebox.
5. Must not rely on the knowledge, skills and participation of the consumer for its ongoing operation once installed.	The Whitebox is "plug-and-play".
6. Must not collect data that might be deemed personal to the consumer without their consent.	The consent of the consumer regarding the use of their personal data as required by relevant legislation.
7. Must be easy for a consumer to completely remove any hardware and/or software components of the solution if they do not wish to continue with the research programme.	The hardware solution can be disconnected at any time from the home router. As soon as the router is reconnected the connection is resumed as before.
8. Must be compatible with a wide range of xDSL and DOCSIS modems.	The hardware solution can be connected to any router with Ethernet ports.
9. Where applicable, must be compatible with a range of computer operating systems, including but not limited to, Windows XP, Windows Vista, Windows 7, Mac OS and Linux.	The hardware solution is independent of PC operating system and therefore includes all current market standards.

SamKnows Technical Objectives	SamKnows Solution
10. Must not expose the consumer's PC to increased security risk, i.e., it should not be susceptible to viruses, it should not degrade the effectiveness of the user's existing firewalls, anti virus and spyware software etc.	Most user firewalls, antivirus and spyware systems are PC based. The hardware solution is plugged in before the PC. Its activity is transparent and does not interfere with those protections.
11. Must be upgradeable from the remote control centre if it contains any software or firmware components.	The Whiteboxes are controlled centrally for updates without involvement of the consumer PC, providing the Whitebox is switched on and connected.
12. Must be removable from the remote control centre if it is a software only solution.	N/A, the Whitebox is hardware- based.
13. Must identify when a user changes broadband provider or package (e.g. by a reverse look up of the consumer's IP address to check provider, and by capturing changes in modem connection speed to identify changes in package).	Regular monitoring of any changes in speed, ISP, IP address or performance. Should a consumer change package, they will be invited to notify us of the change or confirm that no change took place since the last report.
14. Must permit, in the event of a merger between ISPs, separate analysis of the customers of each of the merged ISP's predecessors.	Data is stored based on the ISP of the panelist, and can therefore be analyzed individually or as a whole.
15. Must identify if the consumer's computer is being used on a number of different networks (e.g., if it's a laptop).	The Whitebox is not PC or laptop dependent, but is broadband connection dependent.
16. Must identify when a specific household stops providing data.	The Whitebox needs to be connected and switched on to pull data. If it is switched off or disconnected its absence is detected at the next data pull process.

SamKnows Technical Objectives	SamKnows Solution
17. Must not require an amount of data to be downloaded which may materially impact on any data caps or fair usage policy the ISP has imposed on the end user, or trigger traffic shaping policies to be implemented by the ISP.	The data volume generated by the information collected does not exceed any policies set by ISPs. Panelists with bandwidth restrictions can have their tests set accordingly.
18. Must ensure that its tests are run in a manner which does not make it possible for ISPs to identify the broadband connections which form their Panel and therefore potentially enable ISPs to "game" the data by providing a different quality of service to the Panel members and the wider customer base.	The data packet profile is not identifiable unless it is subject to a DPI process that specifically looks for these profiles. This can only be done if the ISPs are aware of the profile of the data and if the ISP has a level of resources sufficient to monitor its entire customer base.
19. Must be consistent and adhere to all relevant standards for internet measurement.	The measurement platform is being used as the basis for the development of global standards.
20. The solution must be sufficiently scalable to become a global measurement platform.	The performance measurement platform has been designed to be a global platform that can scale to many millions of customers.

Fixed broadband hardware probes

- SamKnows uses hardware probes (Whiteboxes) for the purpose of accurately measuring end-user broadband performance. For this study, there are two types of probes, subject to the achievable speed of the internet connection.
- The Whiteboxes execute a series of software tests over the broadband connection they are connected to. The results of these tests are reported securely up to hosted backend infrastructure.
- The majority of tests run against a network of test nodes. These are dedicated servers either "on-net" (on the local ISP's network) or "off-net" (on the public internet). Some tests will execute against real applications hosted on the internet, mimicking their behaviour and measuring key performance variables.

Fixed broadband hardware probes

- When a testing cycle has completed, the results are encrypted and transmitted over SSL to hosted backend infrastructure for processing and presentation through a web interface to each panellist and other interested parties.
- Panellists are, as part of the terms of service, required to leave their Whitebox and other networking equipment permanently powered on and connected to ensure consistent testing.
- All SamKnows Whiteboxes run a custom distribution of Linux, derived from OpenWrt. Many standard OpenWrt features have been removed to save space on the device, and some additional features have been added to support the measurements.

Fixed broadband hardware probes

- The custom firmware is flashed at the factory and is not directly upgradeable by the user hosting the Whitebox. The firmware is remotely upgradeable by SamKnows.
- This cut-down operating system provides network connectivity and the measurement applications alone – there is no web interface and the Whitebox provides no routing functionality. Panellists have no ability to disable, reconfigure or influence the SamKnows software in any way through normal usage.
- SamKnows' firmware makes use of GPL v2.0 licenced code. The source code for SamKnows' firmware build is available at: https://files.samknows.com/~gpl/

Fixed broadband hardware probes

- All communications between the Whitebox and the Data Collection Service on the backend hosted infrastructure are initiated by the Whitebox, encrypted over SSL and subject to authentication
- The Whitebox communicates with the target test nodes over a variety of TCP and UDP ports. The Whitebox will also communicate with some unmanaged services over both TCP and UDP.
- The SamKnows software suite has the ability to auto-update itself, downloading updated binaries and testing schedules from the Data Collection Service and storing locally in RAM or flash

- **Determining the best measurement server**
  - Upon start up, the application runs a brief latency measurement to all measurement servers hosted by SamKnows. This process allows us to determine the nearest measurement server (in terms of latency) The measurement server with the lowest round-trip latency is selected as the target for all subsequent measurements (throughput, latency and packet loss).
  - Additionally, if the ISP has installed ‘“on-net”’ measurement servers within their network then the application will also select the nearest one of these servers.
  - Measurements are run against both the “on-net” and off-net servers.

- **Cross-traffic, in-home network issues and configuration differences**
  - One of the key advantages of the hardware-based Whitebox is its ability to detect cross-traffic and defer tests. Furthermore, its position within the home network (connected directly to the modem or gateway) means that it is unaffected by in-home network issues (such as those caused by wireless networks).

- A purely software-based approach is not able to account for such issues. However, we can apply a number of mechanisms in an attempt to reduce or detect their impact.
- Cross-traffic within the local client (e.g. PC) is measured and tests will not be executed if the client is transferring more than 64kbit/s.
- Additionally, the web-based test will poll the user's gateway via UPnP for traffic counters. This allows for cross-traffic within the home to be fully accounted for, and measurements will not be executed if the gateway is transferring more than 64kbit/s. However, this UPnP-based approach is far from universally supported. A recent study (February 2012) showed that approximately 22% of gateways in Europe supported traffic counter reporting by UPnP, but this figure is expected to rise.

- In-home network issues (such as poor wireless) cannot be excluded by the web-based test. However, we can attempt to identify them. In particular, the web-based test records the connection media used by the client and its connected speed (e.g. Ethernet at 100Mbps, or Wireless at 54Mbps). Additionally, the web-based test will also run a brief ICMP latency and packet loss measurement to the user's gateway. If this reports more than 2ms latency and 0% packet loss, then the measurements are aborted with a message stating that the user's in-home network appears to be operating poorly.
- Client configuration issues (such as insufficient TCP settings, firewall products, RAM or CPU) are checked for before measurements begin. If these fall outside of accepted bounds then the tests are aborted and the user is informed.
- In all of the error conditions above the user will be informed of the reason why the measurements were not executed. The user may override the failure and run the measurements anyway, but the results will be recorded on the server side with a 'tainted' flag indicating that they were not run under optimal conditions.

- **A comprehensive measurement suite**
  - The SamKnows methodology and platform has been designed to be flexible enough to allow for whatever future modifications or enhancements are required, but at the same time the ‘out of the box’ solution provides a fully inclusive package of every available performance measurement test. The table below details the tests included in the study:

Metric	Primary measure(s)
Web browsing	The total time taken to fetch a page and all of its resources from a popular website
Voice over IP	Upstream packet loss, downstream packet loss, upstream jitter, downstream jitter, round trip latency
Download speed	Throughput in Megabits per second utilising three concurrent TCP (Transmission Control Protocol) connections
Upload speed	Throughput in Megabits per second utilising three concurrent TCP connections
UDP (User Datagram Protocol) latency	Average round trip time of a series of randomly transmitted UDP packets
UDP packet loss	Percentage of UDP packets lost from latency test
DNS (Domain Name Server) resolution	The time taken for the ISP's recursive DNS resolver to return an A record for a popular website domain name

Testing Schedule for Europe (Fixed)

Test Name	Test Target(s)	Test Frequency	Test Duration	Est. Daily Volume
Web browsing	3 popular websites	Hourly, 24x7	Est. 3 seconds	8.4MB
Voice over IP	1 off-net test node	Every other hour, 24x7	Fixed 10 seconds at 64k	1.92MB
Download speed	1 off-net test node	Once 12am-6am Once 6am-12pm Once 12pm-6pm Every hour 6pm-12am	<30Mbps = 6MB 30-50Mbps = 12MB file size >50Mbps = 10 seconds duration	54MB 108MB >~540MB
Upload speed	1 off-net test node	Once 12am-6pm Once 6am-12pm Once 12pm-6pm Once 6pm-12pm	<10Mbps = 3MB fixed size 10-20Mbps = 6MB >20Mbps = 10 seconds duration	18MB 36MB >~216MB
UDP latency	1 off-net test node	Hourly, 24x7	Permanent	1MB
UDP packet loss	1 off-net test node	Hourly, 24x7	Permanent	N/A (uses above)
DNS resolution	3 popular websites	Hourly, 24x7	Est. 1 second	0.1MB

Scenario Matrix

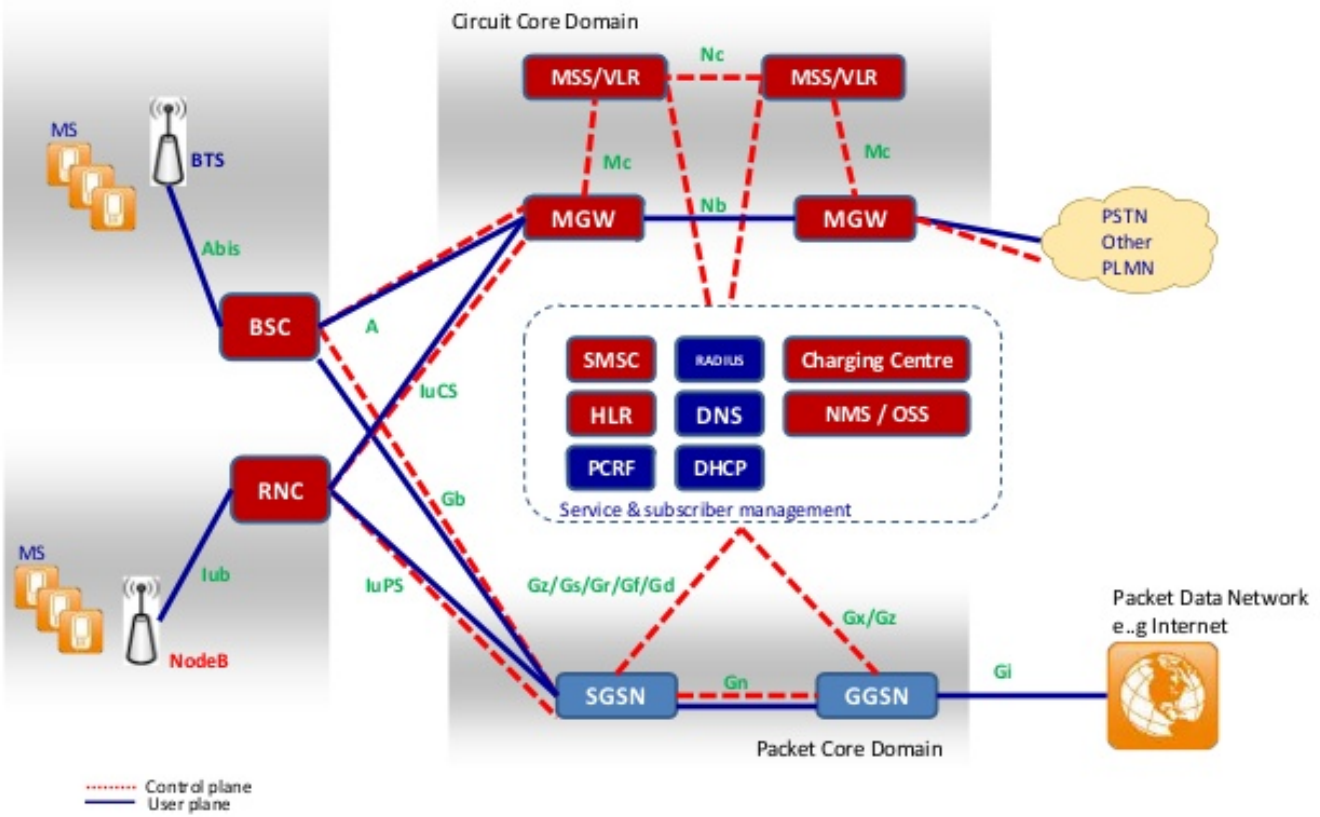
Scenario	Metric	Impact
Low Download Speed	Web Browsing	At download speeds under 10Mbps, web browsing increases speed at a linear rate, and then levels out. So if download speed is under 10Mbps, users will notice a drop in web browsing performance
Low Upload Speed	Download Speed	A really low upload speed could negatively impact download speed, as TCP ACKs cannot reach the server fast enough, effectively choking the download.
	Web Browsing	A really low upload speed (~128k) will hamper web browsing.
High but stable latency (>100ms)	Download Speed	Throughput may be affected on very fast lines (100Mbps+) as bandwidth-delay-product becomes a dominating factor.
	Upload Speed	Throughput may be affected on very fast lines (100Mbps+) as bandwidth-delay-product becomes a dominating factor.
	Packet Loss	Loss will likely be higher as there is more time and locations for packets to be lost.
	Web Browsing	Web browsing performance will suffer very noticeably as round-trips are limited by the latency achieved
Very variable latency (high rtt_stddev in curr_udplatency)	Download Speed	Will likely be very variable.
	Upload Speed	Will likely be very variable.
	Packet Loss	Highly variable latency usually accompanies significant packet loss, so expect larger numbers here.
	Jitter	Jitter would likely be very high.
	Web Browsing	Web browsing performance will suffer very noticeably and we may even see some failures due to any associated packet loss.

Scenario	Metric	Impact
High packet loss (>5%)	Download Speed	Likely to see highly variable speeds at best, and more realistically we will see lots of speed tests failing (failures>0)
	Upload Speed	Likely to see highly variable speeds at best, and more realistically we will see lots of speed tests failing (failures>0)
	Latency	Latency needn't necessarily be affected, but it probably will be.
	Jitter	Jitter needn't necessarily be affected, but it probably will be.
	Web Browsing	Expect lots of web browsing tests to fail completely, or at least show very poor results.
Very high/unstable jitter (>100ms)	Download Speed	Will likely be very variable.
	Upload Speed	Will likely be very variable.
	Latency	Latency will likely be highly variable
	Packet Loss	May or may not be affected.
	Web Browsing	Web browsing performance will suffer very noticeably as round-trips are limited by the latency achieved

- Impact of Unaccounted Variables (IPTV)
  - The SamKnows measurement solution is designed to control for all material variables. Although in some cases IPTV traffic does not directly pass through the Whitebox, the current version of the SamKnows system is able to infer and control for the impact.
  - The key to understanding the impact of IPTV is an ability to profile the performance of an IPTV-enabled internet connection. It is then possible to spot for performance variation that is as a consequence of IPTV, rather than network congestion.

- For example comparing all tests run on the line over the whole period, and specifically at peak time when IPTV is likely to be used against off-peak times. This is something that is being developed by SamKnows analysts, with the intention of this functionality being built-in to the user reporting for subsequent reports.
- Note that the impact of IPTV on broadband performance varies according to provider and package since not all IPTV services share bandwidth with normal internet traffic.

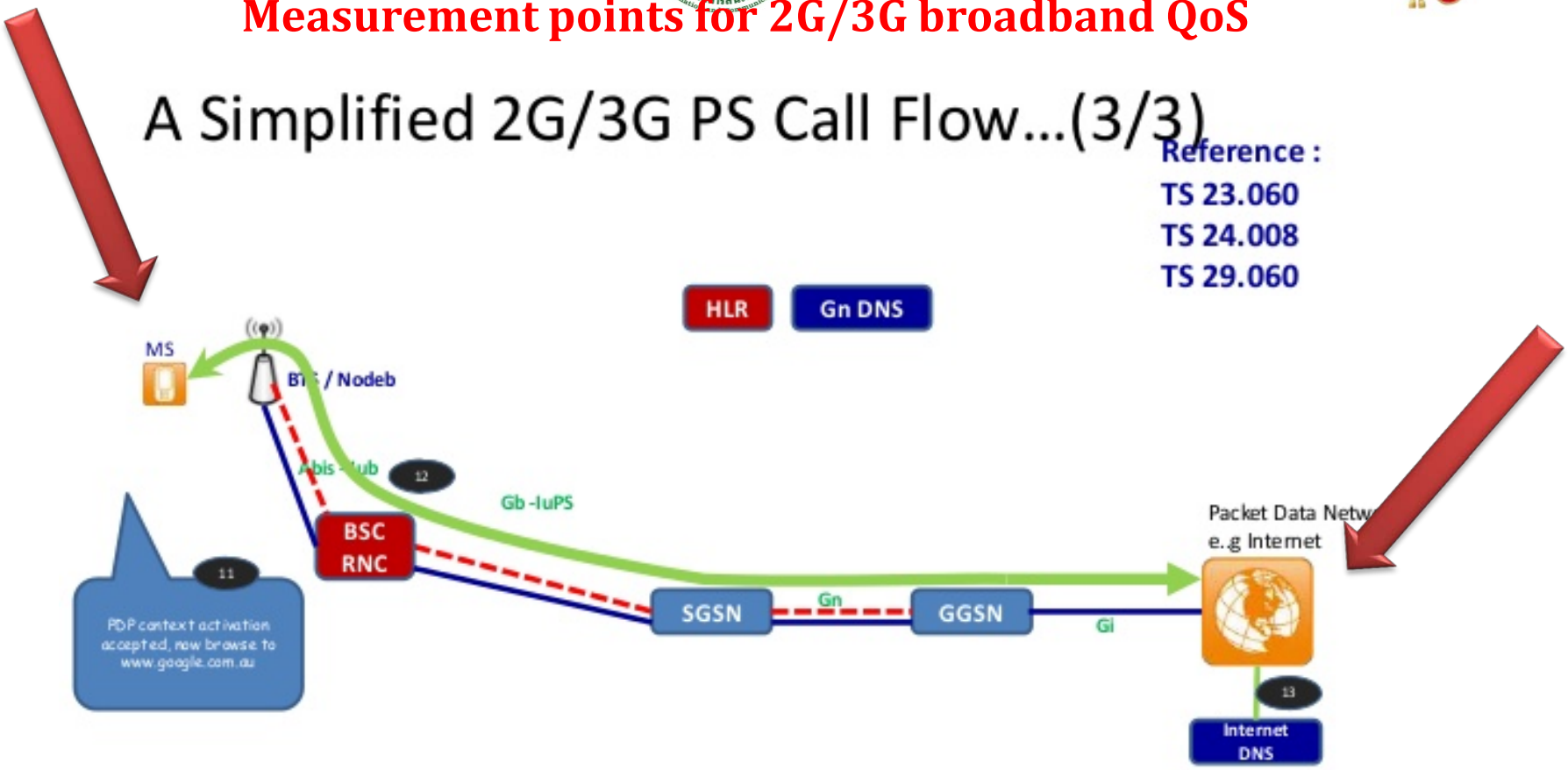
2G and 3G Network Architecture



2G and 3G acronyms

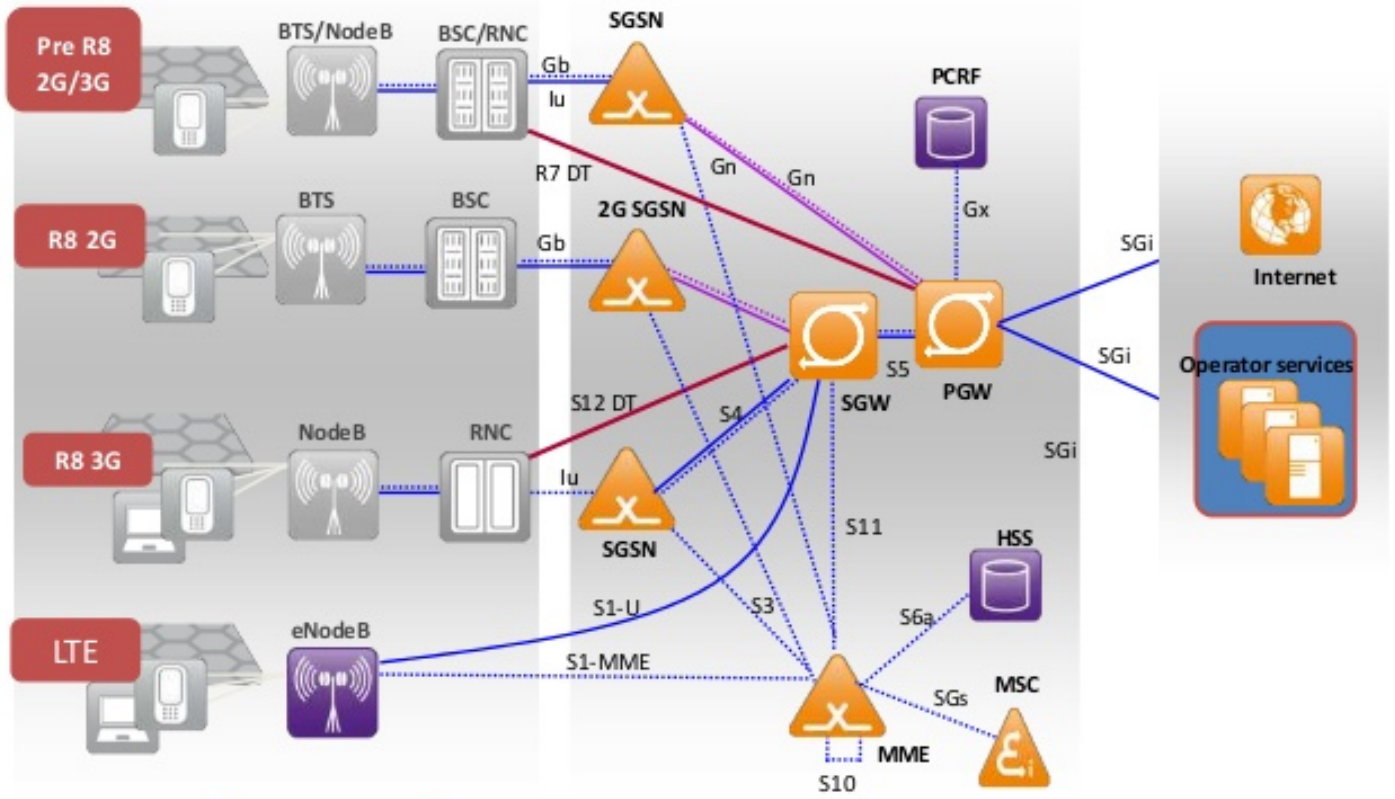
MS	Mobile Subscriber
BTS	Base Transceiver Station
BSC	Base Station Controller
NodeB	Air Interface towards MS in 3G
RNC	Radio Network Contoller
MSS	Mobile Switching Center
VLR	Visitor Location Tegister
HLR	Home Location Register
MGW	Media Gateway
SGSN	Support GPRS Service Node
GGSN	Gateway GPRS Service Node

Measurement points for 2G/3G broadband QoS



Note :
All procedures here are simplified for overview only.
Reader should refer to above reference for detail procedures.

General LTE Architecture

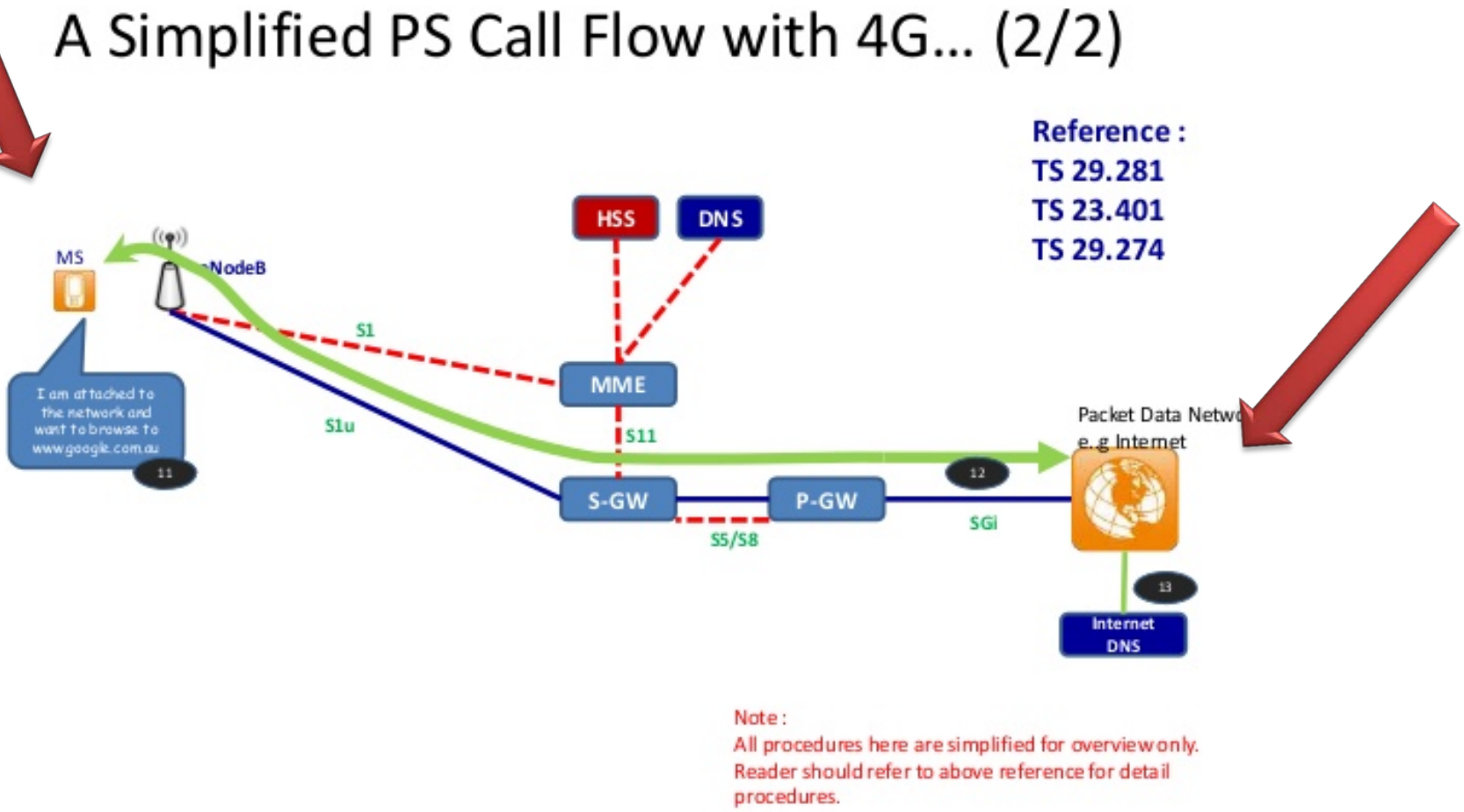


Basic EPS architecture defined in 3GPP TS 23.401

Additional acronyms for 4G/LTE

E-Node B	Air interface towards MS in 4G
MME	Mobile Management Entity
S-GW	Serving Gateway
P-GW	Packet Data Network Gateway
HSS	Home Subscriber Server

Measurement points for 4G/LTE broadband QoS



Mobile broadband measurements

- 3G, LTE etc. are considered broadband access when (e.g.) browser base apps are used
  - Or when LTE is used in place of missing fixed broadband infrastructure
- Testing principles and KPIs are in Recommendation ITU-T E.804
- Drive around and walk around tests
- Rarely reported in the context of broadband

- From a user perspective in a mobile broadband connection with a smartphone, there is no difference to a fixed broadband connection from a laptop, for example.
- Therefore the same following indicators could be used:
  - Web browsing
  - Voice over IP
  - Download speed
  - Upload speed
  - UDP latency
  - UDP packet loss
  - DNS resolution
  - Video streaming
- However in the following two case studies less parameters are used

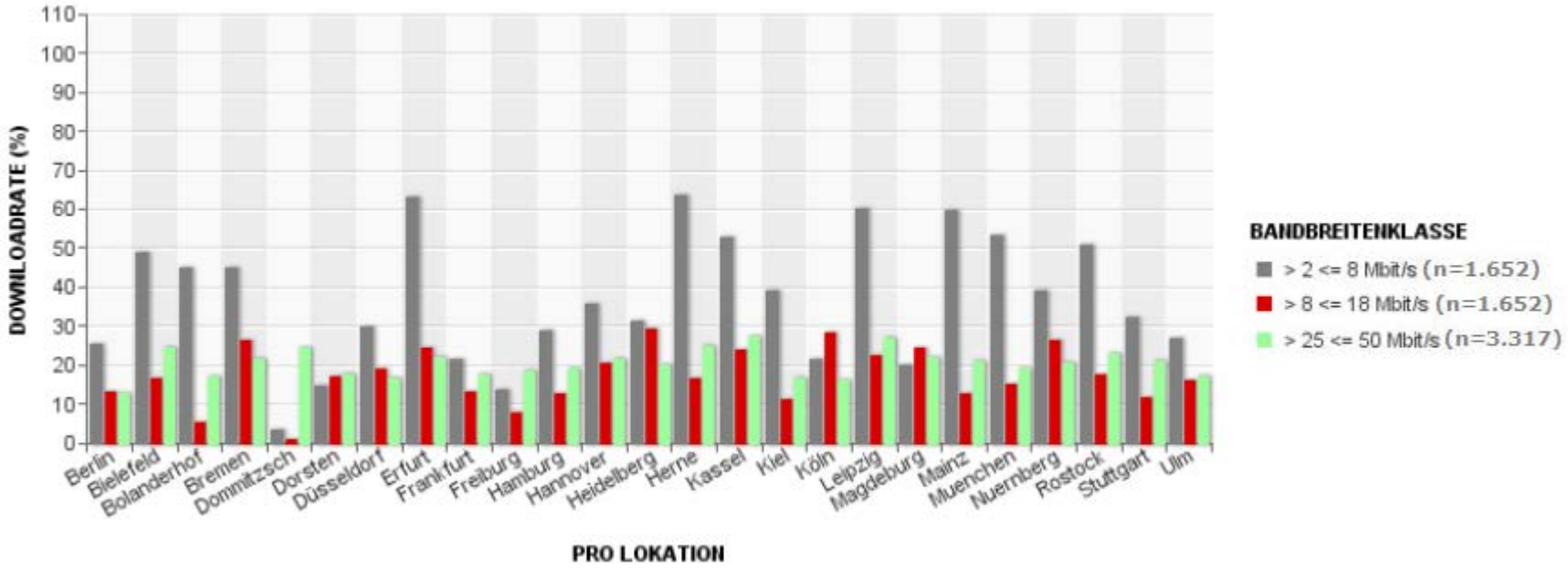
- Selected Results
  Fixed & Mobile
  Broadband Access Study
  Germany

- Related Activities
  Austria

- Results from Study on Broadband Access Speed
  - Initiated by German Regulator
  - Carried out by independant test house
  - Results for both Mobile & DSL access
  - http://www.bundesnetzagentur.de/cln_1411/EN/Areas/Telecommunications/Companies/MarketRegulation/QualityStudy/QualityStudy_node.html
  - Following is a Summary of Results for Mobile Access
    - Categorized by Ranges of Advertised Bandwidth
    - Bar graphs by Location (Major cities in Germany)

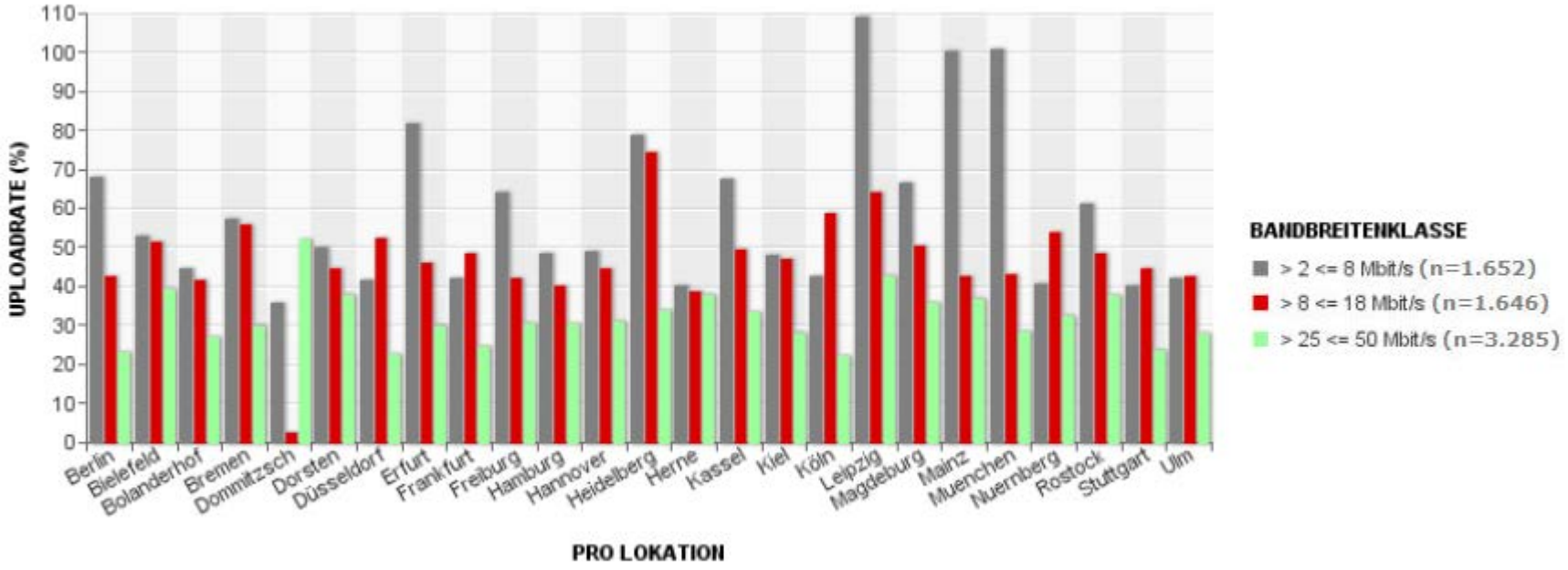
Average Mobile Download Speed

Depicted as Percentage of the Advertised Speed



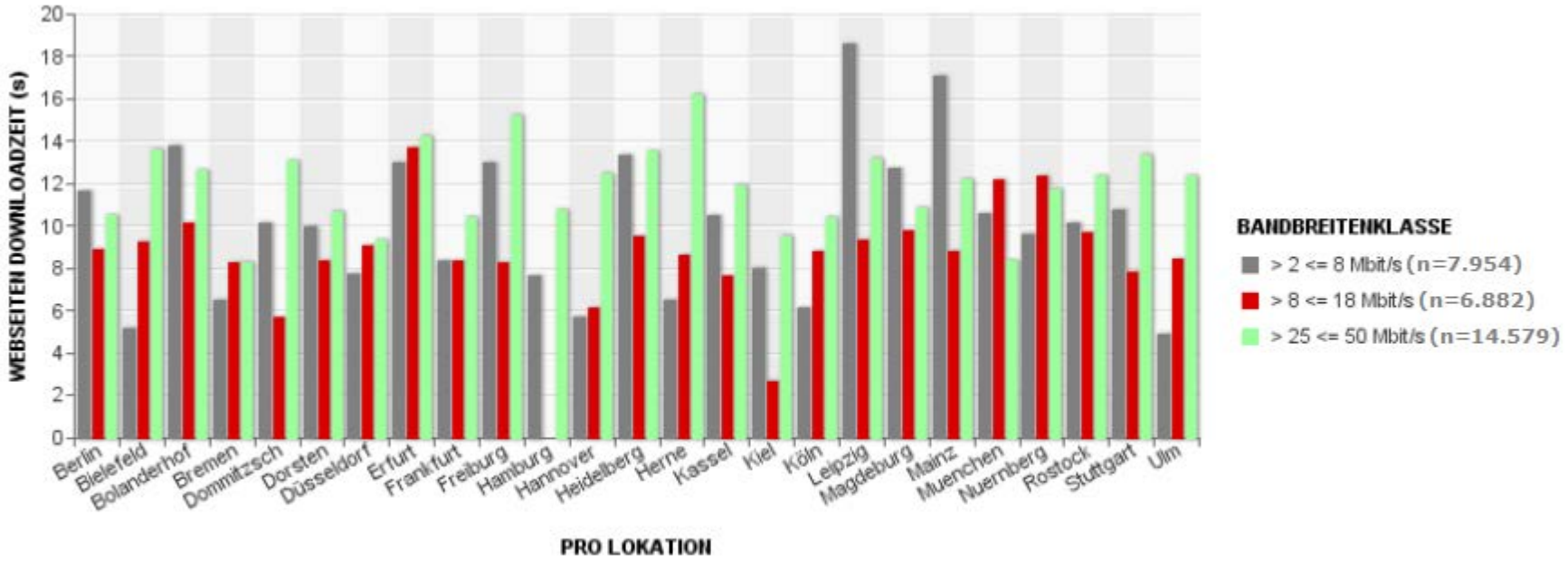
Average Mobile Upload Speed

Depicted as Percentage of the Advertised Speed



Average Mobile Download Time for Web Sites

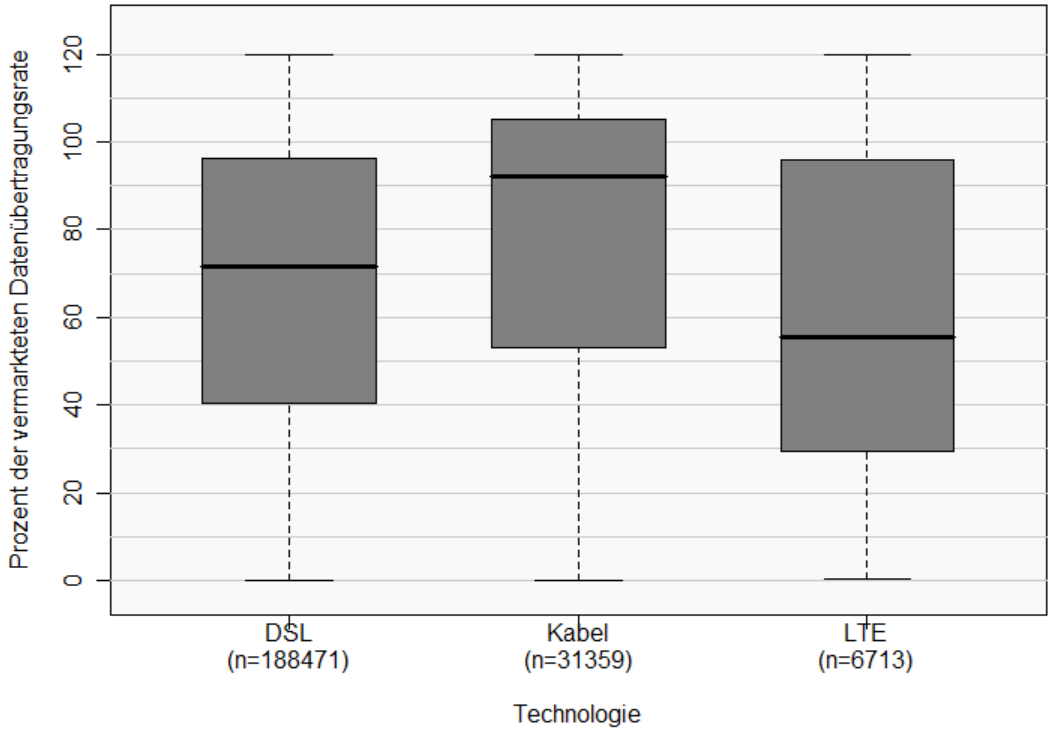
For Alexa Top 10 Web Sites in Germany



- Conclusion of the German Regulator:
  - Quality extremely fluctuating and not predictable
  - A global average quality value across one mobile network has no meaning for the customer
    - (e.g. average UMTS download speed for T-Mobile across Germany = 3 Mbit/s)
  - Customer wants to know quality at current location
  - High resolution required for measurements to be of any use for customer
  - Measurements of quality anddisplay of results must always reference Time and Location
  - Averaging across entire infrastructures not permitted

Compare LTE with other Technologies

Achieved Percentage of Advertised Speed



Examples of Drive Tests

Hauptbahnhof

Universität

Zentrum

Flughafen

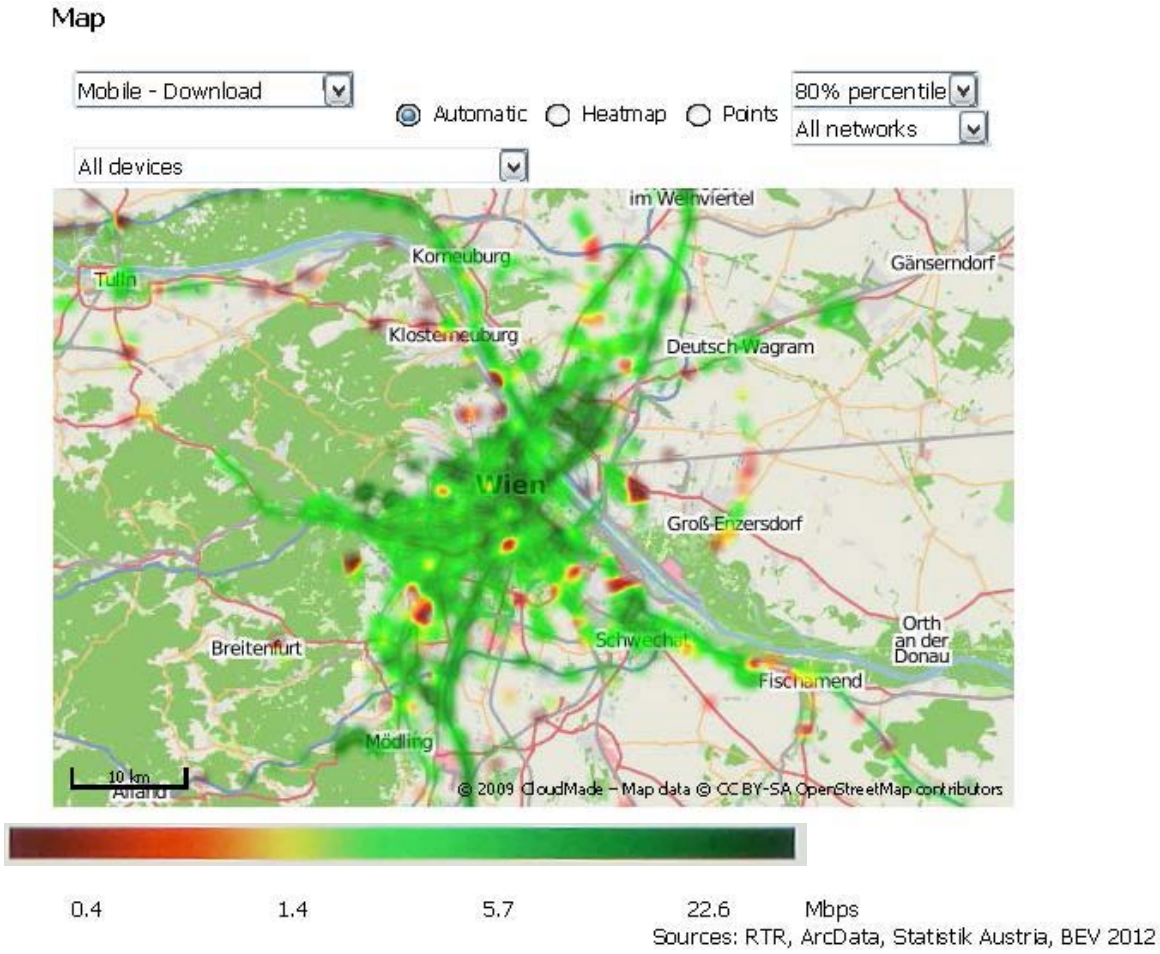
- Development of a measurement methodology for broadband access speed
  - measurement will be done by customers
  - creation of a public data base across all providers
  - enable customers to know the quality before signing the contract
  - enable customers to check the contracted quality

Consequences for Mobile Operators:

- make your own drive test with very high granularity "postal code level" or
- make software measurement on your customers' phones

- Approach via customers' phones requires huge data base
  - On average results per location will "true values"
  - Software must account for terminal aspect in intelligent manner
  - Currently under development by German Regulator

Austria example



- The Austrian Regulator already started measurement campaign based measurements from customers' phone
  - Currently in Beta test phase: https://www.netztest.at/en/
- Results on interactive map: https://www.netztest.at/en/Karte
- Technical Parameters: https://www.rtr.at/de/tk/netztestfaq_technik

Any questions ?

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