Final Report

The Quality of Service of Broadband Accesses II

Study conducted on behalf of the Bundesnetzagentur

Authors:

Kai Lukas
Dr Almuth Marx
Bernd Oliver Schöttler
Christoph Sudhues

zafaco GmbH
Taxetstraße 66
85737 Ismaning

zafaco

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Introduction

1 Background

The quality of Internet access services can be influenced by a number of different factors which determine the end customer's subjective impression of the quality of their Internet access serv1.11.11.11.1ice.

With an Internet access service, a provider establishes communication links between end customers and its own connection to the World Wide Web via its telecommunications infrastructure. Using this connection, the provider transports data packets which the end customer exchanges with other terminal equipment that is connected to the Internet.

The quality of Internet access service depends on a number of different factors here.

First of all, the quality of an Internet access service is determined by the end customer's direct connection to the provider's infrastructure (access). Access can be provided using various technologies such as xDSL, TV cable technologies, fibre optics technologies or a variety of wireless technologies. Together with the underlying infrastructure, the respective technology determines the theoretically maximum possible transmission capacity of the Internet access. For example, the length of the copper line is a decisive parameter for the capability of a DSL connection. Both parameters – infrastructure and connection technology – are known to the provider and are taken into account in the range of services offered to the end customer.

Another important factor that influences the quality of Internet access service is the quality of the transport of data packets within the provider's infrastructure (concentration and core networks). This is dependent on the dimensioning of the network resources (available transmission capacity). Fluctuations due to different levels of network load can influence the stability of the data transfer rate. This can, in turn, lead to differences in the transfer times for the individual data packets. Since some applications are sensitive to this type of fluctuation, the end user also notices differences in application quality when transfer times vary.

Together, the above factors determine the performance of an Internet access service. They also provide the basis for the following parameters for measuring the quality of Internet access services:

1. Quality of the connection. In other words, the theoretical maximum data transfer rate.

2. Transmission quality in the concentration and core networks

   - Dimensioning of the net infrastructure and allocation of network resources for the respective access product

   - Packet transfer times, use of applications

Furthermore, the actual use of an Internet connection requires additional applications and functions which run only on connected terminal equipment. Applications that run at the same time can likewise influence the data transfer rate available to an application. This also applies to end-customer infrastructures with end-customer installations that restrict the possibilities for using individual devices or applications. These factors are further variables that influence quality and must be taken into account when an Internet access service is actually used.

For this reason, when measuring quality (which entails actually using the Internet connection), the possible influence exerted by the terminal equipment must be taken into account in the measuring concept and included in the analysis of the measurement results.

Against this backdrop, the Bundesnetzagentur conducted a study in 2012 on the quality of internet accesses and published the results on 11 April 2013.[1] Based on the analysis of some 250,000 end-customer measurements, the study made statements covering a wide array of technologies and providers regarding the present status of the service quality being offered and the service quality that was actually provided.

Reference measurements were additionally conducted using a nationwide measurement platform; these measurements recorded not only the data transfer rate but also transfer times and web browsing quality.

[1] Cf. http://www.bundesnetzagentur/qualitaetsstudie

The measurement study confirmed the many customer complaints concerning differences between the contractually agreed 'up to' bandwidth and the bandwidth that was actually provided. Across the board for all technologies, products and providers, the measurements taken by many participating users fell short of the maximum possible bandwidth they had agreed with their provider.

Sections of the study (measurements conducted on fixed Internet accesses by end customers, measurements conducted using the nationwide measurement platform) were repeated between 1 July 2013 and 31 December 2013.

1.1 Objectives of the quality study

The 2013 follow-up study was conducted to determine what changes have occurred in the interim. This required determining once again the current status of the communicated service quality and the actual service quality the customer received and comparing the results with the 2012 study. To ensure comparability of the results, the same method was used for conducting the measurements. Since the methodology used in 2012 for mobile network access services did not lead to robust results, the follow-up study was limited to fixed broadband accesses.

The following tests were conducted:

- End-customer measurements of fixed Internet connections to determine the actual data transfer rate of the connection, expressed as a percentage of the advertised data transfer rate of the access.

  For this part of the study, fixed technologies (xDSL, broadband cable access, broadband access and LTE access that is used on a stationary basis) were looked at once again and the data transfer rates of various broadband classes, providers and regions were examined. The data transfer rates measured were then juxtaposed with the respective advertised data transfer rates and expressed as a percentage of the advertised rate. Here, advertised data transfer rates are those rates which the provider specifies in a contract with the end customer or cites on billing documents.

- Measurements of the data transfer rate, transfer time and web browsing conducted on stationary monitoring units that are part of a nationwide measurement platform

1.2 Methods used for the quality study

The above questions were examined in the course of the study using an integrated measuring concept that employed a combination of two components, each with specific features that complemented the other (see Figure 1.1):

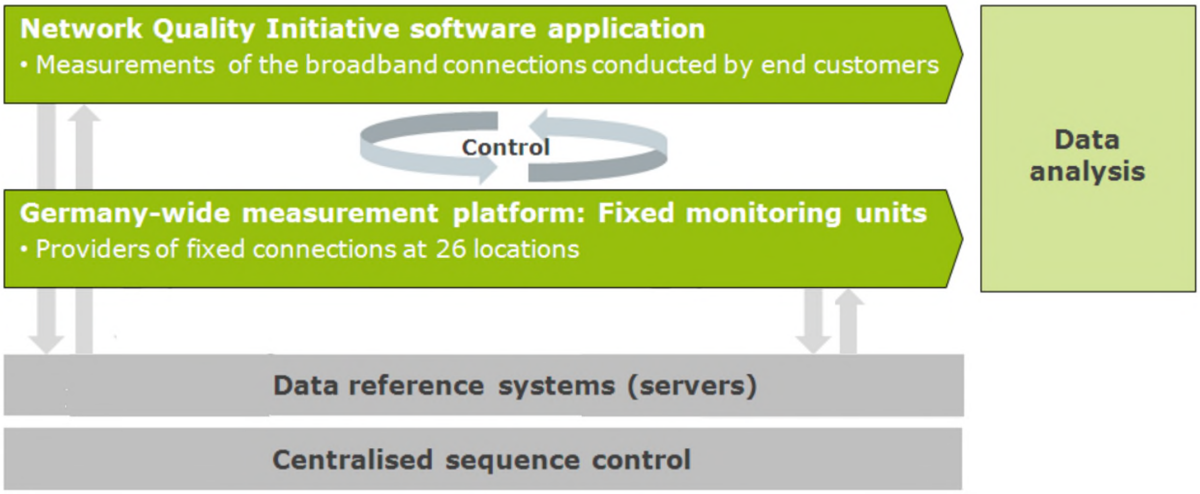

Figure 1.1: Integrated measuring concept

1. A measurement platform (consisting of monitoring units at 26 sites throughout Germany and several server systems which served as, among other things, counter test points for the data measurements) recorded measurements in order to examine traffic management in concentration and core networks in a fully-controlled measuring environment. The temporal distribution of the actual data transfer rates, transfer times and the quality of a typical end-user application (web browsing) were examined in this connection.

2. The (upload and download) data transfer rates of fixed Internet access services on the other hand were ascertained in the course of the measurements conducted by end customers. For this, the Bundesnetzagentur invited end customers between July and December 2013 to measure the data transfer rate of their Internet connection using special software available at the website www.initiative-netzqualitaet.de. The fundamental accuracy of the values obtained using the software was

monitored on an on-going basis by comparing in targeted samples the values generated by the two methods.

3. The measurement and validation processes used in the 2012 study were expanded through the inclusion of additional parameters which resulted in greater accuracy. However, this was possible only for a subset of the end-customer measurements. A separate analysis was conducted for this subset.

Servers (data reference systems) were used as counter test points for the measurements conducted during the study.

All measured values obtained using this concept were stored in centralised systems and subsequently analysed (data warehouse and business intelligence platform).

The following sections describe in detail the individual aspects that were the focus of the study and the methods used to examine them (Sections 2 - 3).

The study findings are presented in context in Sections 4 - 5.

1.3 Executive summary

In 2013, the Bundesnetzagentur repeated its 2012 nationwide measuring campaign. During this campaign users could test whether and the extent to which their actual broadband access speed deviated from the contractually agreed speed. The new campaign aimed to determine whether and the extent to which improvements had taken place over the previous year.

At total of 375,412 end-customer measurements were conducted for the 2013 study; of these measurements 153,216 valid individual measurements were included in the analysis. Only those measurements were deemed to be valid which, for example, the customer had indicated had been conducted in an optimal test environment. The results of the statistical monitoring conducted for this study show that the sample largely approximates the parent population in terms of the parameters Technology, Provider and Geographical Distribution (federal states as well as urban, semi-urban and rural regions).

Measurement setup for end-customer measurements

Irrespective of the technology, product and provider, the measurements taken by many users in the sample from the 2013 study - like those taken by their counterparts in the previous year - fell short of the maximum possible bandwidth they had agreed with their provider.

However, the proportion of participating users in the random sample who received at least 50% of the advertised data transfer rate increased from 69.2% in 2012 to 77.1% in 2013. On the other hand, the proportion of users who measured the full advertised data transfer rate or more declined slightly, from 19.5% in 2012 to 15.9% in 2013.

The measurement results for the fixed access technologies examined for this study - DSL, cable and LTE - show that cable accesses exhibited the least deviation from the advertised download data transfer rates.

An examination of the bandwidth classes also revealed differences in the actual data transfer rates (expressed as a percentage of the respective advertised rate). As was the case in 2012, the lower-most bandwidth class (≥ 0.384 to ≤ 2 Mbit/s) generally exhibited the smallest differences.

On the other hand, the largest differences were measured in the uppermost bandwidth class of > 50 to < 100 Mbit/s for cable accesses and > 25 to ≤ 50 Mbit/s for LTE accesses and in the bandwidth class > 8 to ≤ 18 Mbit/s for DSL accesses.

Similarly to 2012, the differences between rural, semi-urban and urban areas were small on the whole.

The median value – in other words, the percentage value that half of the users receive as a minimum – shifted higher for all technologies, broadband classes and regions.

Special analyses

It is methodologically impossible to completely control the test environment for measurements conducted by end customers. In comparison to the first study, the 2013 study had been improved so that additional values could be read out for certain subsets of routers.

It could thus be determined whether the measurements for this subset had in fact been conducted via WLAN even though the users had indicated that they had performed the measurements in an optimal test environment without WLAN. This was the case for 9% of the measurements from this subgroup.

On the other hand, it was found that there was parallel data traffic – albeit only to a limit extent – during all measurements conducted for the subset. Parallel data traffic accounted for less than 1% of the total data traffic in the case of more than half of the measurements in the subgroup. This figure was less than 4% for 90% of the measurements.

The overall analysis did not include the results from the special analyses. This was done in order to ensure methodological consistency with the 2012 study and avoid statistical bias. As a result, all measurements for which the customer indicated that they were conducted in an optimal testing environment were included in the overall analysis.

However, it seems very likely that comparable effects arise even among participants who use other modems/routers because there are no indications that the participants in the subgroup differ from participants in the total sample in terms of the information they provided concerning an optimal test environment.

Importance of the special analyses for the results of the end-customer measurements

In light of this, it must be assumed that the above results from the end-customer measurements are usually not as good as they would be in an optimal test environment.

Although the results from the subgroup cannot be directly applied to the total sample, they do enable an assessment of the magnitude of the effects (use of WLAN, parallel data traffic) on the measurement results of the total sample.

Results of measurements conducted on the measurement platform

The temporal distribution of the data transfer rates over the course of the day, the transfer time and web browsing were measured at stationary monitoring units using a nationwide measurement platform.

An analysis of data transfer rates over the course of the day showed that the speed of DSL connections did not depend on the time of day. In contrast, cable connections and fixed LTE connections exhibited a slight decline in their data transfer rates in the evening (by up to 10%). These observations tally with the measurements conducted in 2012.

The picture for the transfer time measurements was similar to that seen in 2012. The transfer times for cable connections over the entire course of the day were shorter than the transfer times measured for DSL connections and fixed LTE connections. Cable connections however exhibited a slight increase in the length of transfer times (by up to 10%) during the evening hours.

The examination of web browsing – a typical use scenario – showed that website download times of cable connections were shorter than those measured for DSL connections. Cable connections and fixed LTE connections however exhibited a slight decline in their data transfer rates in the evening (by up to 15%). This occurred with both DSL and cable connections and could be observed in all bandwidth classes.

Material and methods

2 Quality of Internet access service – measurement parameters

The quality of Internet access service as a stand-alone service was evaluated on the basis of the available data transfer rate, the distribution of the data transfer rates realised over the course of the day, the transfer times and the quality of the Internet access service when using a typical end-user application (web browsing).

The following sections detail the method used to conduct the measurements, the products examined and the measurement system for the individual quality parameters.

2.1 Determining the available data transfer rate

2.1.1 Measuring procedure

The available data transfer rate was measured by transmitting data via the Internet (TCP/IP) between a monitoring unit and one of eight servers (data reference system), each time with a connection of 1 Gbit/s. Optimised, stable routing was achieved by linking the data reference systems with Europe's largest and most important peering points / Internet exchange points.

The server-side TCP/IP configuration was carried out and documented in accordance with ETSI EG 202 057-4. Linux was used as the operating system.

Dedicated test equipment (measurement platform) was used for the technical monitoring units or set up on end-customer PCs (end-customer measurements).

Measuring the download data transfer rate

The data transfer rate for downloads was measured on the measurement platform and as part of the end-customer measurements using the same procedure. The results documented in Section 5 regarding the difference between actual transfer rates and advertised transfer rates are based on end-customer measurements. The measurements conducted on the measurement platform for this parameter were used solely for control purposes (see 4.3).

In order to reproduce a realistic user situation, the hypertext transfer protocol (HTTP) that is often used by end customers was employed.

Several parallel HTTP data streams were initiated in order to download a 1 GB file from the data reference system to the monitoring unit for each data stream. The transfer of each of the data streams was stopped after a pre-determined period of 20 seconds. It was thus ensured that, even at the maximum observed data transfer rate, data would be transmitted throughout the entire measurement period and the maximum data transfer rate possible for the respective transmission link could be measured. The effects of TCP congestion control (overload control) were taken into account when determining the window of time for this.

Initiating several parallel data streams also reduces the influence that the monitoring unit's TCP/IP configuration has on the measurement. The higher the data transfer rate to be measured, the stronger this influence is. In the course of extensive (and, since 2002, regular) surveys conducted by zafaco, the use of four data streams has proven to be suitable for the bandwidth range of up to 200 Mbit/s that was covered by this study.

The *HTTP download time* is the amount of time that elapses from the starting time of the last HTTP stream until the time of the first interruption of the four parallel HTTP streams of the standardised HTTP download. Thus, the term HTTP download time refers to the period of time during which all parallel HTTP streams generate load at the same time.

The data volume that was transmitted is calculated by adding the volumes of data loaded by the four individual HTTP streams during the HTTP download time.

The *HTTP download throughput* – and thus the available download data transfer rate in Mbit/s – was calculated on the basis of the data volume and the HTTP download time.[2]

Measuring the upload data transfer rate

The details of the measuring procedure chosen here vary, depending on whether the measurement is conducted on the measurement platform or as part of the end-customer measurements.

The file transfer (FTP) protocol that is widely used for transmitting files was used to conduct measurements on the measurement platform. The upload data transfer rate was measured by conducting a standardised FTP upload[3] of a sufficiently large[4] file in passive mode[5] which was then interrupted after 20 seconds.

In contrast, the upload data transfer rate was ascertained during the end-user measurements with the help of a standardised HTTP upload.[6] For this, a sufficiently large[4] amount of data was generated and transmitted for a measurement period of at least 20 seconds.

The *upload time* for the FTP upload was calculated as the time that elapsed from the starting time until the time when the FTP stream of the standardised FTP upload was interrupted. For the HTTP upload, the upload time is the time from the starting time until the upload stream has been completely transmitted.

The *upload throughput* and thus the product's available upload data transfer rate, measured in Mbit/s, were calculated on the basis of the data volume and the upload time.

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[2] In the case of the end-customer measurements, the calculation included the HTTP protocol header, in other words: The information regarding the data transfer rate refers to the throughput of the Internet access service (IP payload).
[3] In accordance with ETSI EG 202 057, Part 4
[4] Here, 'sufficiently large' means that even at the maximum observed data transfer rate it is ensured that data will be transferred during the entire measurement period and that is it possible to measure the maximum possible data transfer rate for this transmission link.
[5] Passive mode is used when the server is unable to establish a connection with the client. This is the case when, for example, the client is located behind a router which changes the client's IP address via NAT or when a firewall restricts access to the client's network from outside the network.
[6] In accordance with ETSI EG 202 057, Part 4

2.1.2 Measurement setup

2.1.2.1 Measurement platform

The nationwide measurement platform consists of monitoring units at 26 sites, several centralised server systems including a business intelligence platform (data analysis), a data warehouse (data storage), several data reference systems (counter test points for the data measurements) and a management system.

Distribution of the sites

The distribution of the sites was determined on the basis of the following considerations:

- Coverage of at least all single-digit telephone prefix areas must be ensured.
- The sites had to be located in larger cities to ensure the availability of a large number of providers at one location.

At present, 26 measurement sites are in operation throughout Germany. Their locations are shown in Figure 2.1.

Figure 2.1: Locations of the nationwide measurement platform sites

Monitoring units

Powerful hardware and software that were tailored to this particular purpose were used for the measurement platform. Each monitoring unit consists of a computer system that uses 19-inch technology and the Windows XP Embedded operating system which do not require an on-site operator. Self-tests and integrated system monitoring ensure a high level of operational reliability. Self-tests and integrated system monitoring ensured a high level of operational reliability. The operating system's default TCP/IP settings were retained.

The actual measurement tasks were conducted by testing software which was installed on the above-mentioned computer systems. The measurement data was gathered following the recommendations issued by the **German Institute for Standardization** (DIN 66274), the European

Telecommunications Standards Institute (ETSI EG 202 057) and the **International Telecommunication Union** (ITU P.862)[7].

The data was ascertained using test connections at customer interfaces including the provider's router. As a result, the monitoring units were connected to the providers' access network like participants were. The fact that publicly available subscriber lines rather than special test connections were used guaranteed the comparability of the providers. This method also ensured that service quality would be assessed from the customer's perspective because the test included all the system components involved in an end-to-end connection. This offers the following advantages:

- Fully-documented test connections
- Full control of the connections to be tested
- Quick and reproducible results
- No data protection constraints

Figure 2.2 shows an example for the setup of a monitoring unit.

[7] The results of the PESQ measurements conducted in accordance with ITU P.862 for evaluating sound quality were not used for this study.

Figure 2.2: Example of the setup of a monitoring unit at a measurement platform site

The measurements conducted at the individual sites were controlled by a centralised management system. A special test schedule with measurements every hour was carried out for each monitoring unit. As part of this process, connections were generated not only between the measuring sites but also to the measurement platform's data reference systems. The test schedule for the automated measurements was set up so that a 20% reserve was maintained, thus precluding an overloading of the data reference systems. In addition, the servers were monitored by a monitoring system. A night-time maintenance window between 4 am and 5 am was incorporated into every day for scheduled maintenance work.

Unless otherwise indicated, products with the following parameters were examined on the platform:

Provider

Broadband end-customer connections from national, regional and local providers were examined via the platform. Fixed-line providers and cable TV providers were selected for this, based on their respective market share[8] (see Table 1).

Table 1: Providers of fixed broadband connections examined on the nationwide measurement platform (Source: VATM Telecommunications Market Analysis Q3/2013)

Fixed broadband connections		
Provider	Market share	Classification
Telekom	43,8%	National
Vodafone	10,6%	National
United Internet	12,0%	National
Telefónica	8,1%	National
Unitymedia KabelBW	8,5%	Regional
Kabel Deutschland	7,1%	Regional
EWE	2,5%	Regional
Versatel	1,8%	Regional
NetCologne	1,4%	Local
M-net	0,7%	Local
KielNet	in 'others'	Local
congstar	in 'Telekom'	National
Tele2	in 'others'	Regional

[8] VATM Telecommunications Market Analysis Q3/2013

Products

In the area of fixed broadband connections the respective 'best-in-class' products were tested, in other words, the highest-quality connections available at urban locations that are extensively served by providers. A large proportion of the platform locations is to be found in the direct vicinity of the providers' main distribution frame, outdoor DSLAM or CMTS.

LTE

The available data transfer rate of fixed LTE connections was measured at a total of eight measurement platform locations (see Table 2). The level of LTE availability that the respective provider had realised to date was taken into account when selecting the locations.

'Fixed LTE' denotes the use of LTE access technology as an alternative to fixed network connections via an LTE modem / router. LTE connections for mobile use, for example, via a smartphone or surf stick, were not assessed as part of the study.

Table 2: Providers of fixed LTE broadband connections examined at the locations of the nationwide measurement platform

Fixed LTE broadband connections		
Provider	Technology	Sites
Telekom	Fixed LTE	6
Vodafone	Fixed LTE	6
O2	Fixed LTE	4

2.1.2.2 End-customer measurements

In order to determine the data transfer rate of fixed broadband connections, the available data transfer rates of a large number of connections were determined as part of the end-customer measurements. For this, all end customers could measure the data transfer rate of their particular Internet access service between 1 July 2013 and 31 December 2013 using a browser-based test (www.initiative-netzqualitaet.de).

To ensure that the largest possible number of participants could be obtained, the implementation technology had to meet a number of requirements:

- It must not require any special installation in the end customer's infrastructure. This was stipulated in order to avoid making participation more complicated for the end user.
- It must not require a specific type of browser or operating system.
- It must be widely used and robust.

The measurement software used for the 2013 study was not based on Flash, as in the previous study, but rather on Java.

The following aspects were taken into account in this connection:

- The end-customer measurement was conducted using a software application in the form of a *Java PlugIn* in the browser on the end customer’s PC. The switch to Java did not lead to any changes in the actual measuring procedure over the 2012 study.
- Since Java is widely used, end customers could normally use the software application without having to install anything else on their computers, similarly to 2012 when Flash was used.
- In contrast to Flash, Java allows the use of protocols (in particular the Simple Network Management Protocol (SNMP)) which can be used to query the end customer’s modem/router via the *Java PlugIn* in the browser on the end customer’s PC.

- For security reasons, the measurement software (programme code) was signed with a certificate to ensure the authenticity of the source.[9] Likewise, readouts were conducted only in the end-customer environment (LAN). The Internet was not accessed for this since this would mean an additional security risk.

During the study, personal data was collected, stored and processed when necessary or required for conducting the study. The legal provisions that were currently in effect were complied with throughout these activities. Personal data include the user's IP address and the router ID that are ascertained during the measuring process for validation and statistical monitoring purposes. Under certain circumstances, this information could allow the user to be identified (personal reference).

In accordance with the privacy statement of the Network Quality Initiative, only zafaco and the Bundesnetzagentur have access to the users' IP address and router ID. This data is not made available to third parties. Further, neither zafaco nor the Bundesnetzagentur could identify the users. Only an access provider would be able to infer a user's identity using this information because only providers can match an IP address or router ID to a contract.

End-customer test environment

The most reliable measurement results can be achieved when other data-intensive applications and other terminal devices do not access the Internet access / broadband connection that is to be measured and virus scanners, firewalls and the like have been deactivated.

In principle, the following effects can occur that influence the results of the measurement:

- Additional terminal devices (such as smartphones or tablets) access the Internet and generate parallel data traffic at the same time that the measurement is being conducted.
- The connection of the end-customer PC conducting the measurement is limited by

[9] Digitally signing Java applications protects the code from manipulation and links the provider's identity to the code. This provides end users the assurance that the code comes from zafaco GmbH and is trustworthy.

   - a WLAN connection that has lower data transfer rates than the Internet access does,
   - local LAN configurations which limit the data transfer rate of individual end-customer terminals.
- Processes/applications (such as virus scanners and firewalls) might be directly integrated into the data exchange between the software application and data reference system. This can possibly influence the data transfer rate.
- The operating system, browser version, etc. used on the end customer's terminal can influence the measurement results (for example, implementation of the TCP/IP protocol stack).

The end users were informed of these effects and requested to establish an 'optimal test environment'. They were instructed to close all other applications and connect the terminal to be used for the measurement directly via LAN cable to the access unit made available by the provider. They were also asked to close any parallel processes/applications that might be running in the background. Lastly, prior to conducting the measurement, the end user was asked whether the above-described type of optimal test environment was in place during the measurement (see 2.1.3.1).

Only those measurements for which the customer reported having an optimal test environment underwent the validation process conducted for the overall study. As a result, only those data records that, according to the respective customer, were obtained under optimal test conditions were included in the analysis.

Reading additional values

In contrast to the 2012 study, additional values could be read for certain subsets of routers in the 2013 study:

- Synchronised data rate of the connection

  The term 'synchronised data rate' refers to the data rate with which the modem connects with the provider's access network. The synchronised data rate is the data transfer rate that the subscriber line achieves but cannot exceed under optimal conditions. Depending on the design of the provider's product, the synchronised data rate can be less than the maximum data transfer rate that the subscriber line permits according to its quality and – depending on the connection technology – its length. Account must also be taken of the fact that, for example, in the case of some technologies it is possible that more than one consumer can use resources within the access network (such as with cable or mobile communication accesses). In addition, the synchronised data transfer rate does not cover the joint – technology-agnostic – use of resources in the concentration network.

  Compared with the 2012 study, the number of manufacturers able to read the line's synchronised data rate was increased by implementing additional query protocols. This value is useful for determining whether the synchronised data rate falls within the range indicated by the end customer as the advertised data transfer rate (see 5.2.1).

- Query of the router interfaces, including their line speed (interface link speed)

  The properties of the end customer's PC and router/modem (LAN/WLAN) that were used for the measurement, including their line speed (interface link speed), could be read from a subset of modems/routers.

  It was consequently possible to ascertain for this subset whether the measurement was conducted via WLAN and the data rate with which the end customer's PC was connected with the modem/router, irrespective of the end user's statement regarding the use of an optimal test environment.

- Transmitted traffic volume in the upstream and downstream direction of the interfaces (interface traffic counter)

  For this subset, the total transmitted traffic volume in the upstream and downstream direction could be read from the byte or packet counter (interface traffic counter) of the WAN interface (the router's connection to the Internet). The readout was conducted only via the LAN interface between the end customer's PC and modem/router. This made it possible to identify data traffic that occurred above and beyond the data traffic during the measurement. This parallel data traffic can be caused by, for example, applications that are running in the background or other terminal equipment.

Using the above-described values, the customer's statement regarding the use of an 'optimal test environment' can be checked in respect of the quality of the connection of the end customer's PC (e.g. WLAN) and parallel data traffic can be included in the calculation of the data transfer rate (see 2.1.3.2.1).

Since these possibilities did not exist for all participants, the effects for this subgroup were examined in a separate analysis (see 5.2.2 and 5.2.3).

It was consequently decided not to treat differently the subset of measurement results for which it was possible to read out other values as well. This procedure ensured methodological consistency between the first quality study and the current (second) quality study. Treating a subset differently would have also led to bias in the overall study.

Data reference systems

Eight dedicated data reference systems were set up as counter test points at various locations for the end-customer measurements and configured as described above (see 2.1.1).

To prevent the measurements from being influenced by overloaded servers or their overloaded connections, a monitoring-based load control was implemented that ensures that a specific data reference system is used as a counter test point for a measurement only when sufficient resources are available. The invocation is otherwise forwarded to another data reference system. In the event that all servers are overloaded even following a short waiting period – something that has not yet occurred in actual operation in the last two years – the measurement is rejected and the end customer is notified accordingly. The data reference systems were queried on a rolling basis (round-robin principle) as part of this load control system.

As a result of the load control system, it was possible to ensure that the data reference systems had sufficient bandwidth at their disposal for every measurement. A 20% contingency reserve was continuously maintained.

Connections examined for the study

The software application enabled the measurement of data transfer rates of up to 200 Mbit/s. The application could also be used to measure connections with a very low data transfer rate such as those that occur when uploading from connections with an advertised download data transfer rate of 384 Kbit/s.

Only fixed broadband connections being offered with a maximum download data transfer rate of 'up to' 200 Mbit/s in the mass market in Germany were measured as part of the end-customer measurements.

2.1.3 Data transfer rate of Internet access services based on fixed broadband accesses (end-customer measurements)

The data transfer rate of Internet access services that are based on fixed broadband accesses was measured in the course of the end-customer measurements.

2.1.3.1 Measurement process

Upon accessing the website www.initiative-netzqualitaet.de the user was first shown an information page that provides an overview of the study and the steps involved in the test.

By clicking on ‘To the test’, the user came to a page where he/she was asked for information about the connection to be tested (see Figure 2.3). This information pertains to the following:

- **Postal code**

  The postal code for the street address of the connection was requested. This information was necessary in order to determine the region where the tested connection was located.

- **Connection technology**

  Here the end customer was asked which technology would be used to realise the connection to be tested. The answer here had to be entered via a selection menu. It was possible to provide a free-text answer by selecting 'Other'.

- **Provider**

  The answer here had to be entered via a selection menu with an AutoComplete function. In those cases where the user could not find his provider in the list, an e-mail contact address was displayed.

- **Access speed**

  In connection with access speed, the end customer was asked about the advertised download data transfer rate which the provider had specified to the end customer on billing and contract documents.

- **Customer satisfaction**

  When determining customer satisfaction the focus was on evaluating how satisfied end customers are with their provider's overall performance.

- **Optimal test environment**

  It was also determined whether, in the user's view, the measurement was conducted using a cable-based connection (LAN) and without any other applications running in the background on the PC, such as a virus scanner.

After entering the information on these parameters, the end customer could start the measurement. A measurement took approximately 60 seconds. The end user was shown the results of the individual measurement in numerical form and as a bar graph. The results were simultaneously transmitted to the centralised systems (see Figure 2.3). More detailed information regarding the study plus user support in the form of 'Questions and Answers' were also provided.

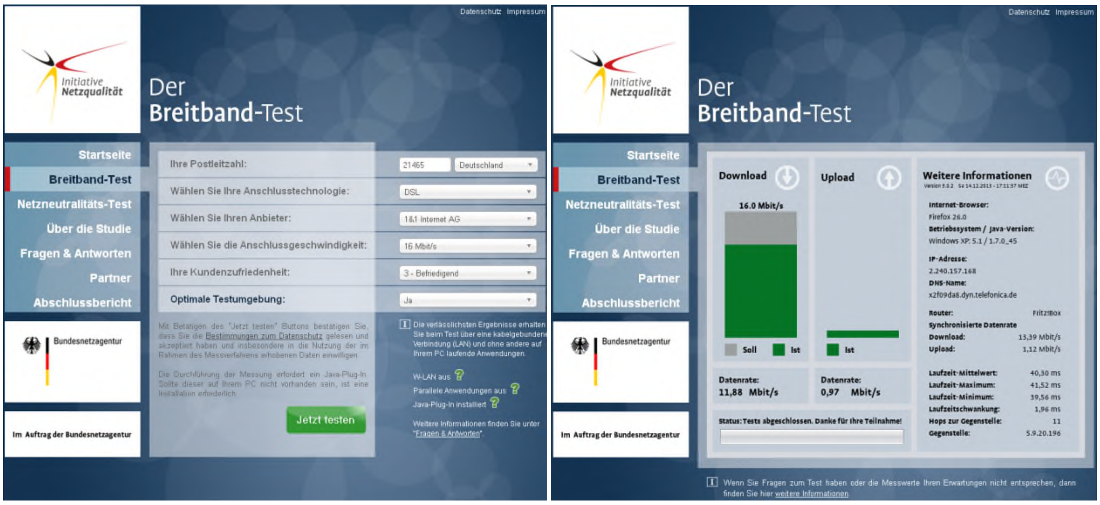

Figure 2.3: User interface of the end-customer test

2.1.3.2 Data preparation and quality assurance

2.1.3.2.1 Technical validation of the parameters

The measured values and the end-customer information were checked regularly in the course of a multi-step validation process. Data records with implausible values were rejected.

Depending on the values ascertained, the following validation steps were conducted:

Provider

- Reject foreign providers.
- Validate the provider identifier based on the IP address in conjunction with a reverse DNS lookup / whois query.
- Map valid resale scenarios (possible combinations of providers based on end-customer information and service providers based on the technical validation).[10]

[10] During the technical validation, the provider is ascertained whose wholesale product the reseller uses in order to offer end customers Internet access service. In the event that this provider could not be a wholesale provider for the provider indicated by the end customer, this data record is rejected as being implausible.

Postal code with attribution to geographical area and federal state

- Attribution to federal state and geographical area (urban, semi-urban or rural[11]) based on the population density[12] of the respective postal code area, with verification of the validity of the specified postal code.

Technology

- Translate free text entries into standard designations with the help of regularly updated conversion tables.
- Check whether the specified technology corresponds to combinations of providers and technologies found in the marketplace.

A separate analysis was conducted for the following values. The results had no effect on the validation of the end-customer measurements. They were used for plausibility checks.

Synchronised data rate of the connection

Using the software application, it was possible to read the synchronised data rate of the connection for devices (router-modem combination) of a subgroup of manufacturers in order to determine whether the synchronised data rate was in the range indicated by the end customer as the advertised data transfer rate.

Query of the router interfaces

The properties of the end customer’s PC and router/modem (LAN/WLAN) that were used for the measurement, including their line speed (interface link speed), could be read from a subset of modems/routers.

On the basis of these values, it was possible to determine whether the measurement was conducted via WLAN and which data transfer rate the interface between the end customer’s PC and the modem/router supported.

[11] Classification according to Eurostat
[12] Federal Statistical Office, “List of Municipalities, territorial status: 31 December 2011 (4th quarter)”, January 2012

Amount of traffic transferred at the interfaces

The amount of traffic transferred in the upstream and downstream direction at the interfaces could also be established with a subset of modems/routers by reading a byte or packet counter (interface traffic counter). As a result, data traffic that is running parallel to the measurement - caused, for example, by applications that are running in the background or other terminal equipment that accesses the modem/router - could be recognised and taken into account.

2.1.3.2.2 Control measurements via the nationwide measurement platform

In order to monitor the accuracy of the measurements taken by the software, the application automatically measured the data transfer rate on test connections at various measurement platform sites.[13]

Using these test connections, the results from the regular data transfer rate measurements conducted by the measurement platform could be compared with the results of the measurements for various providers and advertised data transfer rates that were carried out on the test connections using the software application.

Obvious deviations were not observed during the period covered by the study. The results of the control measurements are presented in Section 4.3.

Optical fibre accesses were not activated at the nationwide measurement platform's sites during the study. Consequently it was not possible to conduct any control measurements for this technology to check the quality of the measurements conducted using the application. For this reason, measurements of optical fibre accesses were not included in the analysis.

[13] The concept and structure of the measurement platform are detailed at 2.1.2.1.

2.1.3.3 Statistical aspects of the study

2.1.3.3.1 Sampling structure

What does an optimal random sample look like?

The study was designed to permit conclusions regarding the parent population of the some 28 million private households with broadband access in Germany. For this purpose, a sample was to be selected that would enable valid conclusions to be drawn regarding the parent population, in other words, that represented the parent population as closely as possible.

In statistics, a simple random sample is considered representative when all members of the parent population – in this case, every person with broadband access – have equal chances of being selected.

Given that the market shares held by the providers vary greatly in size and valid estimates of the actual average bandwidth in the parent population were to be made as far as possible for smaller providers as well, a simple random sample would not be optimal. In the case of a random sample with 2,000 participants, a provider with a market share of 0.8% would have an average of only approximately 16 participants. At the same time, a major provider with a 45% market share would be represented in the study with some 900 participants. Assuming that the variance of the measured values is not linked to the size of the provider's market share, it would be possible to estimate the average for the large provider with much greater accuracy than for the small provider.

For this reason, if the random sample were to be drawn on a targeted basis, it would be better to give preference to a stratified sampling method which would lead to smaller providers being more strongly represented than larger providers. When calculating an overall average for all providers combined, the stratification could be taken into account by means of weighting.

Both the simple random sample and the stratified sample allow unbiased estimates of the simple averages in the parent population. Unbiased means that on average, when multiple samples are drawn, the averages of the sample match those of the parent population.

Why was it not possible to obtain an optimal sample for this study?

As explained above, for a sample to be random, the probability of being included in the sample must be the same for each member of the parent population.

For this study, a random sample could have been realised by, for example, randomly selecting N participants from a list of all private households with broadband access. A precondition for such a list is that all Internet access providers make their customers' particulars available. In our view, this approach was not workable.

The alternative of leaving it up to the Internet access providers to randomly select the sample from their databases also had to be ruled out due to reasons of neutrality because it would not be possible to verify the selection procedure and there would be the risk of the results being influenced.

Even if it were possible to make a random selection from all households with broadband access, a bias would arise through the fact that not all selected households would be willing to participate.

For this reason, the following section outlines alternative methods for sampling.

Which alternative methods for sampling were feasible for this study?

Open end-customer measurements

Here, advertising appeals would be launched with the aim of inducing as many of the approximately 28 million private households with broadband access in Germany to conduct measurements with the special software. Participation in the study would be voluntary. Consequently, the question of whether a member of the parent population would participate depends on, firstly, whether the advertising campaign reached him/her and, secondly, whether he/she was motivated to take a few minutes' time and take part. By launching the calls for participation widely in a variety of media, it would be possible that a large proportion of the parent population learned about the study. It could not however be ruled out that not all Internet users who see the appeal would be equally motivated to participate in the study. It is possible that customers who are dissatisfied with the quality of their Internet access tend to be more interested in measuring their actual bandwidth than customers who are largely satisfied. In the case of voluntary participation, the sample is subject to self-selection by the participants and consequently is not a random sample.

Panel method

Panel solutions have been chosen for a number of studies (some of which are still ongoing) involving similar issues in Great Britain, the USA and the European Union. The measurements for these studies were conducted using hardware boxes that had been provided to the end customers. The individual measurements themselves were conducted on an automated basis without the need for interaction with the end customer. In these cases, Internet users were invited via advertising appeals to apply for a chance to participate. A panel was then selected from the total population of the applicants in such a way that the distribution of the market shares in the panel reflected the distribution in the parent population as closely as possible. It is obvious that this approach is just as subject to self-selection as the solution outlined in the above section in which all applicants automatically participate in the study rather than having to first undergo an application and selection process.

Likewise, a panel comprised of selected volunteer applicants is by no means a random sample because in such cases the issue of whether the Internet users can be reached by the advertising and the question of their level of motivation play an essential role as early as the application process. Only those Internet users will apply who have become aware of the study and who at the same time are interested in participating. Only this subgroup of the parent population would be available for selection as members of the panel. Here too, a panel that has been selected in this way cannot be representative of the entire parent population.

Effects of bias

The extent to which the above-described bias in the selection of the sample influences the informational value of the study depends on the type of statements to be made.

It is likely that the bias applies equally to all providers, products, regions and technologies. In particular, it is not to be expected that only highly dissatisfied customers of provider A and only especially satisfied customers of provider B would take part in the study. Assuming that the motivation to participate in the study is not dependent on the factors that are the actual object of the study (provider, product, region, technology), valid statements regarding differences such as between providers, regions or technologies can be made despite bias in the sample.

Method chosen for the study

Of the above-mentioned sampling options, an open end-customer measurement in which every end customer can generate a measurement offered better conditions than a standing study panel with a fixed composition. In this type of panel every participant generates numerous measurements. These cannot however be considered genuine replications because they are measurements of the same Internet connection that are taken numerous times at staggered intervals. In light of this, the measured values would have to be averaged for each hardware box so that, for example, when there are 2,000 participants only 2,000 (averaged) measured values are available. Since it can additionally be assumed that the variability in a connection is much less than the variance between several connections, preference was ultimately given to the end-customer measurement over a measurement panel.

A total of 375,412 measurements were conducted during the 2013 study; out of these measurements a total of 153,216 valid individual measurements were included in the analysis. The figures for these measurements were 547,978 and 226,543 respectively for the 2012 study, with the call for participation in the 2013 study being issued approximately six weeks later (24 July 2013) than in 2012 (14 June 2012).

As a result, it was possible to make estimates for smaller subgroups which would have been too imprecise in the case of a panel-based study because the sample would have been very small.

In order to obtain the largest possible sample, the Bundesnetzagentur issued press releases for wide distribution in various media to invite end customers to conduct measurements.

This was done with the aim of ensuring that the largest possible share of the parent population would be reached and persuaded to take part in the study. This approach was particularly chosen so that not just broadband customers with a particularly strong affinity for the Internet would participate in the study.

2.1.3.3.2 Statistical monitoring

As part of the study, end-to-end controls were conducted to ensure that the measurements correctly reflected the parent population of private households with broadband access in Germany in terms of provider, bandwidth class, technology and spatial distribution. This was done on the basis of the following distribution parameters:

Provider

The study examined data transfer rates on the basis of fixed broadband accesses of various providers. For the statistical monitoring, the market shares held by the ten largest providers were compared with the sample. The sample included national, regional and local providers in order to provide a representative picture of the providers operating in the German market (see Table 3). The providers are not named in the Results section but rather listed as provider A, provider B, provider C and so on. Together, they represent 96.5% of the market. The remaining providers were grouped together under Others.

Table 3: Providers of fixed broadband accesses
(Source: VATM Telecommunications Market Analysis Q3/2013)

Fixed broadband connections	
Provider	**Market share**
Telekom	43,8%
Vodafone	10,6%
United Internet	12,0%
Telefónica	8,1%
Unitymedia KabelBW	8,5%
Kabel Deutschland	7,1%
EWE	2,5%
Versatel	1,8%
NetCologne	1,4%
M-net	0,7%
Other	3,5%

Connection technology

The measurements were compared with the national distribution of the different connection technologies.

Bandwidth class

The data transfer rates were grouped into the following broadband classes for statistical monitoring purposes:[14]

- ≥ 0.144 Mbit/s to ≤ 2 Mbit/s
- > 2 Mbit/s to < 10 Mbit/s
- ≥ 10 Mbit/s to < 30 Mbit/s
- ≥ 30 Mbit/s to < 100 Mbit/s
- ≥ 100 Mbit/s

Region

The study also examined how the measured data transfer rates are distributed across urban, semi-urban and rural areas (see Figure 2.4). The population density was calculated for each postal code[15] on the basis of the List of Municipalities[16] and the postal code database of Deutsche Post AG[17]. In a second step the postal codes were then classified as urban, semi-urban and rural, based on their population density.

The classification used here was based on the following criteria which were developed by the Statistical Office of the European Communities (Eurostat) in cooperation with the Member States:[18]

---

[14] Reference distribution according to the bandwidth clustering of the European Commission COCOM, as of 31 December 2011. The change in the lower two classes that took effect in 2012 was not applied in this study.
[15] The postal codes for post office boxes were not taken into consideration because they do not directly indicate a specific geographical area.
[16] Source: Federal Statistical Office: List of Municipalities, territorial status: 31 December 2011 (4th quarter), month of publication: January 2012, excerpt of selected attributes from municipal data (supplemented with data relating to the municipal association); all autonomous municipalities in Germany, broken down by surface area, population, population density and postal code of the municipality's administrative seat
[17] www.postdirekt.de/plzserver
[18] Source: Press release No. 237 of the Federal Statistical Office dated 30 May 2005

- Urban: Population density of more than 500 residents/km²
- Semi-urban: Population density of 100 to 500 residents/km²
- Rural: Population density of less than 100 residents/km²

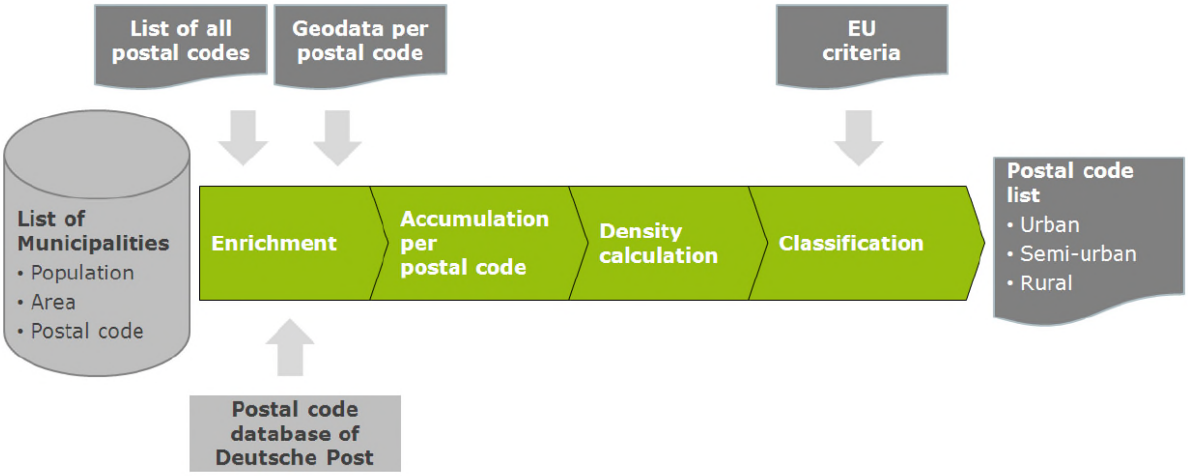

Figure 2.4: Geographical classification

Since the measurement was supposed to represent a statistically independent random sample, it was also limited to one measurement per access. Consequently multiple measurements had to be identified as such.

- In cases where an AVM Fritz!Box was used, multiple measurements could be identified on the basis of the Fritz!Box ID.
- A combination of IP address and postal code was used in all other instances.

When multiple measurements were identified, only the last measurement was used. In addition, it was pointed out to the end customer before the measuring process began that only one measurement per access was needed.

2.1.3.3.3 Statistical analysis of the data

In order to be able to compare the measured data transfer rates for different advertised data transfer rates, the measured data transfer rates were divided by the advertised data transfer rates of the connections as reported by the users and then multiplied by 100. In other words, the "measured data transfer rate expressed as a percentage of the advertised transfer rate" was analysed.

The proportions of users for whom at least x% of the advertised data transfer rate was measured were calculated for various threshold values.

In addition, a 95% confidence interval was calculated for these proportions. A confidence interval is an interval that covers the actual proportion in the parent population with a 95% probability.

The calculation uses the approximation formula developed by Wilson and the confidence interval is given as $[p_u, p_o]$ with

$$p_{o,u} = \frac{1}{1+\frac{c^2}{n}} \cdot \left(\hat{p} + \frac{c^2}{2n} \pm c \cdot \sqrt{\frac{\hat{p} \cdot (1-\hat{p})}{n} + \frac{c^2}{4n^2}} \right).$$

Here, c = 1.96 (0.975 quantile of the standard-normal distribution[19]).

The data from the Network Quality Initiative was analysed using the R 3.0.2 software.

[19] Agresti, Alan, und Coull, Brent A.: *Approximate is better than 'exact' for interval estimation of binomial proportions*, The American Statistician 52, 119-126 (1998)

2.1.3.4 Determining the data transfer rate at different times of the day

In addition to the data transfer rate, it was also determined whether the measured data transfer rates varied depending on the time of day. These measurements were not however conducted by end customers. Instead, the data transfer rates of the fixed test accesses on the nationwide measurement platform were measured at different times of the day.

This was due to the fact that the causes for the fluctuations observed at different times of the day in the data transfer rate for fixed broadband connections are probably primarily to be found in the province of the networks and not in the area of the individual connection. In light of this, it did not appear necessary to determine the temporal distribution for each end-customer connection.

Measuring procedure

The data transfer rate was determined at different times of the day by measuring the upload and download data transfer rates. The measurements were conducted using the method described at 2.1.1, 23 hours a day, seven days a week for a period of six months in order to record day-specific and time-specific fluctuations in the available data transfer rate.

Time frame

These measurements were conducted from 1 July 2013 to 31 December 2013.

2.2 Transfer time measurement (measurement platform)

The transfer time measurements were conducted on the fixed test connections on the nationwide measurement platform (see 2.1.2.1).

The transfer time measurement involves sending a ping request to a data reference system. This request is transmitted by the network nodes along the transmission path and answered by the queried system in the opposite direction. The transfer time is the time that has elapsed between the sending of the request and the receipt of the response.

A transfer time measurement conducted on the measurement platform consists of 30 consecutive ping measurements[20] that are carried out in 1-second intervals from a monitoring unit to the data reference systems.

The *transfer time* measurement is defined here as the time that elapses between sending a ping request (ICMP echo request) and the receipt of the response to it (ICMP echo reply).

The *average transfer time value* is the average response time in milliseconds for all transfer times in a transfer time measurement.

2.3 Quality of a standard application – web browsing (measurement platform)

The quality of web browsing as a standard application was also ascertained on the fixed and mobile test accesses of the nationwide measurement platform (see 2.1.2.1).

In order to simulate typical user behaviour, the ten websites which, according to the Alexa Top Sites list[21], were visited most often in July 2013 were accessed (see Table 4). The composition of the list was kept the same during the measurement period.

[20] ICMP echo requests with a packet size of 32 bytes
[21] See www.alexa.com/topsites/countries/DE

Table 4: Alexa Top 10 Sites (as of: July 2013)

Alexa Top 10 Websites in Germany // July 2013	
Ranking	Website
1.	http://www.google.de
2.	http://www.facebook.com
3.	http://www.youtube.com
4.	http://www.amazon.de
5.	http://www.ebay.de
6.	http://www.google.com
7.	http://www.wikipedia.org
8.	http://www.web.de
9.	http://www.gmx.net
10.	http://www.yahoo.com

In connection with the web browsing use scenario, the time it takes for a website to load completely was ascertained. The end user perceives this process as a single event. From a technical standpoint however different phases can be measured (DNS response time, HTTP response time and website download time). These quality parameters were individually ascertained as outlined below.

DNS response time

This measurement states the time it takes in milliseconds to translate domain names to IP addresses.

DNS response time is defined here as the time that elapses between the sending of a DNS request (DNS query) to the terminal and the receipt of the resolved IP address (DNS query response).

HTTP response time

This value is the response time of an HTTP initialisation to the websites of the *Alexa Top 10* in milliseconds.

HTTP response time is defined here as the time that elapses between the sending of the initial HTTP request (GET HTTP) until the receipt of the first TCP packet of the HTTP response.

Website download time

This measurement indicates the amount of time in seconds that is needed to download completely the Alexa Top 10 websites.

The *website download time* is defined here as the time that elapses between the sending of the initial HTTP request (GET HTTP) and the receipt of the last HTTP response (HTTP 200 OK).

A WebKit browser engine that supports JavaScript and Web 2.0 sites was used to record DNS response times, HTTP response times and website download times. It consequently permits the accurate observation and recording of the processes that take place when websites are called and loaded. As a result it is possible to precisely determine the individual times for the complete download of websites.

3 Presentation of the measurement results

3.1 Presentation parameters

The evaluated data records are presented in the Results section using the following parameters:

Provider

The study examined the data transfer rates achieved using fixed broadband accesses of various providers. The data records for the ten largest providers and the group of Others were used here.

Between 1,204 and 69,667 validated measurements were collected for the ten providers with the largest market shares (see Table 1). The names of the providers were not specified. Instead they were listed as provider A, provider B, provider C, and so on. Smaller providers were grouped under Others.

Technology

The fixed broadband connections are shown broken down by the following technologies:

- DSL
- Cable
- Fixed LTE

Bandwidth class

The data transfer rates are grouped in the following bandwidth classes:[22]

- ≥ 0.384 Mbit/s to ≤ 2 Mbit/s
- > 2 Mbit/s to ≤ 8 Mbit/s
- > 8 Mbit/s to ≤ 18 Mbit/s
- > 18 Mbit/s to ≤ 25 Mbit/s
- > 25 Mbit/s to ≤ 50 Mbit/s
- > 50 Mbit/s to < 100 Mbit/s

Accesses with data transfer rates of ≥ 100 Mbit/s were not included in the analysis.
The reasons for this are detailed at the start of Section 5.

Regions

In addition, the data transfer rates of various regions are presented. The criteria that were already used in connection with statistical monitoring were used as the basis for defining urban, semi-urban and rural areas (see 2.1.3.3.2).

[22] In contrast to those bandwidth classes that provide the basis for statistical monitoring, bandwidth classes for the evaluation of the measured values were based on the typical data transfer rates for the respective transmission technology (such as xDSL or cable) and the commercially-available products.
This made it possible to form suitable control groups and depict effects that are typical of the respective technology with respect to the data transfer rates.

3.2 Graph-based presentation of the measurement results

The available data transfer rate is shown in the Results section as a percentage of the advertised data transfer rate.

The following tables and graphs show the estimated values in individual subgroups only when enough measurements were available for the respective subgroup to permit a sufficiently accurate statistical estimate. The width of the confidence interval for the respective estimated proportion was used as a criterion for accuracy. Only subgroups with a maximum confidence interval width of 10 percentage points are shown.

The confidence intervals are shown in square brackets in the following tables.

Empirical distribution functions and box plots are used for the graph-based presentations of the measurement results.

Empirical distribution functions

Average values do not always provide an accurate picture of how a sample behaves in terms of the parameters under examination. The average value of 60% can be reached when all users receive exactly 60% of the advertised data transfer rate. However, a sample in which half of the users receive 80% of the advertised data transfer rate and the other half of the users receive 40% would also have an average actual data transfer rate (expressed as a percentage of the advertised rate) of 60%. For this reason, distribution functions can provide a better overview of the structure of the measured values.

Figure 3.1 shows an example for the data transfer rates of two subgroups using simulated downloads. The actual data transfer rates (expressed as a percentage of the advertised data transfer rate) that were measured range between 0 and 120% (x-axis). This chart shows for each actual data transfer rate x (expressed as a percentage of the advertised data transfer rate) the number of users who measured at least x% of the advertised data transfer rate. The blue curve is an example of a nearly optimal ratio between the advertised and the realised data transfer rate. A total of 97.6% of the users in this group received at least 90% of the advertised data transfer rate; this figure is approximately 20% for users in the red group.

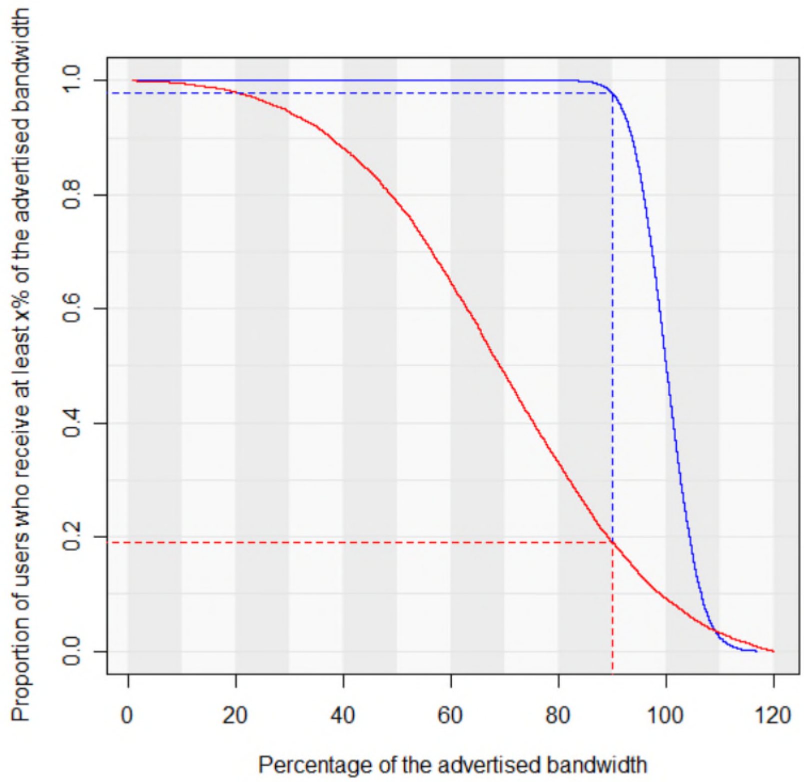

Figure 3.1: Example of two empirical distribution functions

Box plots

While conducting the analysis, some of the measured values were also broken down by several parameters such as region or technology. Box plots were used to provide an easily understandable depiction of the dependencies in the distribution of several parameters. A box plot can quickly indicate the value range in which the data are located and their distribution within this range.

A box plot always consists of a rectangle or square – the box – and two lines that extend from the box. These lines are called 'antennas' or 'whiskers' and are capped by a line. The box represents the area in which the medial 50% of the data lie and consequently gives an impression of the distribution of the data.

The horizontal line in the box marks the median of the distribution. This line divides the entire diagram into two halves, each containing 50% of the data. The position of the median within the box provides an indication of the skew of the data's underlying distribution. For example, a median of 80% of the advertised bandwidth means that half of all customers received less than 80% of the advertised bandwidth while the other half received more than 80%. Twenty-five per cent of all measurements are less than the lower edge of the box and 25% are greater than the upper edge of the box.

The length of the *whiskers* was limited to 1.5 times the box length. The whiskers do not however extend beyond the smallest or largest value. Measurements that are located more than 1.5 times the box length from the lower or the upper quartile are individually shown as outliers.

Figure 4.2 shows as an example a box plot for a positively skewed attribute and the corresponding histogram.

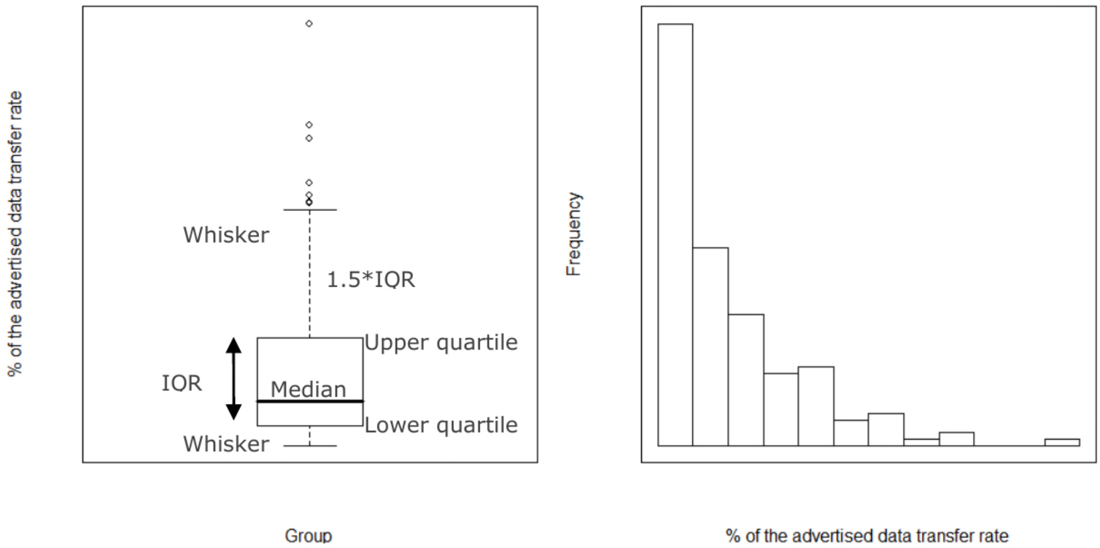

Figure 3.2: Example of a box plot and corresponding histogram

3.3 The 2012 and 2013 studies in comparison

The results from the study conducted in 2013 are compared with the results of the 2012 study in the Results section.

This is done using box plots and empirical distribution functions with the results from the 2012 study being shown in a lighter colour.

Figure 3.3 shows an example of a comparison that is illustrated with the help of a box plot. The results from the 2013 study are shown in green and the results from the 2012 study in light green. The same principle was used for the comparison of the empirical distribution functions shown in Figure 3.4.

In the interest of clarity, comparisons in table form were not used. Tables with the results from the 2012 study can be found in the final report for the 2012 study.

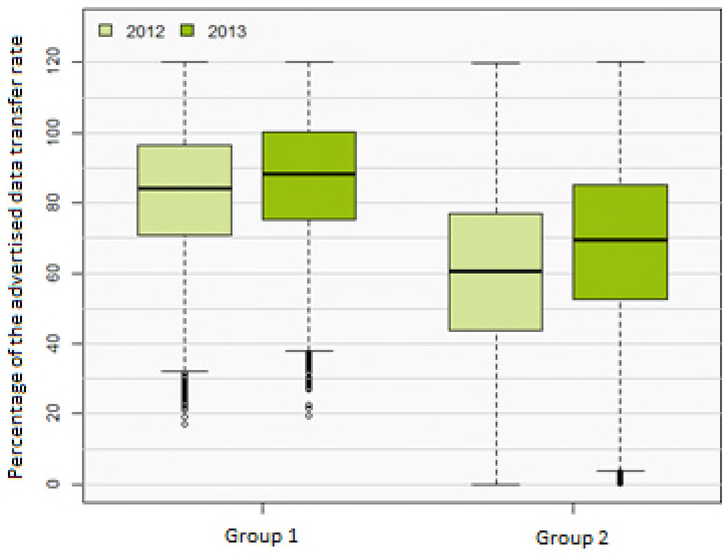

Figure 3.3: Example of a box plot used for a comparison

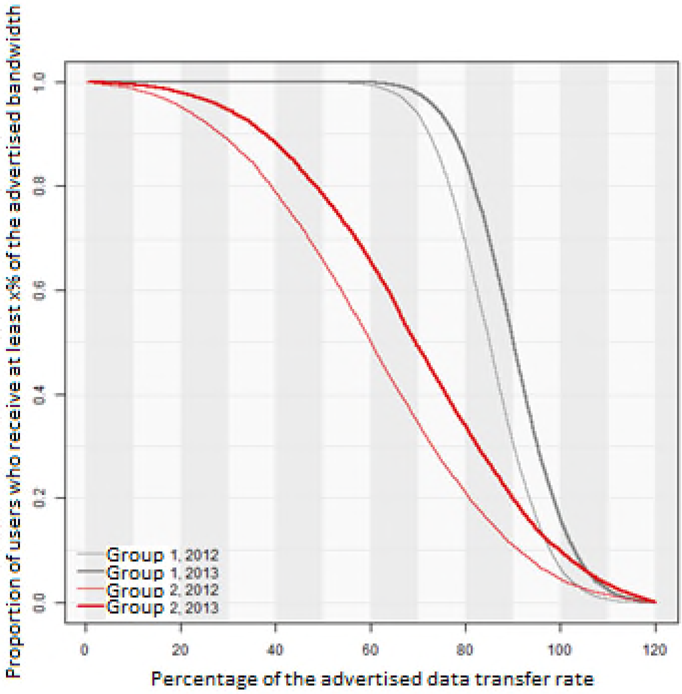

Figure 3.4: Example of empirical distribution functions presented as a comparison

Results

4 Underlying data

4.1 End-customer measurements (Network Quality Initiative)

4.1.1 Sampling structure

The sample used was not a random sample, but rather all customers could participate who had learned of the study through calls to participate and were motivated to carry out measurements on their terminal equipment.

Several times during the course of the study, the sampling structure was checked on the basis of the collected parameter data and compared to the respective distribution in the parent population. These parameters were:

- Provider
- Federal state
- Geographical area (urban, semi-urban, rural)
- Technology
- Bandwidth class

An approximation of the population distribution was achieved. The following section outlines the findings from the statistical monitoring.

Only those participants are shown and analysed who remained in the sample after the technical validation and who stated they had Internet access via DSL, cable or fixed LTE with a data transfer rate of < 100 Mbit/s.

Provider

Figure 5.1 compares the percentage proportion held by the respective provider in the sample with the market shares held by providers according to the VATM Telecommunications Market Analysis Q3/2013. These market shares serve as reference distribution. Since these figures reflect only the market share for fixed broadband connections, only those study participants were taken into account who indicated a fixed DSL, cable or LTE access as their technology.

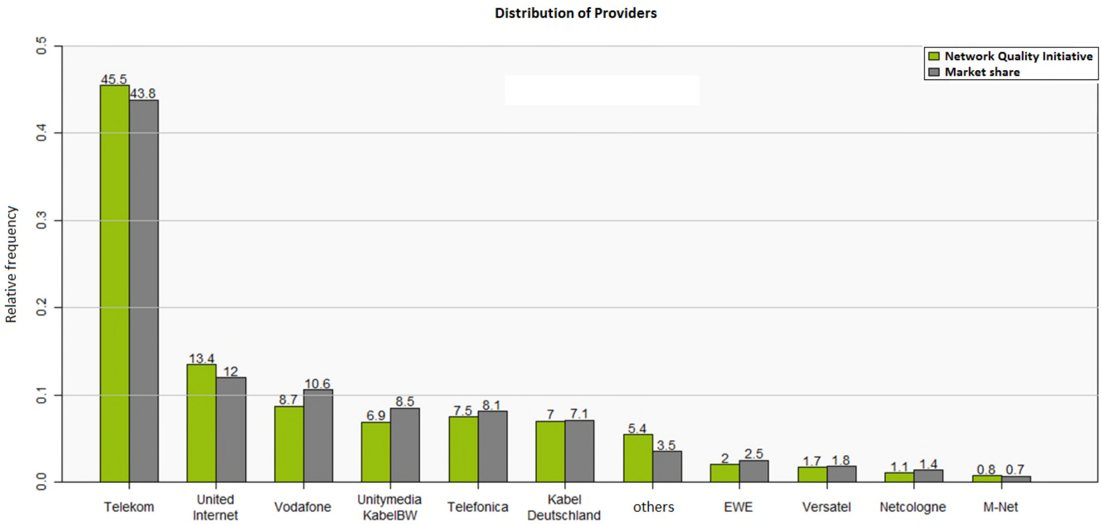

Figure 4.1: Distribution of the providers in the Network Quality Initiative sample compared to their market shares according to the VATM Telecommunications Market Analysis Q3/2013

All in all, the distribution of the test measurements very closely matches the reference distribution of market shares held by the providers examined here.

Federal state

Figure 4.2 shows the distribution of the study participants by federal state compared to the distribution of broadband accesses. The distribution of the broadband accesses by federal state was calculated by multiplying the population distribution as per the Federal Statistical Office's List of

Municipalities[23] by the state-specific broadband index issued by (N)onliner Atlas[24].

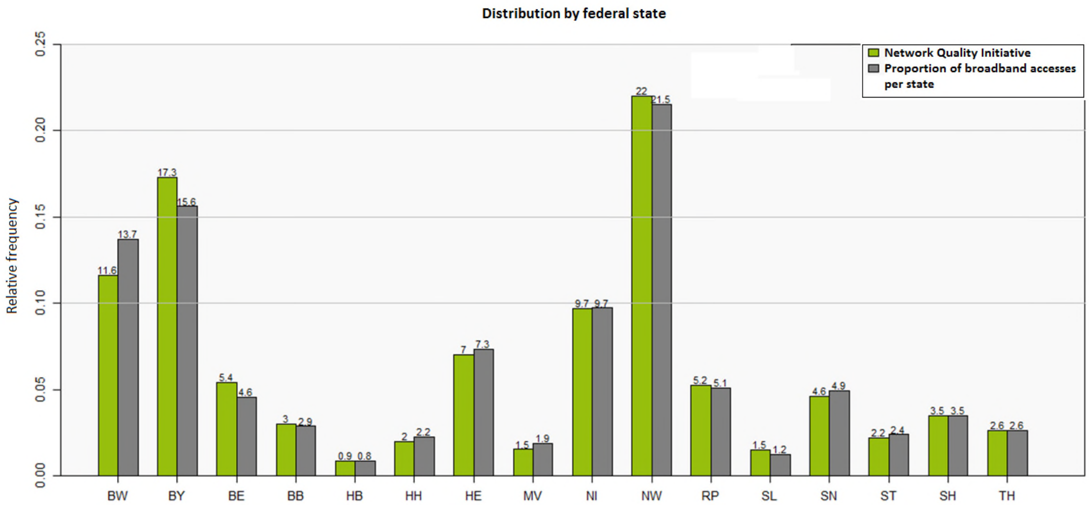

Figure 4.2: Distribution of the study participants by federal state, compared with the distribution of the broadband accesses[25]

The measurements very closely reflect the regional distribution of broadband connections by federal state as well. Broadband connections are slightly underrepresented in Baden-Württemberg whereas Bavaria commands a larger share of the sample than would be expected based on the distribution of the broadband accesses.

Geographical area

The participants' accesses were classified as rural, semi-urban or urban accesses based on the reported postal codes and then compared with the population distribution in the respective region (Figure 4.3).

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[23] Federal Statistical Office "List of Municipalities, territorial status: 31 December 2011 (4th quarter)", January 2012

[24] Initiative D21, "D21 - Digital - Index - (N)onliner Atlas 2013", p. 24 Breitbandnutzung nach Bundesländern (Broadband use by state), April 2013

[25] BW: Baden-Württemberg; BY: Bavaria; BE: Berlin; BB: Brandenburg; HB: Bremen; HH: Hesse; MV: Mecklenburg-Western Pomerania; NI: Lower Saxony; NW: North Rhine-Westphalia; RP: Rhineland-Palatinate; SL: Saarland; SN: Saxony; ST: Saxony-Anhalt; SH: Schleswig-Holstein; TH: Thuringia

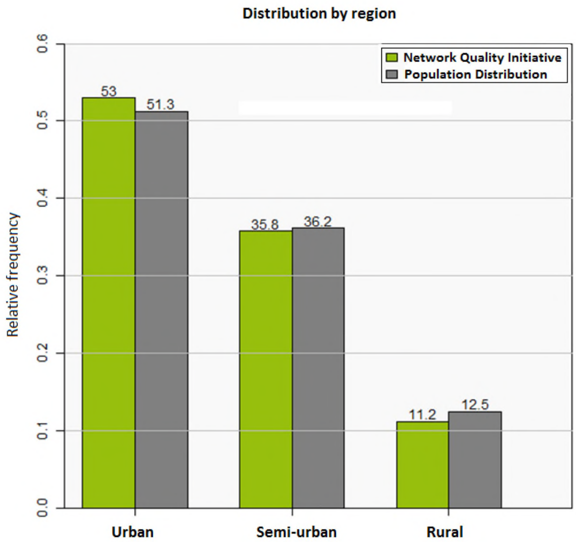

Figure 4.3: Distribution of the study participants by region, compared with population statistics

Here too, when compared with the reference distribution, the distribution of the measurement results was good on the whole.

Although the participants from rural and semi-urban areas are slightly underrepresented compared to population statistics, it must be remembered that the population statistics in Germany were chosen as the basis for the reference distribution because the exact regional distribution of all broadband accesses is not known. It is fundamentally conceivable here that particularly the proportion of broadband accesses per resident is smaller in rural areas than it is in cities. In this case, the deviations would probably be even smaller.

Technology

According to data from the Bundesnetzagentur, DSL accesses account for 82.1%, cable accesses for 17.0% and fixed LTE accesses for 0.9% of the broadband accesses in Germany (see Figure 4.4). The number of measurements of fixed LTE accesses was somewhat higher than seen in the reference distribution.

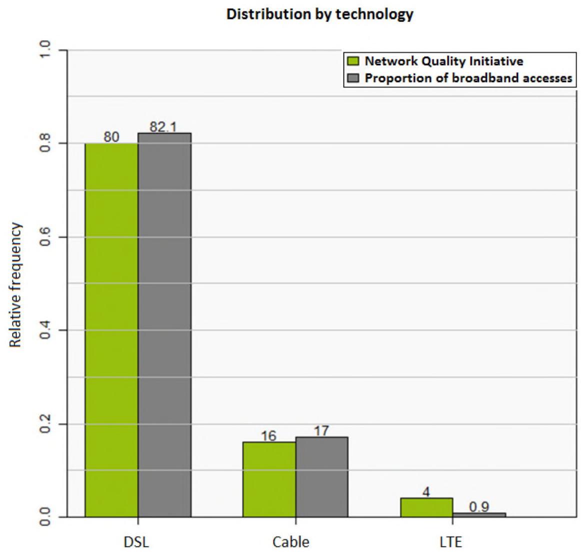

Figure 4.4: Comparison of the technologies study participants indicated that they use, with the distribution of broadband accesses (Activity Report of the Bundesnetzagentur, Q2/2013)

Bandwidth class

Figure 4.5 shows the distribution of the study participants' accesses by bandwidth class. The distribution of all broadband accesses in Germany was chosen as the reference distribution[26]. The bandwidth classes presented here are used solely for a comparison with the parent population. Other, technology-based classes (see 3.1) were chosen for the actual evaluation in the following sections.

[26] Reference distribution according to the bandwidth clustering of the European Commission COCOM

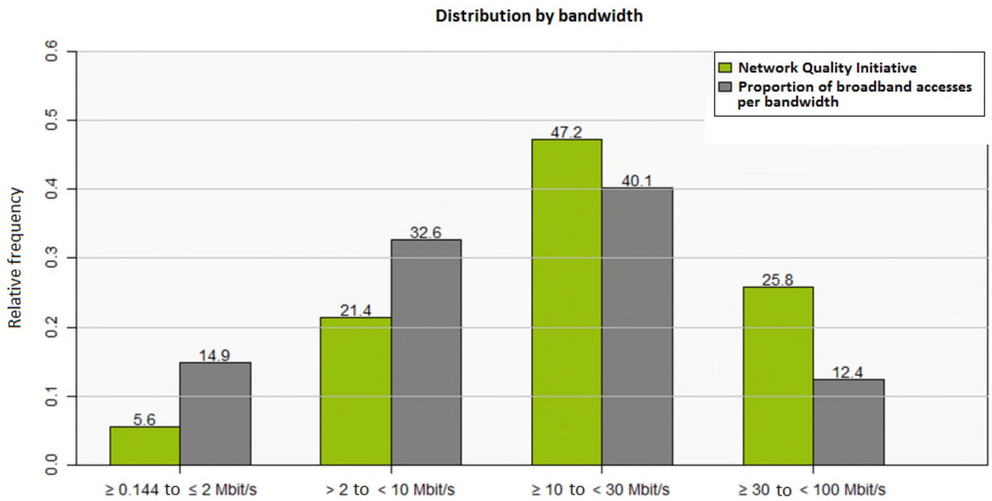

Figure 4.5: Distribution of study participants' accesses by bandwidth class and reference distribution as of Q2/2013 (Source: Bundesnetzagentur)

It is striking that the two lower bandwidth classes are underrepresented while the upper bandwidth classes are more strongly represented than would be expected from a random sample. Customers who generally pay higher prices for more bandwidth are apparently more motivated to measure how much bandwidth is actually being provided. It is also conceivable that less computer-savvy customers who have a standard DSL access are less likely to feel that the calls to take part in the study are directed at them.

Conclusions

The results of the statistical monitoring conducted for this study show that the sample largely approximates the parent population in terms of the parameters Technology, Provider and Geographical Distribution (federal states as well as urban, semi-urban and rural regions). In particular, the customers of all providers and in all of Germany were reached in line with their market shares / population distribution. Further, the sample displays no discernible bias with respect to the parent population when the regions (rural vs. urban) or technology are examined.

The marks that the study participants gave for customer satisfaction likewise exhibit a unimodal distribution with a cluster in the good to satisfactory range (see Figure 5.17). Thus, there is no discernible bias in the sample in the direction of particularly dissatisfied customers.

The proportion of customers with high bit-rate connections in the sample is larger than would be expected in the case of a random sample. In comparison, customers in the lower bandwidth classes were apparently not as motivated to participate. Since the average actual data transfer rates (expressed as a percentage of the advertised data transfer rate) varies from bandwidth class to bandwidth class, it is possible that the unweighted average actual data transfer rate (expressed as a percentage of the advertised rate) in the sample is not unbiased. This effect cannot be observed within a bandwidth class when the study participants of the respective bandwidth class otherwise constitute a representative sampling of all customers in that bandwidth class. We assume this, based on the above-described results from the monitoring.

For this reason, in addition to the overall averages of the sample, distinctions were also made according to bandwidth class for all the parameters examined during the study. When a bandwidth class is more strongly represented in the sample than its percentage share of the parent population, this leads to the estimate being more precise than is to be expected from a random sample. The estimate is less precise when the subgroups are underrepresented. However, with the sample sizes obtained for this study, this effect is negligible.

Overall, the sample permits valid statistical estimates for the above-mentioned categories and requirements.

4.1.2 Optimal test environment

As part of the test, the participants were asked if the measurement was conducted via a wired connection (LAN) and without any other applications, such as a virus scanner, running in the background on their PC. An 'optimal test environment' is deemed given when this was not the case (for further details, see 2.1.2.2).

The effect of measurements performed via WLAN or measurements with parallel data traffic was examined in separate analyses for a subgroup of participants for whom additional router values could be read (see 5.2.2 and 5.2.3).

For this subgroup it was possible to (1) identify measurements that were not conducted under optimal conditions, irrespective of the participant’s statement regarding the conditions, and (2) exclude such measurements from the analysis or take their effects into account. This represents an important improvement over the first study.

The subsample examined in this case was a non-random subgroup of the total sample. As a result, the identified effects (proportion of participants who - despite reporting they had an optimal test environment - conducted the measurement via WLAN; effects of parallel data traffic) cannot be directly applied to the total sample. However, it seems very likely that comparable effects occur even among participants who use other modems/routers. The reason: There is no evidence of any difference between participants in the subgroup and participants in the total sample in terms of the information they provide regarding whether they had an optimal test environment.

Processes or applications (such as virus scanners or firewalls) that are directly integrated into the data exchange between the software application and the data reference system can also influence the measurement results. This could not yet be taken into account (see 2.1.2.2).

Software-based methods for conducting measurements are considered to be less trustworthy due to the above-mentioned effects because they are not used in a controlled environment (different end-customer installations). In contrast, hardware solutions can be specifically configured and installed so that the test environment is always the same.

It was determined in the course of this study that several aspects of the disadvantages presented by software solutions could be remedied through the possibility of reading additional values from the modem/router on an automated basis.

Since the interfaces used are read out and the actual data transfer rate between the end customer's PC and router/modem is measured, it is possible to detect whether a bad connection from the end customer's PC has impaired a measurement. Such measurements can be rejected.

The volume of the traffic that actually occurs on the Internet access is determined during the measuring process (traffic counter at the WAN interface) and, as a result, it is possible to identify and take into account any parallel data traffic that might occur.

However only the customer’s statement regarding the presence of an optimal test environment was taken into account during the validation process that was conducted in conjunction with the overall study, even when additional measurements for participants in the subgroup were available which would make it possible to determine whether the customer’s statement was accurate.

The measurements which, according to the customer’s statement, were obtained under sub-optimal conditions were excluded from the detailed analysis. This was the case for a total of 65,709 measurements.

Therefore measurements taken by the subgroup for which it was known that they were not conducted under optimal conditions even though the customer reported having an optimal test environment were also included in the analysis.

This procedure ensured methodological consistency between the first quality study and the current, second quality study. Treating a subset differently would have also led to bias in the overall study.

The analysis of the subgroup however enabled an assessment of the magnitude of the effects (use of WLAN, parallel data traffic) in the overall sample.

The results of the 2013 study must be understood against the backdrop of the available findings on the influence of the end customer’s test environment (see introduction to Section 5.)

4.1.3 Technical validation

The technical validation was conducted as outlined at 2.1.3.2.1.

Out of the 375,412 measurements conducted by end consumers, a total of 47,221 measurements were rejected based on cascaded plausibility checks.

The elimination of multiple measurements resulted in the rejection of a further 90,070 measurements.

A total of 3,728 measurements from connections using fibre optics technology and 600 measurements in the Others technology category (such as WiMAX and UMTS) were not considered in the analysis. Out the remaining measured values, 14,868 measurements taken on accesses with rates of 100 Mbit/s or more were excluded from the further, more detailed analyses.

Subsample with ascertained synchronised data rate of the connection

As part of the measurement, the synchronised data rate of the connection was also read for 34,051 users (22.2%) in the sample in order to compare the advertised data transfer rates specified by the users with the synchronised data rates of the connection. The synchronised data rate is a data rate that is set by the provider and which, viewed on an end-to-end basis, is the maximum rate the end customer can receive, without every factor that influences the data transfer rate being taken into account. This could only be done with users who use equipment from a specific subgroup of manufacturers.

It became clear here that the synchronised data rate regularly fell in the range that the end customers had specified as being the advertised data transfer rate. This indicates that end customers can differentiate between the data transfer rate that is referred to in advertising campaigns (such as on posters) for mass-market products and the data transfer rate of their own Internet access. Consequently, there is no particular reason to assume that the end customers – consciously or unconsciously – reported the faster advertising claim. The results are presented in detail at 5.2.1.

This conclusion probably applies to the entire sample. A comparison of the distribution of these measurements with the distribution of broadband accesses in Germany, broken down by region, federal state, technology and bandwidth class, showed that the distribution of users for whom the synchronised data rate of the connection could be determined reflects the distribution of the parent population just as closely as the entire sample did.

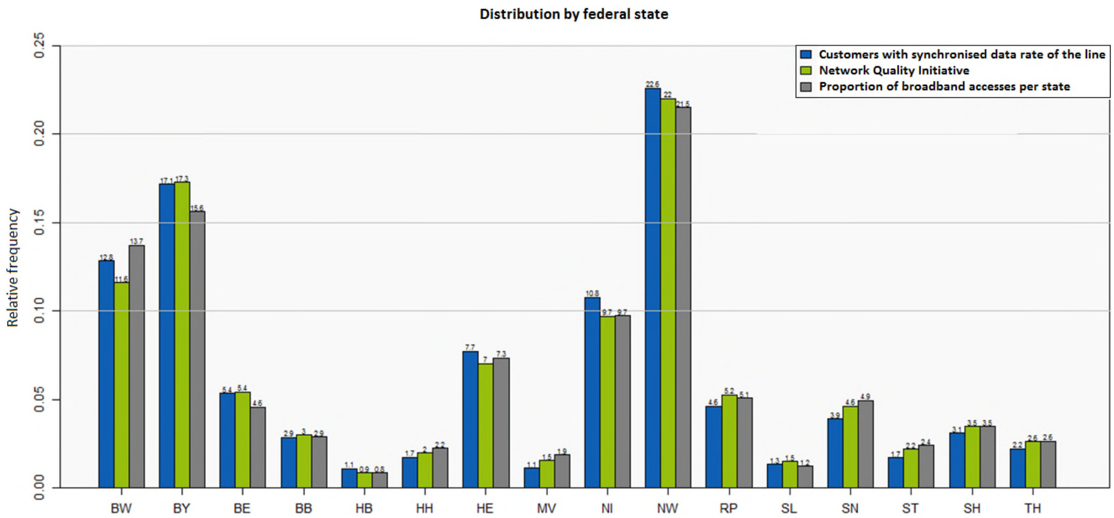

Figure 4.6: Distribution of the 2013 study participants by federal state in comparison to the distribution of the broadband accesses and in comparison to the subsample of customers for whom the synchronised data rate of their connection had been determined

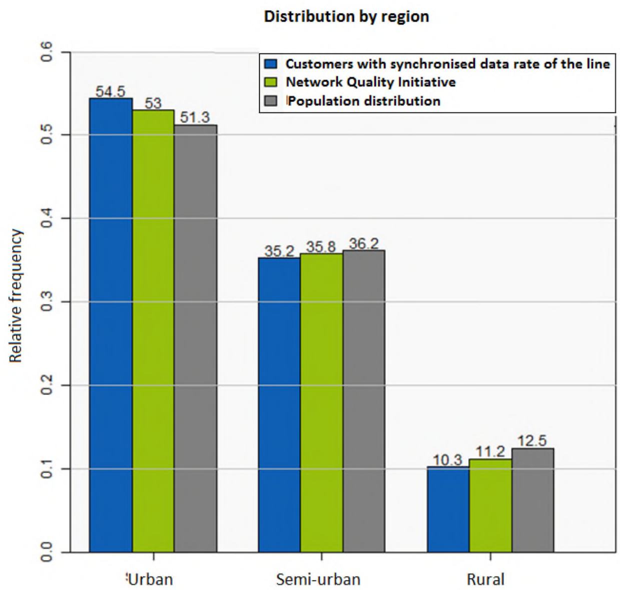

Figure 4.7: Distribution of the 2013 study participants by region in comparison to the population statistics and to the subsample of customers for whom the synchronised data rate of their connection had been determined

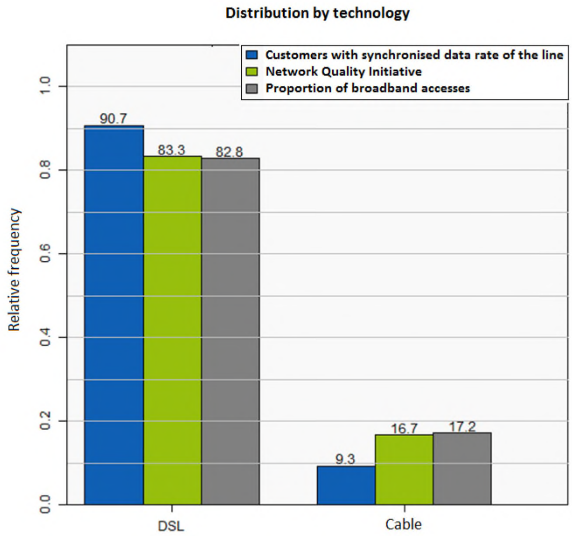

Figure 4.8: Comparison of the technologies specified by the study participants with the distribution of the broadband accesses (CoCom Q2/2012) and with the subsample of customers for whom the synchronised data rate of their connection had been determined

Marked differences in comparison to the parent population were discernible only with regard to the distribution of the providers as shown in Figure 4.9. This can be explained by the fact that the devices for which the synchronised data rate of the connection could be determined are standardly co-marketed by some providers, while other providers supply devices from other manufacturers.

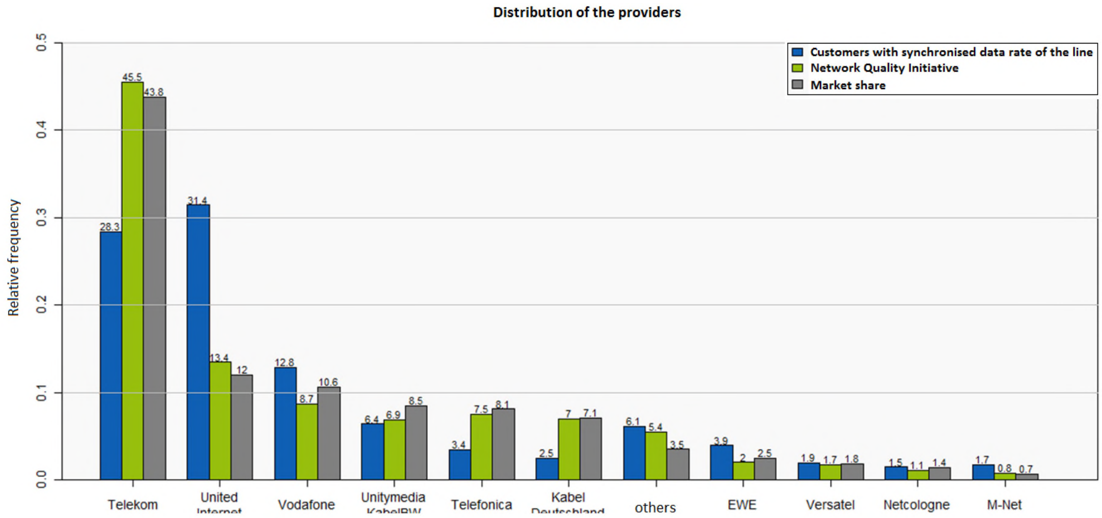

Figure 4.9: Distribution of the providers in the 2013 Network Quality Initiative sample compared with their market shares according to the VATM Telecommunications Market

Analysis Q3/2013 and with the subsample of customers for whom the synchronised data rate of their connection had been determined

4.1.4 Measurement period

The measurements taken in connection with the Network Quality Initiative which were examined as part of this study were conducted between 1 July 2013 and 31 December 2013.

4.2 Nationwide measurement platform

The measurements of fixed broadband connections conducted on the nationwide measurement platform were likewise carried out from 1 July 2013 to 31 December 2013.

The transfer times and the distribution of the data transfer rates over the course of the day were measured for fixed connections on the nationwide measurement platform. The typical end-user scenario 'web browsing' was also examined.

Table 5 shows the number of measurements conducted on the measurement platform in connection with the study. Control measurements were additionally conducted as part of the software's quality assurance testing.

Table 5: Number of measurements of fixed broadband connections conducted on the nationwide measurement platform for various tests

Fixed broadband connections	
Measurement	**N**
HTTP download	327.955
FTP upload	324.412
Transfer time	318.749
Web browsing	3.033.108

4.3 Control measurements

In order to monitor the accuracy of the measurements, the data transfer rate was measured on test accesses at various sites of the nationwide measurement platform on an automated basis using the software application.

The accesses tested at the sites of the nationwide measurement platform were the highest-quality accesses available at these metropolitan locations are extensively served by providers.

The regular data transfer rate measurements for these accessses as carried out on the measurement platform were compared with (1) the measurements that were ascertained for the individual providers using the software application and (2) the advertised data transfer rates.

To compare the measuring procedures, measurements obtained using the software and measurements that were conducted on the measurement platform close to the same time were examined for ten example accesses. A total of 25,648 reference measurements were conducted for this.

The percentage deviation was calculated as

100*(software measurement platform)/measurement platform

and shown as a box plot in Figure 4.10.

It emerged that the deviations exhibited by the connections ranged on average between -1.9% (average) or -2.4% (median) and +3.9% (average) or +4.1% (median).

Here, positive values mean that the software measured slightly higher values than than the measurement platform did. Negative values indicate that the software measured slightly lower values on average than the measurement platform did.

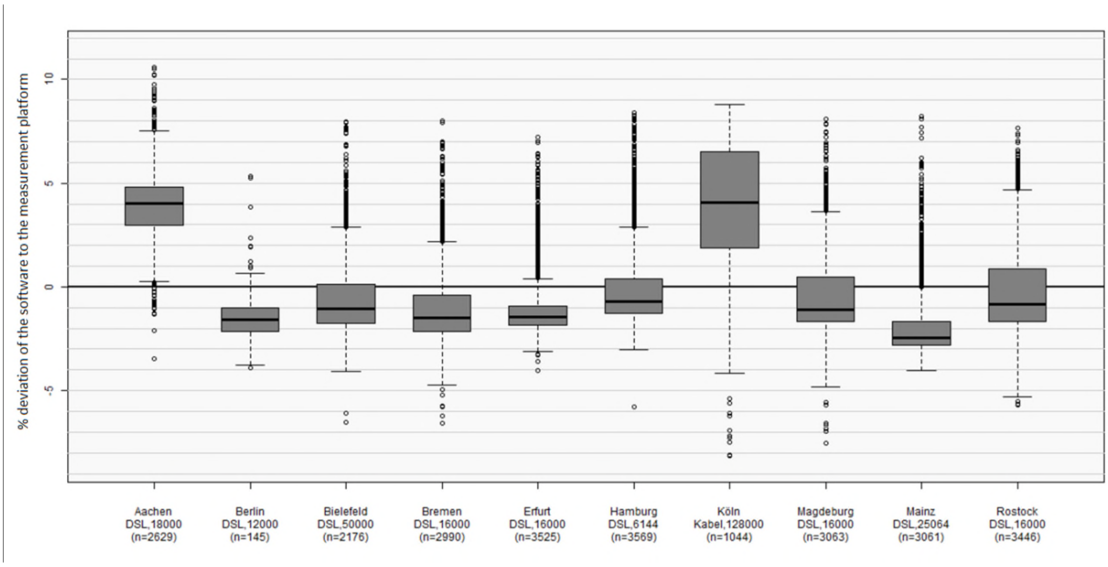

Figure 4.10: Comparison of the results of the regular data transfer rate measurements carried out on the measurement platform with the values ascertained using the software for ten connections

Some of the deviations are probably attributable to the fact that the measurements obtained with the software and the measurements conducted on the measurement platform that were compared with one another were not carried out at the same time. This would have been a prerequisite for an exact comparison of the measuring procedures. However, it is not possible to conduct a measurement on the same access using two different procedures at the same time because the two would influence each other.

5 Fixed broadband accesses

As already explained at Section 1, it is methodologically impossible to completely control the test environment for measurements conducted by end customers. Consequently it cannot be ruled out entirely or through the methodology used that measurements have been influenced by the end-customer environment. This means that the measurement results shown below are generally lower than those that were measured when the end customer's test environment is fully controlled.

When interpreting the measurement results, it is important that the effect of the influencing factors (use of WLAN, influence of parallel data traffic and processes, the end customer's setup in terms of hardware and software) is taken into account in the analysis of the measurement results. In addition, it is important that the influencing factors occur uniformly. In other words, that they do not affect certain test connections more than they do others.

The above-mentioned influencing factors are:

- **The connection between the end customer's PC (client) and the router/modem**
  In the case of one subgroup of modems/routers, it was possible to determine whether the measurement was conducted via WLAN by reading out the corresponding values from the modems/routers, irrespective of the statements the users provided regarding the test environment. It was determined that 9.0% of the measurements that were purportedly conducted in an optimal test environment according to the users were actually performed via WLAN although the user reported that the measurement was conducted in an optimal test environment without WLAN (for detailed results, see 5.2.2).

  However, it is not possible to precisely quantify or strip out the influence that WLAN has on the measurement results because values for measurements conducted on the respective access in a truly optimal test environment were not available. It can only be shown that the data transfer rate in the subgroup was lower when it was measured via WLAN rather than when using LAN.

  This subsample was a non-random subgroup of the total sample. For this reason, it is not directly possible to apply to the total sample the identified proportion of participants who - despite reporting they had an optimal test environment - conducted the measurement via WLAN. However, it seems very likely that a comparable proportion of participants who use other modems/routers also conducted their measurements via WLAN. It can be assumed that excluding these measurements from the total sample would lead to better results.

- **Parallel data traffic**
  In this subgroup of modems/routers, it was also possible to read out the amount of data traffic running parallel to the measurement, irrespective of the user's statement regarding having an optimal test environment.

As expected, it was found that parallel data traffic occurred during all measurements. Parallel data traffic accounted for less than 1% of the total data traffic in the case of more than half of the measurements in the subgroup. This figure was less than 4% for 90% of the measurements (for detailed results, see 5.2.3).

As with the examination of WLAN's influence on the measurement results, it is not directly possible to apply this to the total sample. However, it seems very likely that comparable effects arise also among participants who use other modems/routers and that the measurement results were consequently slightly worse.

- **Processes / Applications that influence the access used to perform the measurement**
  The measuring process can be influenced by processes or applications that are directly integrated into the data exchange between the software application and data reference system (such as virus scanners and firewalls). This could not be taken into account to date.

- **End-customer infrastructure**
  One possible factor in the end-customer setup that could possibly influence the achievable data transfer rate is the hardware used. Older PCs with network cards or modem/router interfaces with reduced energy consumption will support data transfer rates of no more than 100 Mbit/s.

  The effects of these factors are not uniformly distributed throughout the sample. Rather, they are relevant to broadband connections with an advertised download data transfer rate of ≥ 100 Mbit/s.

  In light of this, it appeared justified not to include connections with data transfer rates of ≥ 100 Mbit/s in the analysis. Consequently, only connections with an advertised data transfer rate of more than 50 Mbit/s and less than 100 Mbit/s are shown in the bandwidth class > 50 to < 100 Mbit/s.

- **Operating system on the end customer's terminal (client)**
  The operating system or browser used can also influence the achievable data transfer rate. A comparison of the measurement results for common operating systems and browsers showed that varying data transfer rates were achieved for them. These differences are however small and there was a uniform effect regardless of technology or

bandwidth class. In addition, it can also be assumed that operating systems and browser types were uniformly distributed across providers, products, regions and technologies.

Therefore it cannot be fundamentally ruled out that end users incorrectly evaluated the quality of their test environment. However, this was probably uniformly the case for the accesses examined. There is no reason to assume that only the end customers of a certain provider, product class or technology would incorrectly assess the quality of their test environment. Consequently, this factor generally applies uniformly to all tested connections. The same probably also applies, once the very high bit-rate accesses have been eliminated, to the effect that the parallel use of the Internet access service by other applications or terminal equipment has on the respective measurement.

When examining and assessing the following measurement results for data transfer rates that were measured by end customers it must be remembered that the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) could possibly be somewhat higher when the test environment is optimal. This does not however have any effect on the comparisons between the different subgroups.

5.1 Data transfer rate (end-customer measurements)

As already explained in 2.1.3.3.3, the measured data transfer rate was juxtaposed with the advertised data transfer rate.

Figure 5.1 shows the empirical distribution function of the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) for all users in the sample. The actual data transfer rates were between 0.9% and 120% of the advertised data transfer rates.

Compared to 2012, 'delivery reliability' improved throughout the entire sample, particularly in the mid-range of the proportions of the advertised data transfer rate received. A total of 77.1% of the users received 50% of the advertised data transfer rate or more (2012: 69.2%).

The proportion of users who measured the full advertised data transfer rate or more declined from 19.5% in 2012 to 15.9% in 2013.

The median shown in the box plot in Figure 5.2 rose from 73.4% in 2012 to 81.7% in 2013.

A possible reason for this could be - in addition to changes in the provider profiles - changes in the providers’ marketing or communication behaviour regarding the actual data transfer rate provided for the respective access.

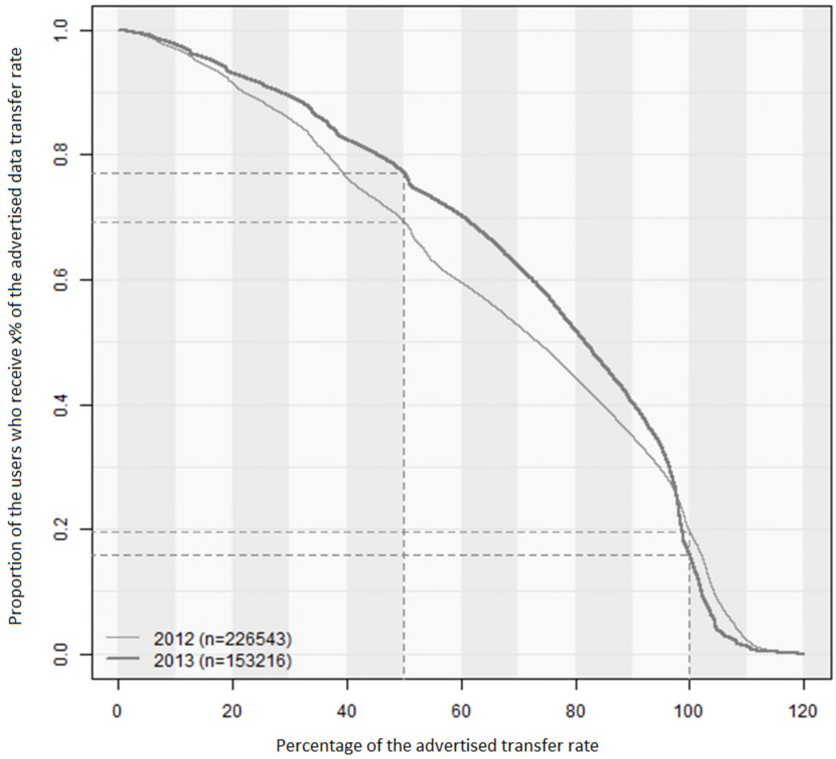

Figure 5.1: Empirical distribution function of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate) for all users in the sample

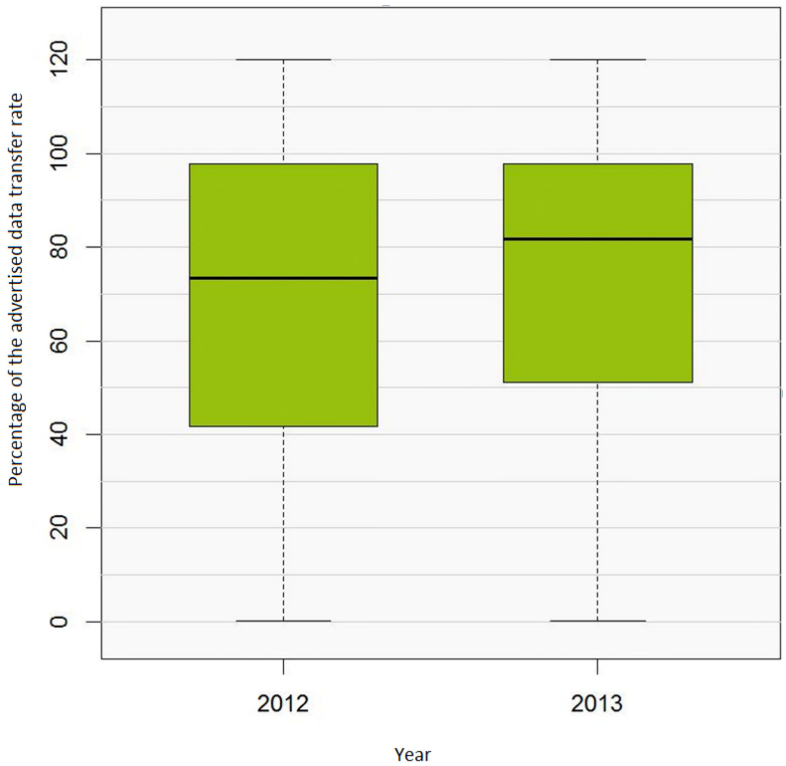

Figure 5.2: Boxplot of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate) for all users in the sample

5.1.1 Technology

Figure 5.3 (box plot) shows the medians and quartiles of the data transfer rates (expressed as a percentage of the advertised data transfer rate), broken down by the technology used for the connection. Figure 5.4 (empirical distribution function) shows the distribution of the data transfer rates (expressed as a percentage of the advertised data transfer rate).

Table 6 shows the proportions of users who received at least x% of the advertised data transfer rate and the corresponding 95% confidence intervals.

All in all, the data transfer rates measured exhibited a large span regardless of technology (< 1% to 120% for all technologies). On the other hand, the interquartile range which is used as a measure for distribution – shown as box length in the box plot – was smaller than in 2012 for all technologies. Compared to the 2012 study, the median for all technologies shifted to higher percentage values (see box plot Figure 5.3).

Clear differences between the data transfer rates (expressed as a percentage of the advertised data transfer rate) achieved for the respective technology were observed.

- **DSL**
  Looking at DSL accesses, the proportion of participants who measured 50% or more of the advertised data transfer rate increased by some eight percentage points, from 68.2% in 2012 to 76.2% in 2013, while the proportion of users who measured the full advertised data transfer rate or more fell from 15.7% to 9.0%.

- **Cable**
  In comparison to the other technologies, the best data transfer rates (expressed as a percentage of the advertised data transfer rate) were measured for cable accesses once again in 2013. In the empirical distribution function presented in Figure 5.4, the results for cable accesses are higher across the board than those for DSL and LTE

  A total of 86.7% of the cable access users (approximately eight percentage points more than in 2012) measured at least 50% of the advertised data transfer rate in 2013 (2012: 78.1%). The proportion of users who measured the full advertised data transfer rate or more grew by more than eight percentage points to from 41.8% (2012) to 50.7% for cable accesses.

- **LTE**
  LTE accesses exhibited the least improvement. Here, the proportion of users measuring 50% of the advertised data transfer rate increased by not quite two percentage points, from 55.6% (2012) to 57.4% in 2013. It is particularly striking that the values measured in 2013 for larger percentages of the advertised data transfer rates (starting from ca. 75%) were lower than they were in 2012. The proportion of users who measured the full advertised data transfer rate or more declined by more than six percentage points from 20.9% to 14.5%.

The differences could be due to differences in the technical specifications of the products or the differences in the number of users.

For example the throttling of the subscriber line is probably a particularly important factor in the case of xDSL infrastructures. The providers' marketing or communication behaviour regarding the data transfer rate available for the respective subscriber line possibly also plays a role.

On the other hand, in the case of both cable and LTE, the joint use of resources (shared medium) is an important factor that influences the performance of the respective connection. When such networks serve a relatively small number of users, relatively good data transfer rates are to be expected. However, the more users this infrastructure serves, the lower the data transfer rate will be that remains for the individual user as long as network capacity is not expanded.

In the case of LTE, other factors besides the aforementioned shared use of resources could additionally play a role. These include the current location and factors involving the environs.

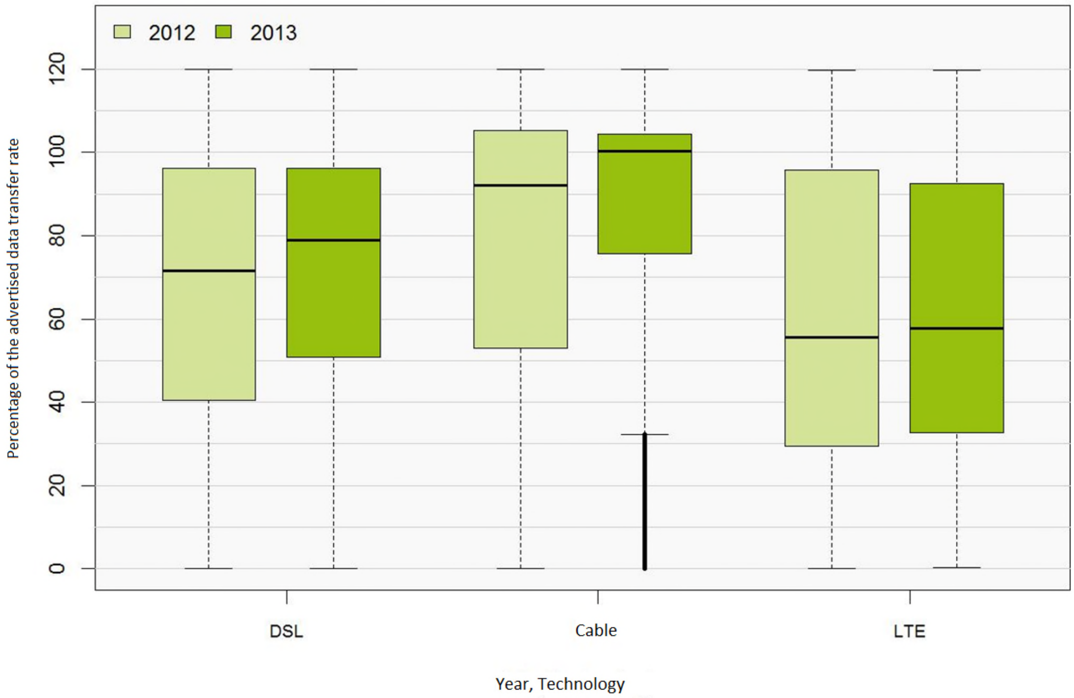

Figure 5.3: Actual data transfer rate (expressed as a percentage of the advertised data transfer rate), by technology

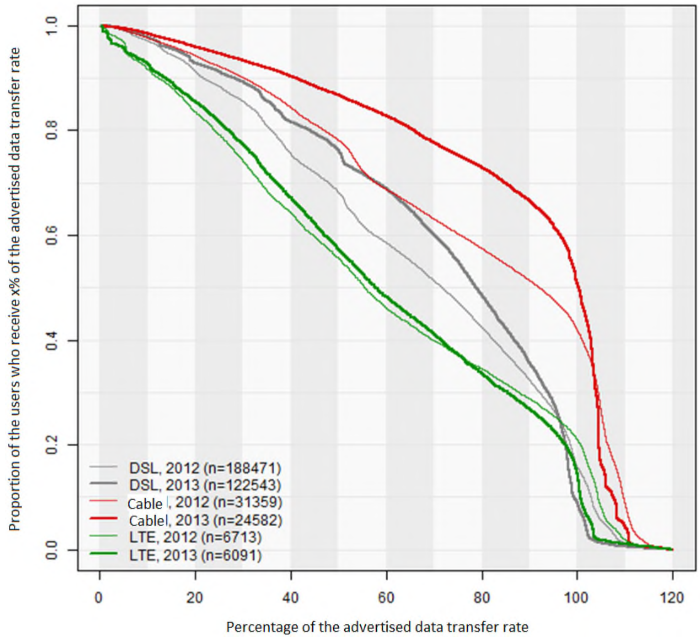

Figure 5.4: Empirical distribution function of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate), by technology

Table 6: Proportions of users who receive at least x% of the advertised data transfer rate and 95% confidence intervals, by technology

Percentage of advertised data transfer rate						
Technology	50%	60%	70%	80%	90%	100%
DSL	76.2% [76-76.4]	68.9% [68.6-69.1]	60.1% [59.8-60.4]	48.7% [48.4-48.9]	35.6% [35.3-35.9]	9% [8.8-9.1]
Cable	86.7% [86.3-87.2]	82.8% [82.3-83.3]	77.7% [77.1-78.2]	72.9% [72.4-73.5]	66.5% [65.9-67.1]	50.7% [50.1-51.4]
LTE	57.4% [56.1-58.6]	48.2% [47-49.5]	41.1% [39.9-42.3]	33.6% [32.4-34.8]	26.9% [25.8-28]	14.5% [13.7-15.4]

5.1.2 Bandwidth class

The broadband accesses were divided into six bandwidth classes on the basis of the advertised download data transfer rates specified by the study participants (see 3.1). Figure 5.5 and Figure 5.6 show the results in these classes.

Table 7 shows the proportions of users who received at least x% of the advertised data transfer rate and the corresponding 95% confidence intervals.

The box plot in Figure 5.5 shows that the median in all bandwidth classes shifted to higher percentage values in comparison to 2012 and that there was less dispersion in 2013.

The best measurement results were generally achieved in the lowermost bandwidth class. Here 39.8% of the users received the advertised data transfer rate or more (2012: 42.6%), while 85.5% measured at least half the advertised rate (2012: 80.0%).

However, at 41.3%, the best results measured in the 2013 study for the full advertised data transfer rate or more were reported for the bandwidth class > 50 to < 100 Mbit/s.

Accesses in the middle bandwidth classes did not fare as well. As in 2012, connections with a nominal bandwidth of > 8 to ≤ 18 Mbit/s reported the worst measurement results. In this category, only 5.4% (2012: 6.9%) measured the full data transfer rate or more and 73.6% (2012: 64.4%) measured 50% of the advertised data transfer rate or more.

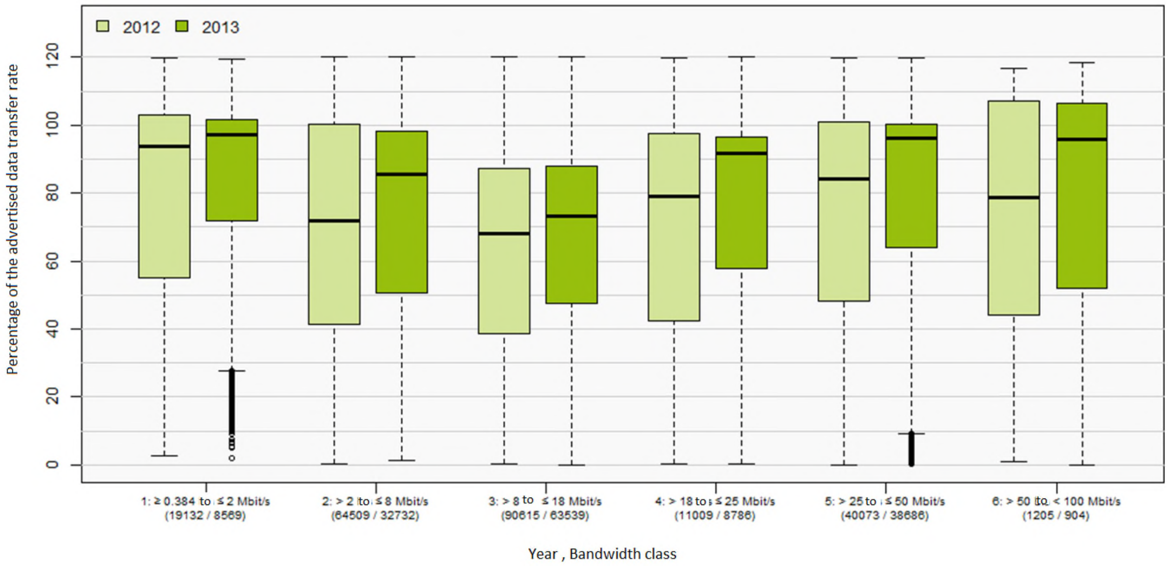

Figure 5.5: Data transfer rate (expressed as a percentage of the advertised data transfer rate), by bandwidth class

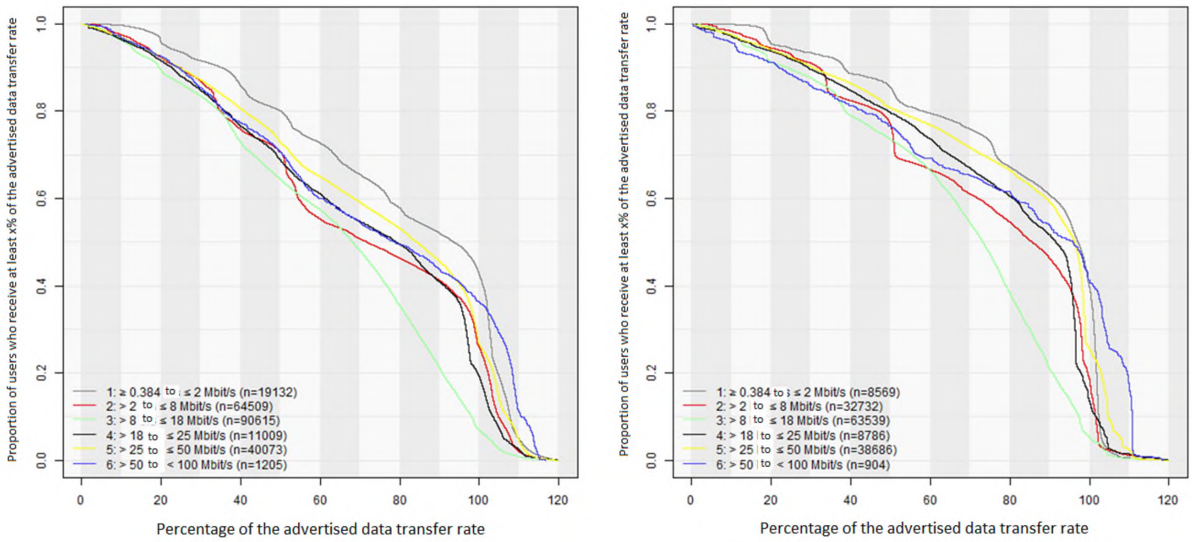

Figure 5.6: Empirical distribution function of the actual transfer rate (expressed as a percentage of the advertised data transfer rate), by bandwidth class (left: 2012 - right: 2013)

Table 7: Proportions of users who have received at least x% of the advertised data transfer rate and 95% confidence intervals, by bandwidth class

Percentage of advertised data transfer rate						
Bandwidth in Mbit/s	50%	60%	70%	80%	90%	100%
1: 0,384 to ≤ 2	85.5% [84.7-86.2]	79.5% [78.6-80.3]	76% [75.1-76.9]	67.2% [66.2-68.2]	60.8% [59.7-61.8]	39.8% [38.8-40.8]
2: > 2 to ≤ 8	76.9% [76.4-77.3]	66.6% [66.1-67.1]	61% [60.5-61.5]	54.6% [54.1-55.1]	46.3% [45.8-46.8]	18.7% [18.3-19.1]
3: > 8 to ≤ 18	73.6% [73.3-73.9]	66.5% [66.1-66.9]	54.4% [54-54.8]	38.4% [38-38.7]	20.9% [20.6-21.2]	5.4% [5.2-5.5]
4: > 18 to ≤ 25	79.7% [78.8-80.5]	73.7% [72.8-74.6]	66.9% [66-67.9]	60.5% [59.5-61.5]	51.7% [50.7-52.8]	13.6% [12.9-14.3]
5: > 25 to ≤ 50	80.8% [80.4-81.2]	76.8% [76.4-77.2]	71.6% [71.2-72.1]	66.5% [66-67]	59.3% [58.8-59.7]	25.5% [25.1-25.9]
6: > 50 to < 100	76.5% [73.7-79.2]	69.1% [66.1-72.1]	65.3% [62.1-68.3]	61.5% [58.3-64.6]	54% [50.7-57.2]	41.3% [38.1-44.5]

The irregularity in the course of the distribution function that was particularly evident in the bandwidth class from > 2 to ≤ 8 Mbit/s in 2012 was also observed in 2013; it falls off sharply in several segments and is subsequently flatter (see Figure 5.6, e.g. 2013: 35% and 52%). This would suggest that the products marketed by the providers in this bandwidth class are bundled under an 'up to' data transfer rate but actually differ greatly in the data transfer rate they realise.

Correspondingly, the distribution of the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) for all 6-Mbit/s accesses, for example, exhibit peaks at 6, 3 and 2 Mbit/s (see Figure 5.7). This indicates that different data transfer rates indeed continue to be marketed as 'up to 6 Mbit/s'. This effect is however less pronounced than in the 2012 study.

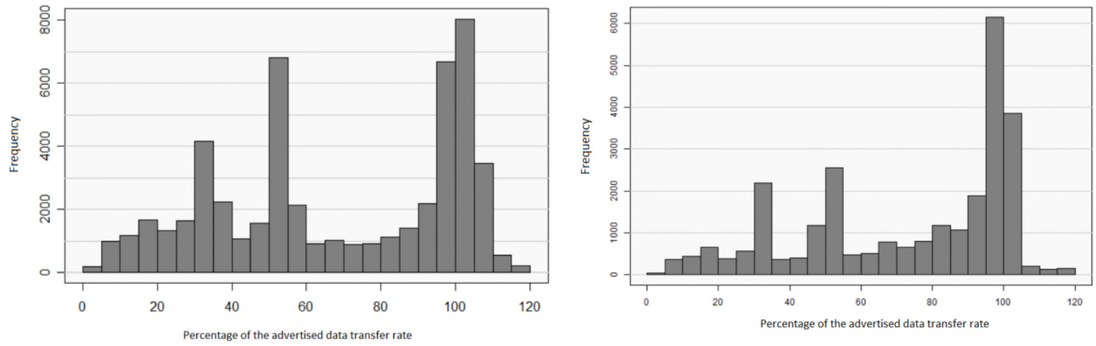

Figure 5.7: Frequency of the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) in the case of an advertised data transfer rate of 6 Mbit/s (left: 2012 - right: 2013)

These results were confirmed by the analysis of the synchronised data rates of the connections (see 5.2.1).

In this case, while conducting the measurement of the data transfer rate, the synchronised data rate of the connection was also measured for some of the users in order to compare the advertised data transfer rates specified by the users with the synchronised data rates of the connection.

Synchronised data rates which fell short of the advertised data transfer rates could be observed for a large percentage of end customers in the bandwidth range > 2 to ≤ 8 Mbit/s. For example, only 60.2% of the customers with an 6 Mbit/s access actually had a connection with a synchronised data rate of 6 Mbit/s or more.

Table 8: Frequency of the individual bandwidth classes, by technology

Bandwidth classes by technology												
Technology	1: 0,384 to ≤ 2 Mbit/s		2: > 2 to ≤ 8 Mbit/s		3: > 8 bis ≤ 18 Mbit/s		4: > 18 to ≤ 25 Mbit/s		5: > 25 to ≤ 50 Mbit/s		6: > 50 to < 100 Mbit/s	
	N	%	N	%	N	%	N	%	N	%	N	%
DSL	8526	7,0%	31089	25,4%	59049	48,2%	4489	3,7%	19352	15,8%	38	0,0%
Cable	43	0,2%	570	2,3%	3430	14,0%	1989	8,1%	17686	71,9%	864	3,5%
LTE			1073	17,6%	1060	17,4%	2308	37,9%	1648	27,1%	2	0,0%

Products are not offered in every bandwidth class for each technology (see Table 8) and the distribution of the users varies greatly between the bandwidth classes.

For this reason, the distribution of the measured data transfer rates (expressed as a percentage of the advertised data transfer rate) is shown here for the individual technologies, broken down by bandwidth class (Figure 5.8).

As in 2012, the largest deviations seen in the shared-medium technologies cable and LTE were observed in the uppermost available bandwidth class. Looking at DSL accesses, the largest deviations occurred in the bandwidth class > 8 bis ≤ 18 Mbit/s, as was also the case in 2012. This is probably likewise due to the fact that very heterogeneous accesses are grouped together in the products of this bandwidth group and providers do not differentiate their products any further.

Furthermore, a significant spread of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate) could be observed for the measured LTE connections. Since the very high bandwidths are primarily marketed in urban areas, the high density of users with smartphones and tablets could have already had a noticeable effect on the actual data transfer rates here. Although this study examined only fixed LTE accesses, these accesses share the network infrastructure with mobile LTE devices as well.

In the case of DSL accesses, the connections in the lowest bandwidth class performed the best. In this class, 85.5% received half the advertised data transfer rate and 39.8% received the full advertised data transfer rate (2012: 80.1% and 42.5% respectively). These figures were only 72.9% and 1.8% respectively in the class > 8 to ≤ 18 Mbit/s (2012: 63.4% and 4.5% respectively).

The best bandwidth class for cable accesses was the class > 2 to ≤ 8 Mbit/s. Here, 90.5% of the customers (2012: 84.3%) measured half of the data transfer rate and 61.8% of the customers measured the full transfer rate (2012: 50.5%). By comparison, these figures were 79.9% and 43.2% in the class > 50 to < 100 Mbit/s (2012: 70.5% and 36.3%).

Of the LTE accesses in the best class > 2 to ≤ 8 Mbit/s, 71.0% received half the data transfer rate (2012: 67.5%) and 29.5% received the full transfer rate (2012: 33.1%). Only 5.5% of the customers in the worst bandwidth class > 25 to ≤ 50 Mbit/s received the full transfer rate (2012: 1.6%) and 38.7% received half the transfer rate (2012: 23.3%).

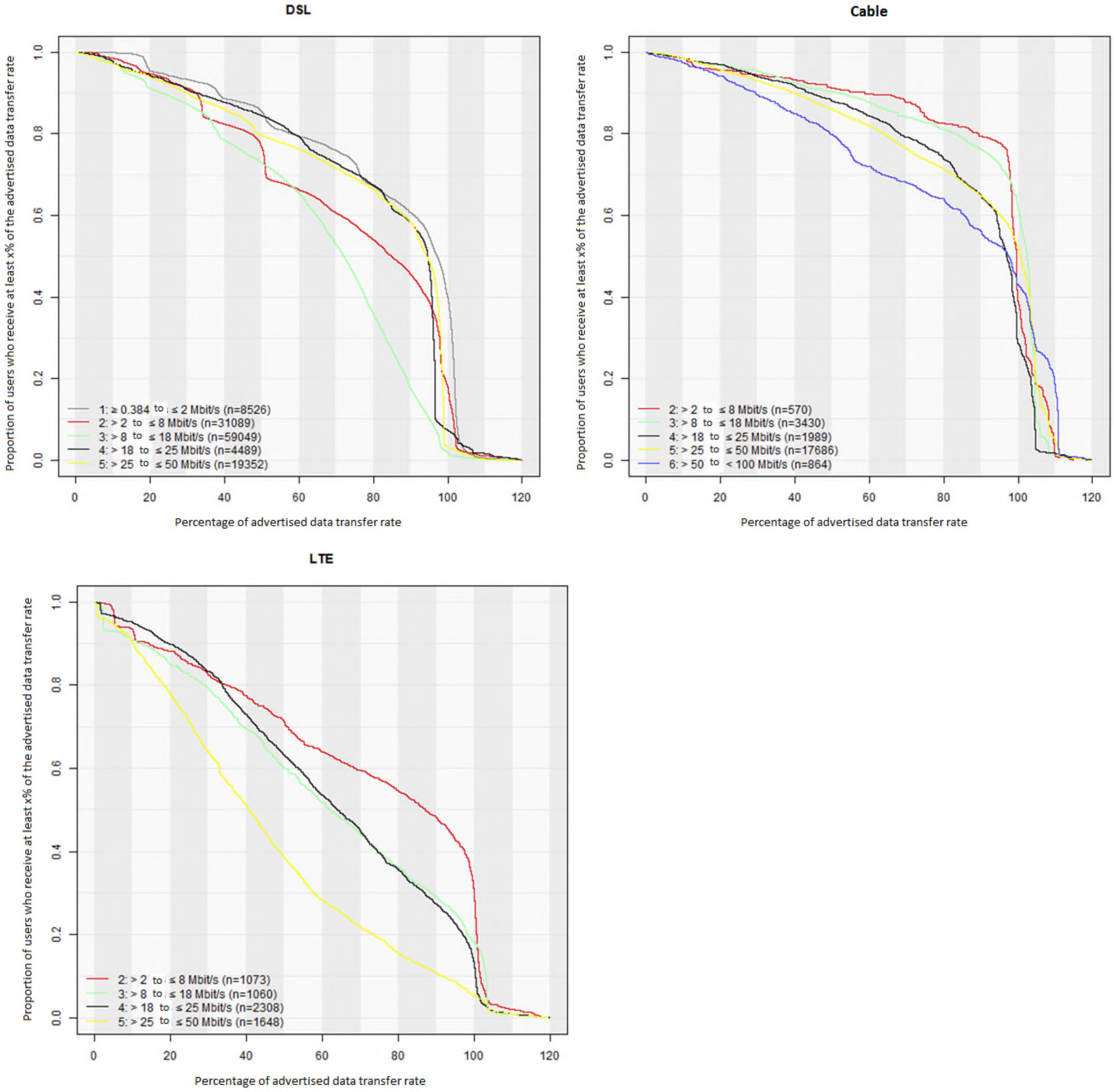

Figure 5.8: Empirical distribution function of the actual data transfer rates (expressed as a percentage of the advertised data transfer rate), by technology and bandwidth class

Table 9: Proportions of users who receive at least x% of the advertised data transfer rate and 95% confidence intervals, by technology and bandwidth class

Percentage of advertised data transfer rate							
Technology	Bandwidth in Mbit/s	50%	60%	70%	80%	90%	100%
DSL	1: 0,384 to ≤ 2	85.5% [84.7-86.2]	79.5% [78.6-80.3]	75.9% [75-76.8]	67.1% [66.1-68.1]	60.6% [59.6-61.7]	39.8% [38.8-40.9]
	2: > 2 to ≤ 8	76.8% [76.3-77.3]	66.3% [65.7-66.8]	60.6% [60-61.1]	54.1% [53.5-54.6]	45.6% [45.1-46.2]	17.9% [17.5-18.4]
	3: > 8 to ≤ 18	72.9% [72.5-73.2]	65.5% [65.2-65.9]	52.9% [52.5-53.3]	35.9% [35.5-36.3]	17.5% [17.2-17.8]	1.8% [1.7-2]
	4: > 18 to ≤ 25	84.4% [83.3-85.5]	79.3% [78.1-80.4]	72.8% [71.5-74.1]	67.5% [66.1-68.8]	58.3% [56.8-59.7]	7.4% [6.7-8.2]
	5: > 25 to ≤ 50	79.6% [79-80.1]	76.3% [75.6-76.8]	71.5% [70.9-72.2]	66.4% [65.7-67.1]	58.3% [57.6-59]	3.1% [2.9-3.3]
Cable	2: > 2 to ≤ 8	91.2% [88.6-93.3]	89.8% [87.1-92]	87.7% [84.8-90.2]	82.6% [79.3-85.5]	79.5% [76-82.6]	38.9% [35-43]
	3: > 8 to ≤ 18	90.5% [89.5-91.4]	87.8% [86.6-88.8]	84.1% [82.8-85.3]	81% [79.7-82.3]	76.3% [74.8-77.7]	61.8% [60.2-63.4]
	4: > 18 bis ≤ 25	88.1% [86.6-89.4]	84.5% [82.8-86]	79.3% [77.4-81]	73.9% [71.9-75.7]	65.1% [62.9-67.1]	28.7% [26.7-30.7]
	5: > 25 to ≤ 50	86% [85.5-86.5]	81.9% [81.3-82.5]	76.4% [75.7-77]	71.3% [70.6-72]	64.9% [64.2-65.6]	51.9% [51.1-52.6]
	6: > 50 to < 100	79.9% [77.1-82.4]	72.1% [69-75]	68.1% [64.9-71.1]	64.1% [60.9-67.2]	56.2% [52.9-59.5]	43.2% [39.9-46.5]
LTE	2: > 2 to ≤ 8	71% [68.2-73.7]	63.9% [61-66.8]	59.5% [56.5-62.4]	54.7% [51.7-57.7]	48.2% [45.2-51.2]	29.5% [26.8-32.2]
	3: > 8 to ≤ 18	60.1% [57.1-63]	51.8% [48.8-54.8]	44.2% [41.3-47.3]	36.2% [33.4-39.2]	29.2% [26.6-32.1]	18% [15.8-20.4]
	4: > 18 to ≤ 25	63.2% [61.2-65.2]	53.5% [51.5-55.5]	44.9% [42.9-46.9]	35.6% [33.6-37.5]	27.4% [25.6-29.3]	12.5% [11.2-13.9]
	5: > 25 to ≤ 50	38.7% [36.3-41]	28.4% [26.3-30.6]	21.8% [19.9-23.9]	15.5% [13.9-17.4]	10.7% [9.3-12.3]	5.5% [4.5-6.7]

5.1.3 Provider

Not all providers offer all technologies and bandwidth classes and, consequently, differences can be observed in their product portfolios. For this reason, a comparison of providers makes sense only for specific technologies or bandwidth classes. Figure 5.10 and Figure 5.11 show distribution by provider and technology / bandwidth class, albeit without naming the individual provider. The providers are assigned a different letter in each graph. Provider A in the DSL graph is not necessarily Provider A in the LTE graph. However, the Others group in all the graphs contains all the providers except for those named in Table 3.

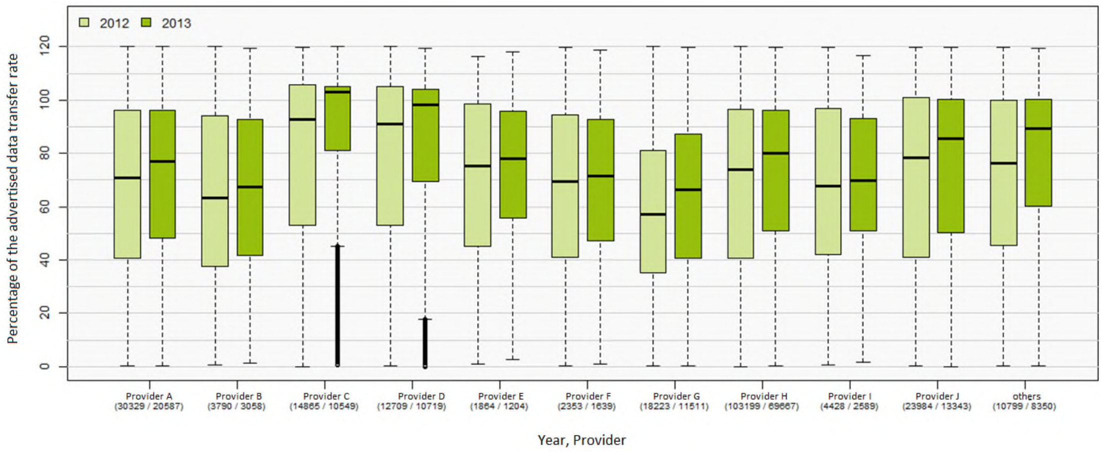

Figure 5.9: Data transfer rate (expressed as a percentage of the advertised data transfer rate), by provider

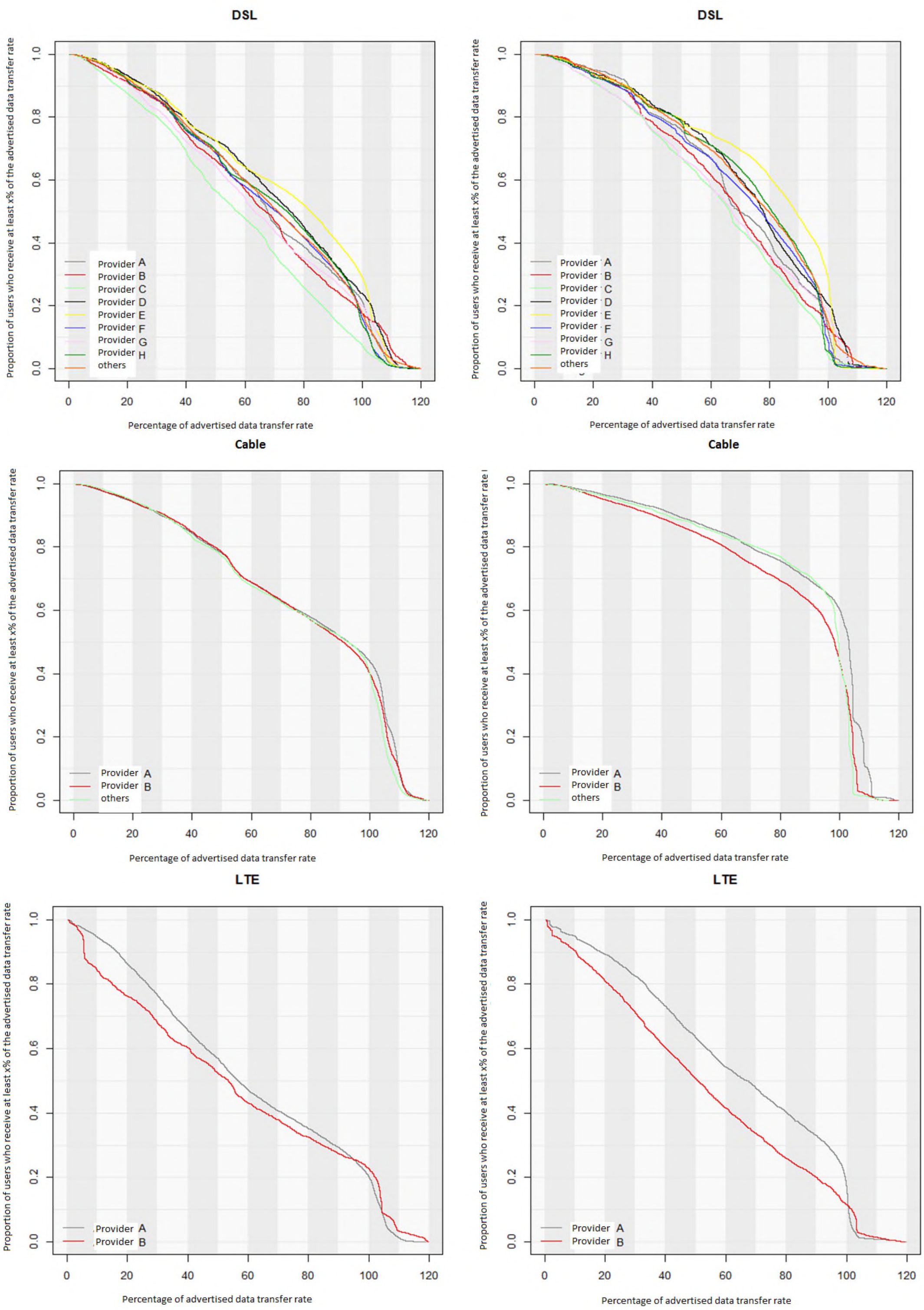

Figure 5.10: Empirical distribution functions of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate), by provider and technology (left: 2012 – right: 2013).

These graphs show recognisable differences between providers, broken down by the respective technology. Here the spread is smaller for cable accesses than it is for DSL or LTE. The differences in product availability from region to region for the respective provider could be the reason for this. As can be seen in Table 10, the majority of the measured cable accesses are located in semi-urban or urban areas, while DSL accesses were present in all regions.

The breakdown by bandwidth class exhibits a similar picture (Figure 5.11).

The pronounced fanning out in bandwidth classes > 2 to ≤ 8 Mbit/s and > 8 to ≤ 18 Mbit/s is striking. The accesses here are usually ASDL accesses.

In bandwidth class > 8 to ≤ 18 Mbit/s, providers that use cable technology comprise a distinct subgroup.

For bandwidth classes > 18 to ≤ 25 Mbit/s and > 25 to ≤ 50 Mbit/s it was observed that these two classes also contain providers with a large proportion of fixed LTE accesses.

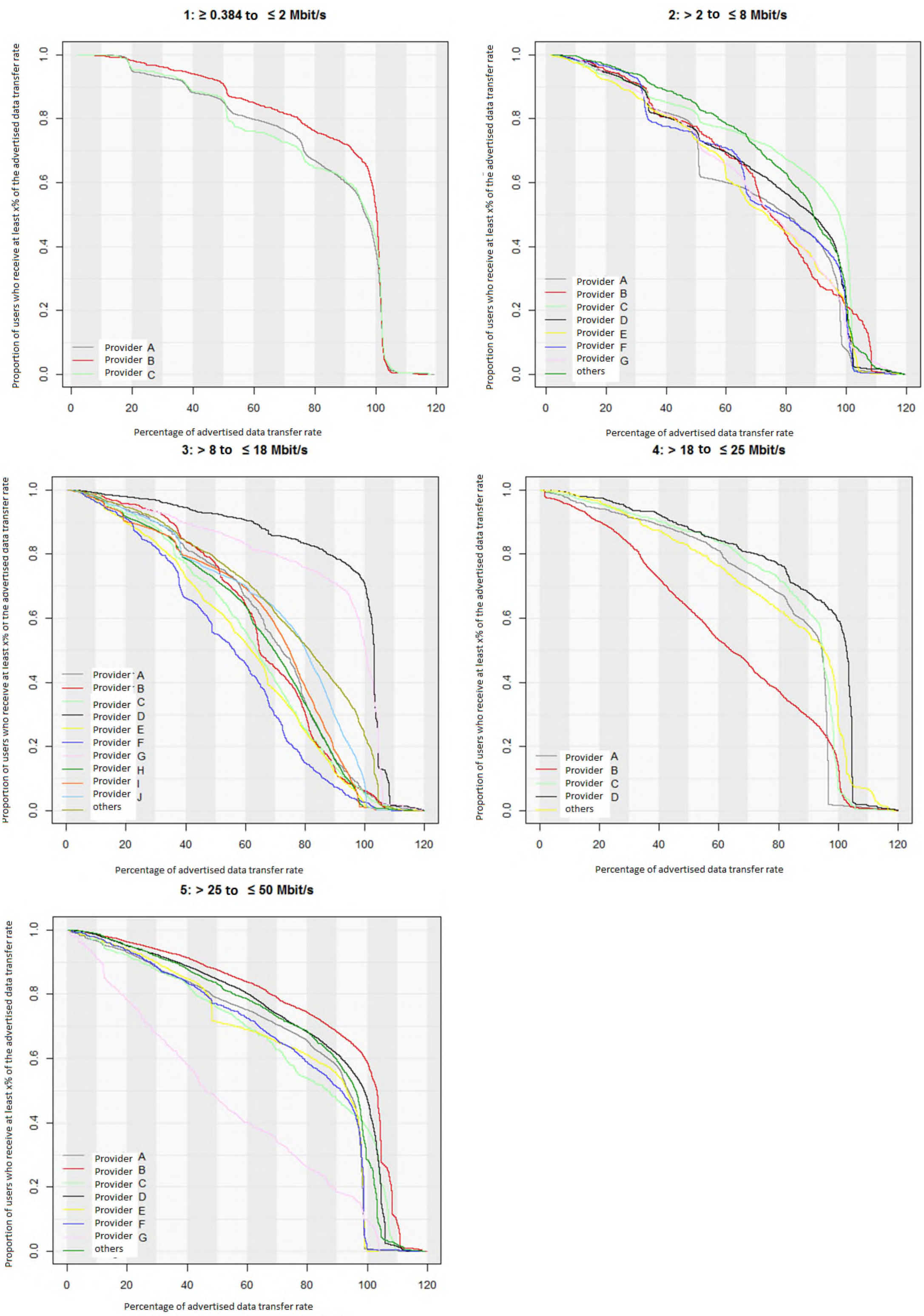

Figure 5.11: Distribution of the actual transfer rate (expressed as a percentage of the advertised data transfer rate), by provider and bandwidth class

5.1.4 Geographical area

The following section presents the results with a focus on the geographical distribution of the broadband accesses.

As in 2012, no significant differences in the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) were observed in 2013, regardless of technology, bandwidth class or provider (see Figure 5.12 and Figure 5.13). Compared to the 2012 study, the slightly better values in the urban areas improved somewhat in the 2013 study. In all areas, the mean improved and there was less dispersion.

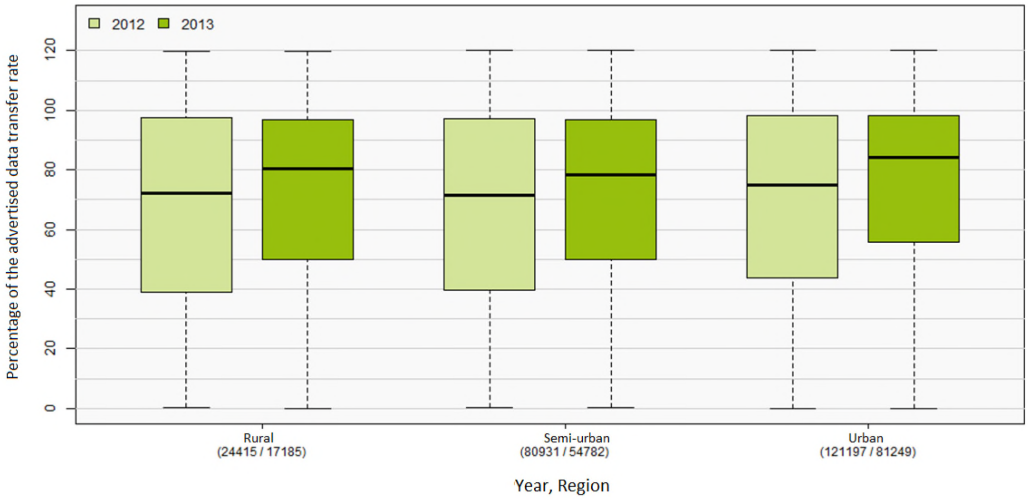

Figure 5.12: Actual data transfer rate (expressed as a percentage of the advertised data transfer rate), by geographical area

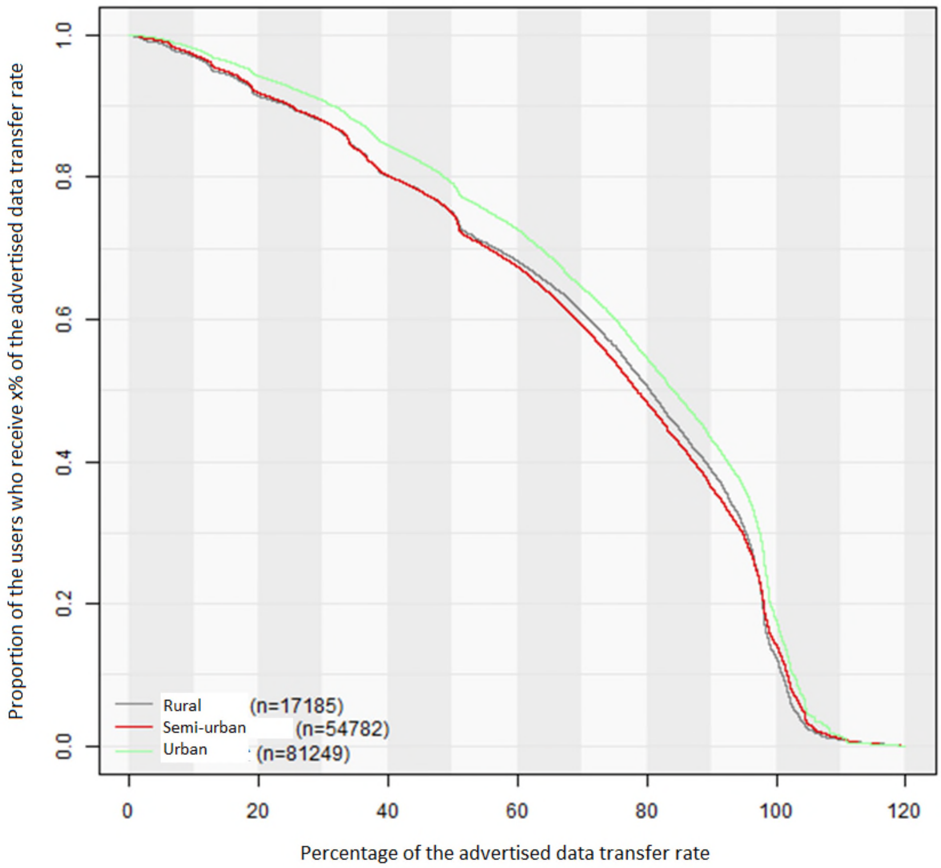

Figure 5.13: Empirical distribution function of the actual transfer rate (expressed as a percentage of the advertised data transfer rate), by geographical area.

The fact that subscriber lines in rural areas are typically longer than in more densely populated areas and therefore tend to permit less bandwidth does not have a noticeable effect at this level of aggregation.

This is probably largely due to the distribution of the technologies and bandwidth classes in the respective region. Rural areas have more broadband accesses in the lower bandwidth classes and fewer with high advertised data transfer rates. In rural areas there are fewer cable accesses but more LTE and DSL accesses than in conurbations (see Table 10 and Table 11).

Consequently the high percentages seen in the actual transfer rates in the low bandwidth category in rural areas have a stronger effect and, when the analysis does not differentiate between bandwidth classes, can partly offset the effect of generally longer subscriber lines.

Table 10: Frequency of the individual technologies, by geographical area

Technologies by region						
Region	DSL		Cable		LTE	
	N	%	N	%	N	%
Rural	14400	83,8%	771	4,5%	2014	11,7%
Semi-urban	44759	81,7%	6880	12,6%	3143	5,7%
Urban	63384	78,0%	16931	20,8%	934	1,1%

Table 11: Frequency of the individual bandwidth classes, by geographical area

Bandwidth classes by region												
Region	1: 0,384 to ≤ 2 Mbit/s		2: > 2 to ≤ 8 Mbit/s		3: > 8 to ≤ 18 Mbit/s		4: > 18 to ≤ 25 Mbit/s		5: > 25 to ≤ 50 Mbit/s		6: > 50 to < 100 Mbit/s	
	N	%	N	%	N	%	N	%	N	%	N	%
Rural	1867	10,9%	3890	22,6%	6961	40,5%	1395	8,1%	3054	17,8%	18	0,1%
Semi-urban	4106	7,5%	13034	23,8%	23388	42,7%	3336	6,1%	10755	19,6%	163	0,3%
Urban	2596	3,2%	15808	19,5%	33190	40,8%	4055	5,0%	24877	30,6%	723	0,9%

Figure 5.14 provides a regional breakdown of the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) of the individual bandwidth classes. A tabular presentation of the user proportions which received at least x% of the advertised data transfer rate, plus the corresponding 95% confidence intervals can be found in Table 12.

It can be seen from this that the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) in urban areas were higher on average than in semi-urban or rural areas in almost all bandwidth classes in 2013 as well. In the bandwidth class > 8 to ≤ 18, the rural accesses exhibit - as in 2012 – smaller deviations from the advertised data transfer rates than the semi-urban and urban accesses do. The reasons for this are not yet apparent.

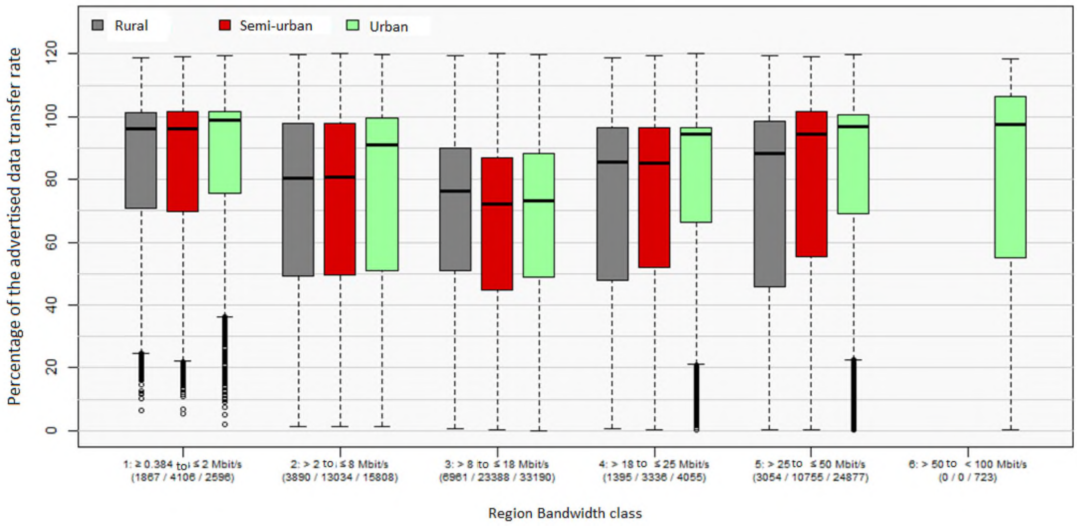

Figure 5.14: Actual data transfer rates (expressed as a percentage of the advertised data transfer rate), by geographical area and bandwidth class

Table 12: Proportions of the users who receive at least x% of the advertised data transfer rate, and 95% confidence intervals, by bandwidth class and region

Percentage of advertised data transfer rate							
Bandwidth in Mbit/s	Region	50%	60%	70%	80%	90%	100%
1: 0,384 to ≤ 2	Rural	83.8% [82.1-85.4]	78.8% [76.9-80.6]	75.5% [73.5-77.4]	65.9% [63.7-68]	59.5% [57.2-61.7]	37.2% [35-39.4]
	Semi-urban	85.2% [84-86.2]	78.5% [77.2-79.7]	74.9% [73.5-76.2]	65.7% [64.3-67.2]	58.5% [56.9-59.9]	38.3% [36.9-39.8]
	Urban	87.2% [85.9-88.5]	81.6% [80.1-83.1]	78% [76.4-79.6]	70.5% [68.7-72.2]	65.3% [63.5-67.1]	44% [42.1-45.9]
2: > 2 to ≤ 8	Rural	73.8% [72.4-75.2]	62.4% [60.8-63.9]	57.1% [55.6-58.7]	50.4% [48.8-51.9]	42.2% [40.7-43.8]	13.2% [12.1-14.3]
	Semi-urban	74.1% [73.4-74.9]	62.6% [61.7-63.4]	56.9% [56.1-57.8]	50.6% [49.8-51.5]	41.8% [40.9-42.6]	14.3% [13.8-15]
	Urban	79.9% [79.2-80.5]	71% [70.2-71.7]	65.4% [64.6-66.1]	58.9% [58.2-59.7]	51.1% [50.3-51.8]	23.6% [22.9-24.3]
3: > 8 to ≤ 18	Rural	75.2% [74.2-76.2]	69.2% [68.1-70.3]	58.8% [57.6-59.9]	43.6% [42.4-44.8]	25.1% [24.1-26.1]	3.1% [2.7-3.6]
	Semi-urban	72.3% [71.7-72.8]	65.5% [64.8-66.1]	53.3% [52.6-53.9]	36.7% [36.1-37.4]	19.2% [18.7-19.7]	3.4% [3.2-3.6]
	Urban	74.2% [73.8-74.7]	66.7% [66.2-67.2]	54.3% [53.8-54.8]	38.4% [37.9-38.9]	21.2% [20.8-21.7]	7.2% [6.9-7.5]
4: > 18 bis ≤ 25	Rural	74.2% [71.8-76.4]	68.3% [65.8-70.7]	61.6% [59-64.1]	54.3% [51.7-56.9]	47.5% [44.8-50.1]	14.3% [12.5-16.2]
	Semi-urban	76.2% [74.7-77.6]	68.7% [67.1-70.3]	61.9% [60.3-63.6]	54.6% [53-56.3]	46.2% [44.5-47.9]	15.5% [14.3-16.8]
	Urban	84.4% [83.3-85.5]	79.6% [78.4-80.8]	72.9% [71.5-74.3]	67.5% [66-68.9]	57.7% [56.2-59.2]	11.7% [10.7-12.7]
5: > 25 to ≤ 50	Rural	71.3% [69.7-72.9]	66.6% [64.9-68.3]	61.6% [59.9-63.3]	56.2% [54.4-57.9]	48.5% [46.8-50.3]	16.5% [15.2-17.8]
	Semi-urban	77.2% [76.4-78]	73% [72.2-73.9]	67.6% [66.7-68.5]	62.3% [61.4-63.2]	55.4% [54.4-56.3]	27.8% [26.9-28.6]
	Urban	83.5% [83-84]	79.7% [79.2-80.2]	74.6% [74.1-75.1]	69.6% [69-70.1]	62.3% [61.6-62.9]	25.6% [25.1-26.2]
6: > 50 to < 100	Urban	78.4% [75.3-81.3]	72.6% [69.3-75.7]	68.6% [65.1-71.9]	64.7% [61.2-68.1]	56.6% [52.9-60.1]	43.8% [40.3-47.5]

However, as in 2012, the differences by geographical area are less striking when individual technologies are observed (Figure 5.15, Table 13).

Larger differences were observed solely with LTE accesses. Additionally, a shift in the differences for LTE accesses since the 2012 study is evident. In 2012, differences were observed between urban areas on the one hand and semi-urban / rural areas on the other. These differences are now between rural areas on the one hand and semi-urban / urban areas on the other. In other words, the area where markedly lower data transfer rates were measured has expanded from the conurbations to include semi-urban areas.

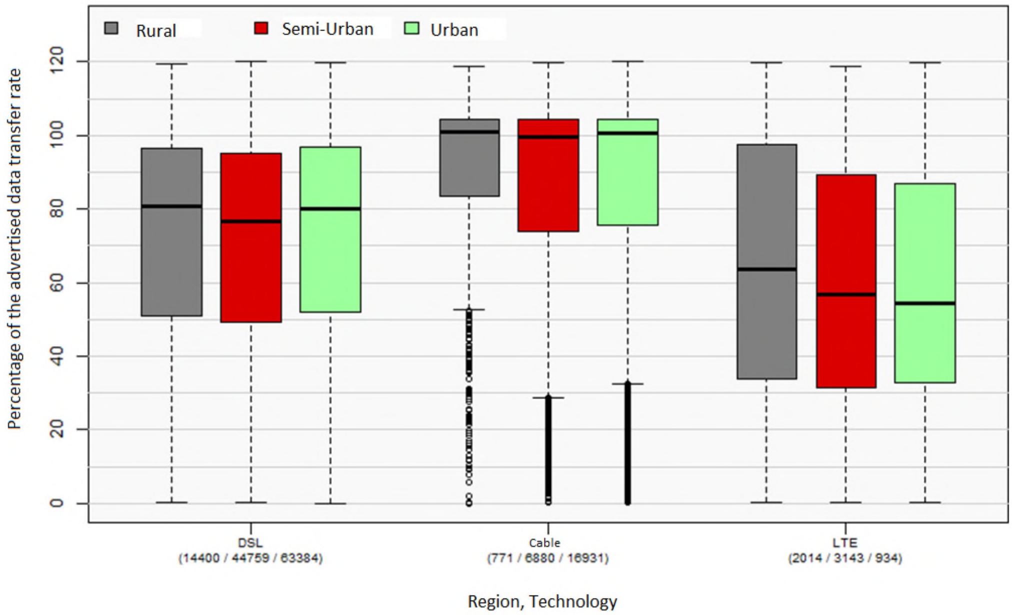

Figure 5.15: Actual data transfer rates (expressed as a percentage of the advertised data transfer rate), by geographical area and technology

Table 13: Proportions of users who receive at least x% of the advertised data transfer rate and 95% confidence intervals, by technology and region

Percentage of advertised data transfer rate							
Technology	Region	50%	60%	70%	80%	90%	100%
DSL	Rural	76.5% [75.8-77.2]	69.4% [68.7-70.2]	62% [61.2-62.8]	50.9% [50.1-51.8]	37.9% [37.1-38.7]	9.5% [9.1-10]
	Semi-urban	74.3% [73.9-74.7]	66.4% [66-66.9]	57.6% [57.2-58.1]	45.8% [45.4-46.3]	32.7% [32.2-33.1]	9% [8.7-9.2]
	Urban	77.5% [77.2-77.8]	70.4% [70.1-70.8]	61.4% [61-61.8]	50.1% [49.7-50.5]	37.1% [36.7-37.5]	8.8% [8.6-9.1]
Cable	Rural	89.2% [86.8-91.2]	86.6% [84.1-88.9]	81.6% [78.7-84.2]	77.4% [74.3-80.2]	70.4% [67.1-73.5]	52.7% [49.1-56.2]
	Semi-urban	87.1% [86.3-87.9]	83% [82.1-83.8]	77.4% [76.4-78.4]	72.3% [71.2-73.3]	65.5% [64.4-66.7]	48.9% [47.7-50]
	Urban	86.5% [86-87]	82.5% [82-83.1]	77.6% [77-78.2]	73% [72.3-73.6]	66.8% [66.1-67.5]	51.4% [50.7-52.2]
LTE	Rural	59.2% [57.1-61.4]	51.9% [49.7-54.1]	45.4% [43.3-47.6]	38.4% [36.3-40.6]	32.2% [30.2-34.2]	17.4% [15.8-19.1]
	Semi-urban	56.8% [55.1-58.5]	47.1% [45.3-48.8]	39.7% [38-41.4]	31.9% [30.3-33.6]	24.6% [23.1-26.1]	13.4% [12.2-14.6]
	Urban	55.2% [52-58.4]	44.3% [41.2-47.5]	36.4% [33.4-39.5]	28.9% [26.1-31.9]	23.1% [20.5-25.9]	12.2% [10.3-14.5]

5.1.5 Customer satisfaction

As part of the study, the participants indicated prior to conducting measurements how satisfied they were with their provider on the basis of a six-point scale.

Using a box plot, Figure 5.16 shows the actual data transfer rate (expressed as a percentage of the advertised data transfer rate), by level of customer satisfaction.

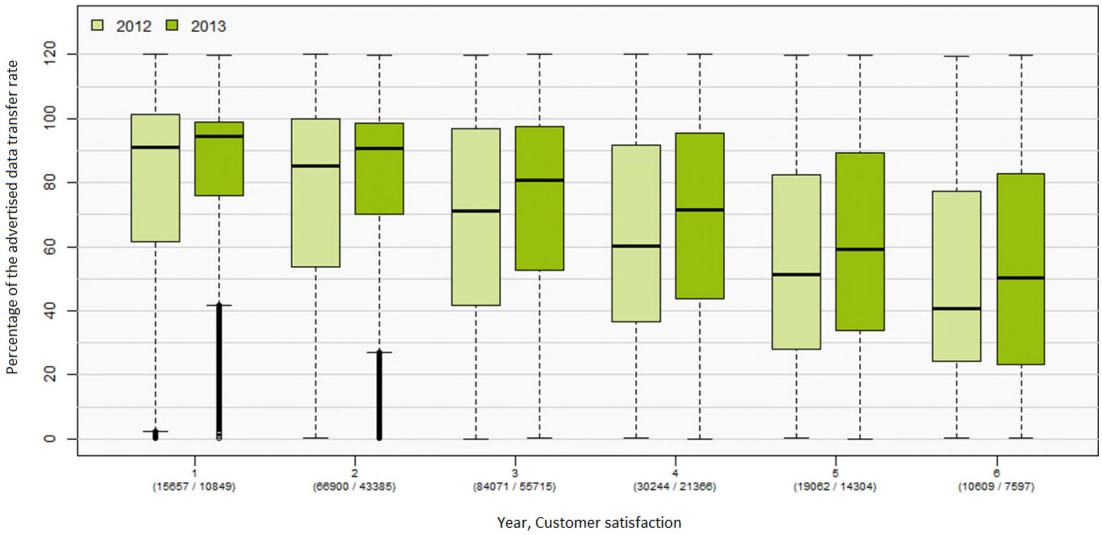

Figure 5.16: Actual data transfer rates (expressed as a percentage of the advertised data transfer rate), by level of customer satisfaction (scale: 1 = 'very good' to 6 = 'unsatisfactory')

Table 14: Proportions of users who receive at least x% of the advertised data transfer rate and 95% confidence intervals, by level of customer satisfaction

Percentage of advertised data transfer rate						
Satisfaction	50%	60%	70%	80%	90%	100%
1	89.4% [88.8-89.9]	85.4% [84.7-86.1]	79.8% [79-80.5]	71.3% [70.5-72.2]	57.9% [57-58.9]	21.2% [20.4-22]
2	86.8% [86.5-87.1]	82% [81.7-82.4]	75% [74.6-75.4]	64.7% [64.3-65.2]	51.1% [50.6-51.6]	19.7% [19.3-20]
3	78.2% [77.9-78.6]	70.9% [70.5-71.3]	62% [61.6-62.4]	50.7% [50.3-51.2]	38.5% [38.1-38.9]	15.4% [15.1-15.7]
4	70% [69.4-70.6]	60.7% [60-61.3]	51.3% [50.6-52]	41.6% [40.9-42.3]	31.2% [30.6-31.8]	13.1% [12.6-13.5]
5	59.2% [58.4-60]	49.6% [48.8-50.4]	41.1% [40.3-42]	32.1% [31.3-32.9]	24.5% [23.8-25.2]	10.3% [9.9-10.8]
6	50.5% [49.4-51.6]	42.9% [41.8-44]	34.6% [33.5-35.7]	26.5% [25.6-27.6]	19.6% [18.7-20.5]	8.8% [8.2-9.5]

The box plot clearly shows that customer satisfaction is evidently directly related to the actual data transfer rate (expressed as a percentage of the advertised data transfer rate). The lower the measured actual data transfer rate (expressed as a percentage of the advertised data transfer rate), the lower the provider was rated. This shows that 'delivery reliability' was an important parameter for customer satisfaction in 2013 as well.

The vast majority of the participants gave their provider positive marks. Therefore, not only dissatisfied customers took part in the study. This would indicate that the sample is not biased in this direction.

Compared to the 2012 sample, satisfaction decreased slightly - even though ‘delivery quality’ improved (see Figure 5.17).

This could be an indication of greater customer awareness, resulting, for example, from the media interest in the 2012 study.

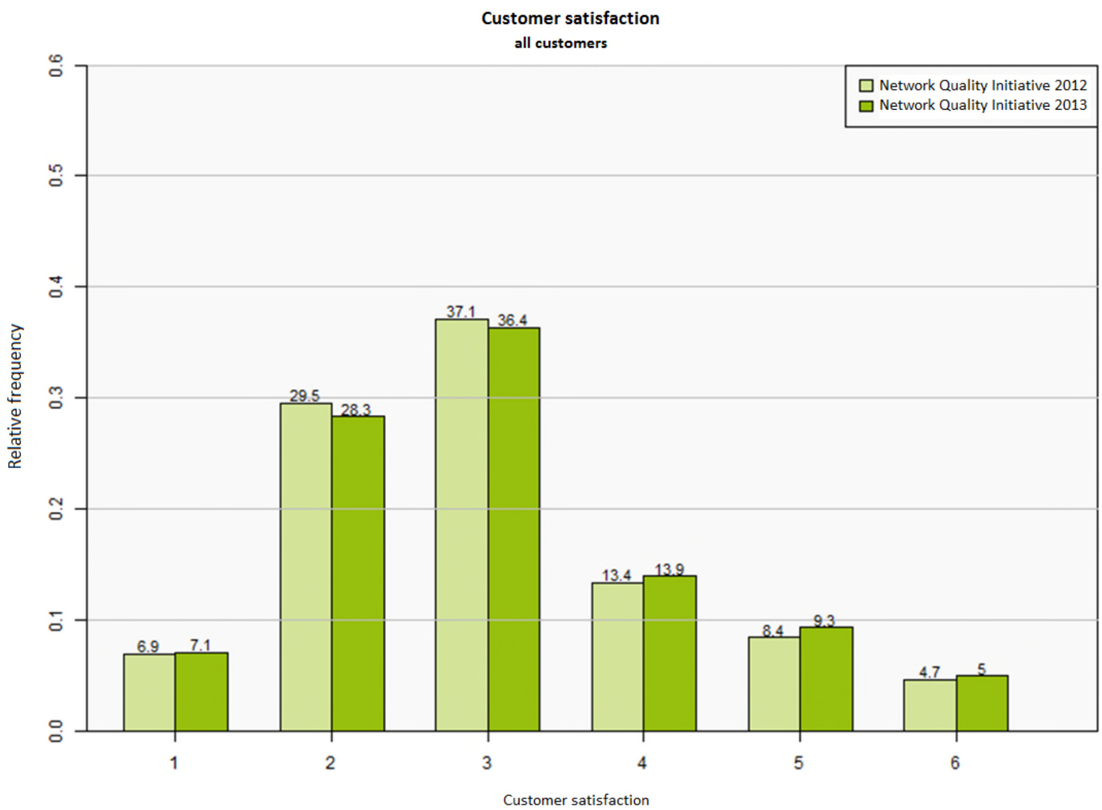

Figure 5.17: Frequency of customer satisfaction of all customers

As already observed in 2012, customers who have higher advertised data transfer rates apparently tend to be more satisfied with their provider than customers with lower advertised transfer rates. This effect can also be observed when the technologies DSL and LTE are examined separately; however a clear relationship between customer satisfaction and advertised broadband class is not discerniable when cable customers are examined.

The correlation between customer satisfaction and the measured actual transfer rates (expressed as a percentage of the advertised data transfer rate) can – as in 2012 – still be observed when the figures are broken down by technology or by bandwidth class. Although customers in the lower bandwidth classes are generally less satisfied than those in the higher bandwidth classes, within the individual class, the higher the measured actual data transfer rate (expressed as a percentage of the advertised data transfer rate), the greater customer satisfaction is.

5.1.6 Upload

Broadband accesses in the mass market which are realised using xDSL, cable or LTE technology regularly exhibit an asymmetrical relationship between the download and upload data transfer rates that are possible. For this reason, upload data transfer rates are very often only a fraction of the advertised download data transfer rate.

Since the upload data transfer rate was not checked and is not always a feature of the advertised products, it is not always possible to render a comparison of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate) with the advertised upload data transfer rate.

For this reason, the relationship between the measured upload and download data transfer rates that are typically seen for the individual technology and bandwidth class is examined in general terms in the following section.

The measured upload data transfer rates are therefore also shown here as a percentage of the advertised *download* speeds.

Cable accesses exhibit the greatest asymmetry. In this category, only 56.5% of the users receive an *upload* data transfer rate of 5% or more of the advertised download data transfer rate, while 0.5% of the users receive 15% or more of the advertised *download* data transfer rate (see Table 15).

By contrast, at least 5% of the advertised download data transfer rate was measured for 80.8% of the customers uploading with DSL accesses; 15% was measured for 19.3% of the users in this group (2012: 11.8%).

Looking at fixed LTE accesses, this 5% value was achieved by 80.6% of the users; the 15% value was reached by 54.4% of the users (2012: 50.1%).

In comparison to the 2012 study, the values in the cable area remained virtually unchanged. The values for DSL and fixed LTE accesses increased slightly.

Table 15: Proportions of users who receive at least x% of the advertised *download* data transfer rate when uploading and 95% confidence intervals, by technology

Upload data transfer rate as a percentage of the download data transfer rate						
Technology	5%	10%	15%	20%	25%	30%
DSL	80.8% [80.5-81]	27.3% [27.1-27.6]	19.3% [19.1-19.6]	2% [2-2.1]	1.2% [1.2-1.3]	0.8% [0.7-0.8]
Cable	56.5% [55.8-57.1]	1.6% [1.4-1.7]	0.5% [0.4-0.6]	0.2% [0.1-0.2]	0.1% [0.1-0.1]	0.1% [0-0.1]
LTE	80.6% [79.5-81.5]	60.9% [59.7-62.2]	54.2% [52.9-55.4]	36.3% [35-37.5]	17.8% [16.9-18.8]	5.8% [5.2-6.4]

5.2 Special analyses

5.2.1 Synchronised data rate of the connection

As part of the measurement, the synchronised data rate of the connection was also read for 34,051 users (22.2%) in the sample in order to compare the advertised data transfer rates specified by the users with the synchronised data rates of the connection. Only users who used equipment from a specific subgroup of manufacturers could do this.

The frequencies of the synchronised data rates of the connection for the most common advertised data transfer rates are shown in bar chart form in

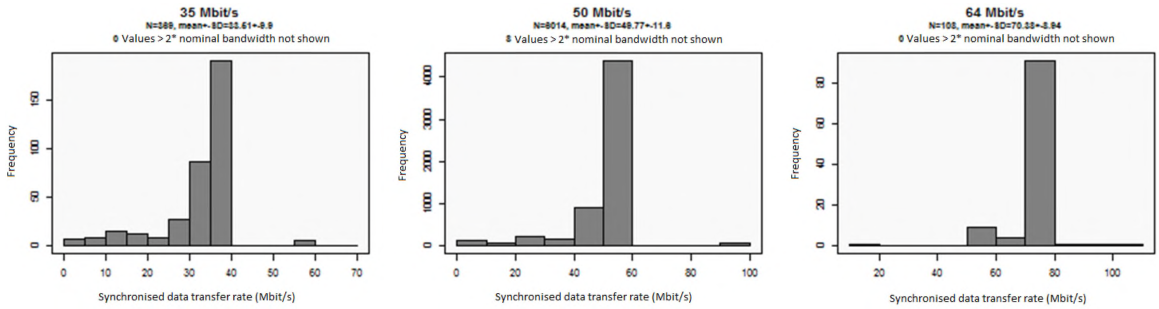

Figure 5.18.

Overall, the peaks in the distribution of the synchronised data rates lie within the range of the advertised data transfer rates specified by the customers, as was also the case in 2012.

The other observations made here can be interpreted on the basis of the respective technology being used.

Nearly all of the accesses examined here – with advertised data transfer rates of 32 Mbit/s and 64 Mbit/s – used cable technology. In this case, the synchronised data rate of the access was at least as fast as the advertised data transfer rate for the majority of customers. For example, 99.2% of the customers with 32-Mbit/s accesses (2012: 99.5%) had a synchronised data rate that was as fast as or faster than their advertised data transfer rate.

Most of the accesses with bandwidths of 25 Mbit/s, 35 Mbit/s or 50 Mbit/s were VDSL accesses. Here too, a very large proportion of these accesses was synchronised with the advertised data transfer rate or a higher rate.

Bandwidths of 18 Mbit/s or less were primarily realised with ADSL technology. This range exhibited synchronised data rates that fall below the advertised data transfer rates – and consequently below the values cited in the 'up to' contracts – for a large percentage of end customers. Only 60.2% of the customers with 6 Mbit/s accesses actually received a synchronised data rate of 6 Mbit/s or more (2012: 57.1%). In the case of 18 Mbit/s accesses, this proportion was just 16.64% (2012: 23.2%).

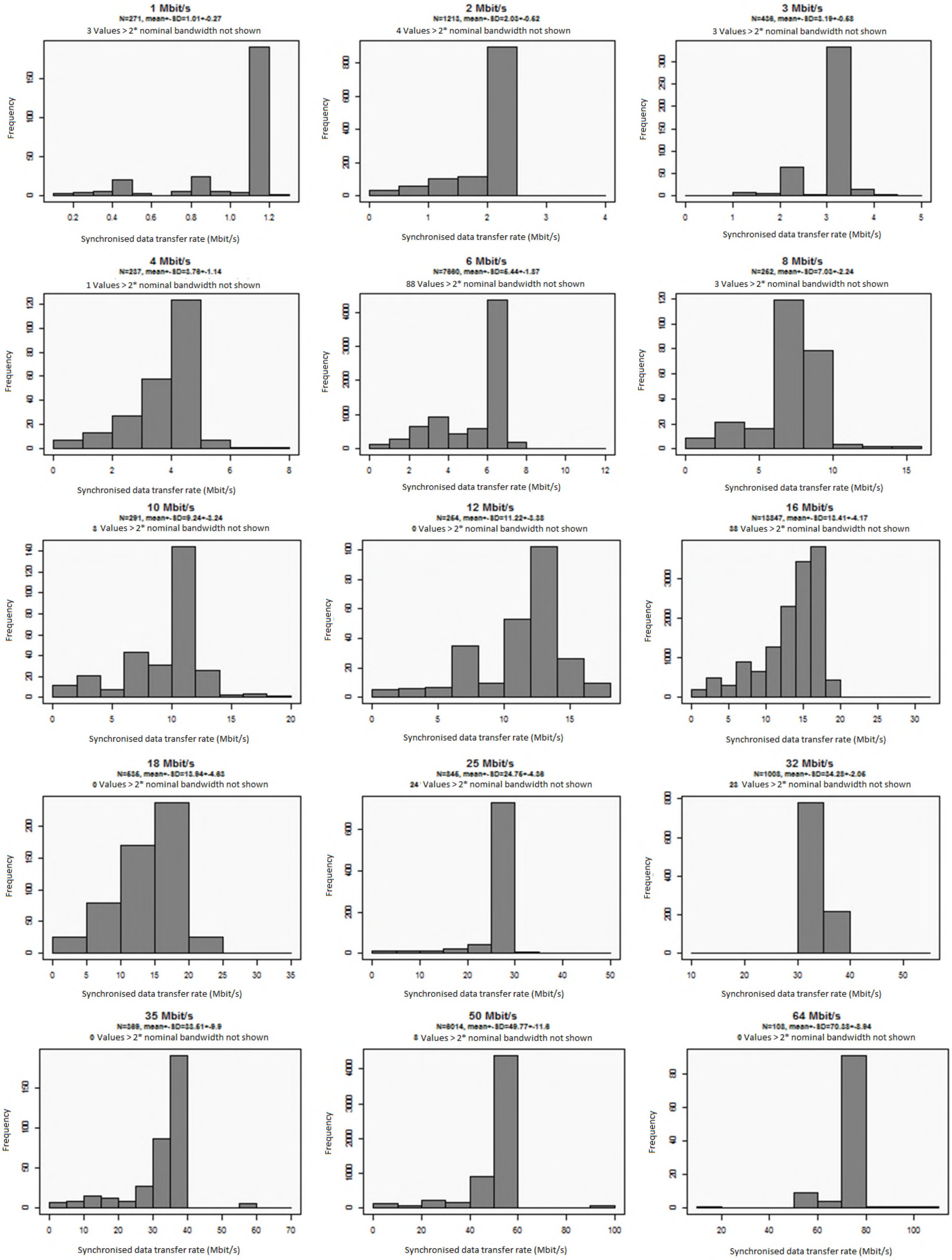

Figure 5.18: Frequency of the synchronised data rates for the 15 most-frequently advertised data transfer rates (To ensure comparability, the graphs here do not show 20 Mbit/s accesses, but rather the 64 Mbit/s accesses which were also used for the 2012 analysis.)

5.2.2 Router interfaces used to conduct the measurements

In the analysis of another subgroup, 3,294 measurements (2.2%) were observed for which the interfaces used (WLAN/LAN) could be determined using read-outs of the values. Here too, only those measurements were examined that the users reported as being conducted in an 'optimal test environment'.

It was found that 9% of the users in this analysis conducted their measurements via WLAN despite the fact that they specified the use of an optimal test environment.

This subsample was a non-random subgroup of the total sample. For this reason, it is not directly possible to apply to the total sample the identified proportion of participants who - despite reporting they had an optimal test environment - conducted the measurement via WLAN. It appears however very likely that a comparable proportion of those customers who used other modems/routers in fact also conducted their measurements via WLAN.

Within the subgroup, the data transfer rates measured via LAN can be compared with those that were actually measured via WLAN.

Measurements conducted via WLAN produced worse results than those conducted via LAN, particularly in the middle range of the percentages of the advertised data transfer rate. At 70% of the advertised data transfer rate, the difference is 8.9 percentage points (see Figure 5.19). A total of 82.5% of the measurements conducted via LAN and 77.2% of the measurements by WLAN reached 50% of the advertised data transfer rate or more.

The full advertised data transfer rate was achieved in 30.3% of the measurements conducted via LAN and 25.5% of the measurements performed via WLAN.

However, it is not possible to precisely quantify or strip out the influence that WLAN has on the measurement results because values for measurements conducted on the respective access in a truly optimal test environment are not available.

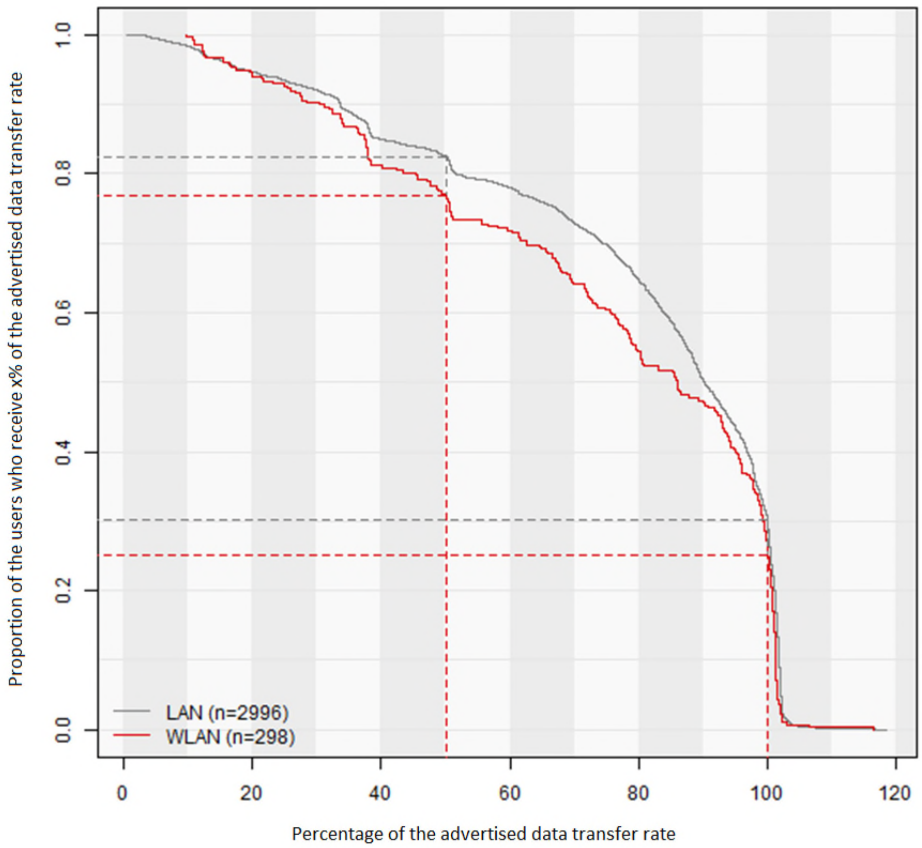

Figure 5.19: Empirical distribution functions of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate) for the subsample, by measurement via LAN and WLAN[27]

5.2.3 Parallel data traffic

For the examination of this subgroup, the interface traffic counters were also read out separately for the upstream and downstream direction (byte or packet counter). As a result, it was possible to identify data traffic flowing parallel to the measurement (such as through applications that are running in the background or other terminals that are accessing the modem/router) and then take it into account in the calculation of the data transfer rate.

The data volume transmitted via the WAN interface was ascertained at the start and at the end of the measurement. The read-out was conducted

[27] The calculated confidence interval width for the WLAN group ranges from 9.5 to 11.3 percentage points due to the small sample size.

only via the LAN interface between the end customer's PC and modem/router. The difference between the value at the end of the measurement and the value at the start of the measurement represents the data volume that was transferred via the WAN interface while the measurement was being conducted. This data volume includes both the data exchanged between the software and the data reference system during the measurement and, where applicable, any parallel data traffic. The data transfer rate can then be calculated on the basis of the total volume including parallel data traffic.

It was found that parallel data traffic took place during all the measurements, even though it represented only a very small proportion of total traffic for most participants (see Table 16).

For more than half of the measurements in the subgroup, parallel data traffic accounted for less than 1% of the total data traffic transmitted via the WAN interface. For 90% of the measurements, it was less than 4%. Parallel data traffic can however be precisely quantified and taken into account.

Table 16: Frequency of different proportions of parallel data traffic

Proportion of parallel data traffic								
Frequency	≥ 0% to < 1%	≥ 1% to < 2%	≥ 2% to < 3%	≥ 3% to < 4%	≥ 4% to < 5%	≥ 5%to < 6%	≥ 6% to < 7%	≥ 7% to < 8%
N	1820	843	230	94	58	33	31	35
Per cent	55,3%	25,6%	7,0%	2,9%	1,8%	1,0%	0,9%	1,1%
Frequency	≥ 8% to < 9%	≥ 9% to < 10%	≥ 10% to < 20%	≥ 20% to < 30%	≥ 30% to < 40%	≥ 40% to < 50%	≥ 50% to < 100%	Overall
N	14	18	76	21	12	5	4	3294
Per cent	0,4%	0,5%	2,3%	0,6%	0,4%	0,2%	0,1%	100,0%

Figure 5.20 compares the distribution of the measured data transfer rates with the distribution of the corrected data transfer rates. The correction makes itself particularly felt in the area where the actual data transfer rates (expressed as a percentage of the advertised data transfer rate) are higher.

A value of 82.1% was ascertained for '50% or more of the advertised data transfer rate' when the data traffic running parallel to the measurement was not taken into account. This figure was 82.9% when the total data traffic was taken into account. At 0.8%, this difference is very small.

The full advertised data transfer rate was achieved in 29.9% of the measurements without taking parallel data traffic into account and in 35.7% of the measurements when the entire data traffic was included. The difference here - 5.8% - was noticeably larger.

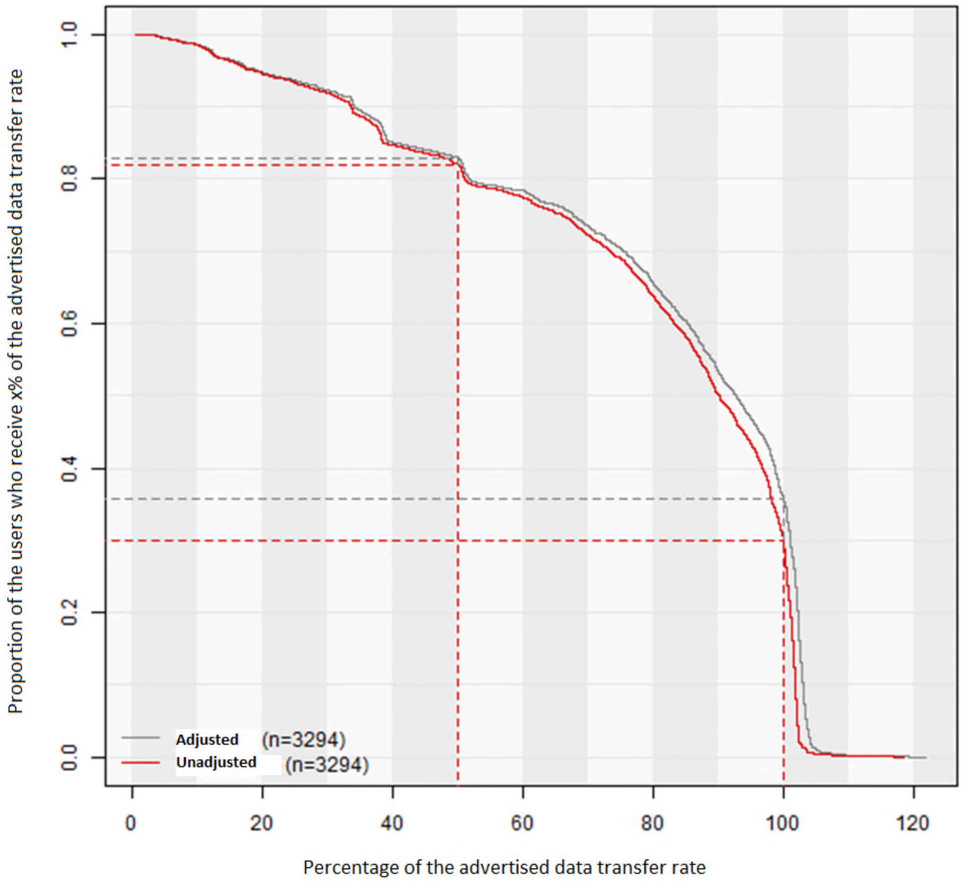

Figure 5.20: Empirical distribution function of the actual data transfer rate (expressed as a percentage of the advertised data transfer rate), for the sample with and without taking the parallel data traffic into account

5.3 Data transfer rates at different times of the day (measurement platform)

The temporal distribution of data transfer rates was examined with the help of the nationwide measurement platform. The accesses tested here were the highest-quality accesses available at these metropolitan locations which are extensively served by providers. The very high actual data transfer rates (expressed as a percentage of the advertised data transfer rate) can be explained by the fact that the platform sites are usually located in the immediate vicinity of the providers' main distributor, outdoor DSLAM or CMTS.

The measurements were conducted on an hourly basis 23 hours a day, seven days a week during the measurement period. The simple average is shown here for all measurements for the respective hour as a percentage of the advertised data transfer rate of the particular access.

Download

As in 2012, the download data transfer rate via a DSL access did not exhibit any dependency on the time of day (see Figure 5.21).

In contrast to this, cable accesses exhibited, as in 2012, a slight decline in their download data transfer rate during evening hours when more end users access the Internet. The measured data transfer rate fell by up to 10% during the evening. A possible cause for this is the fact that several end customers were using the resources (shared medium) at the same time. A similar effect was observed with fixed LTE accesses. A drop in the data transfer rate between 5:00 am and 6:00 am, presumably due to night-time maintenance work, was also observed.

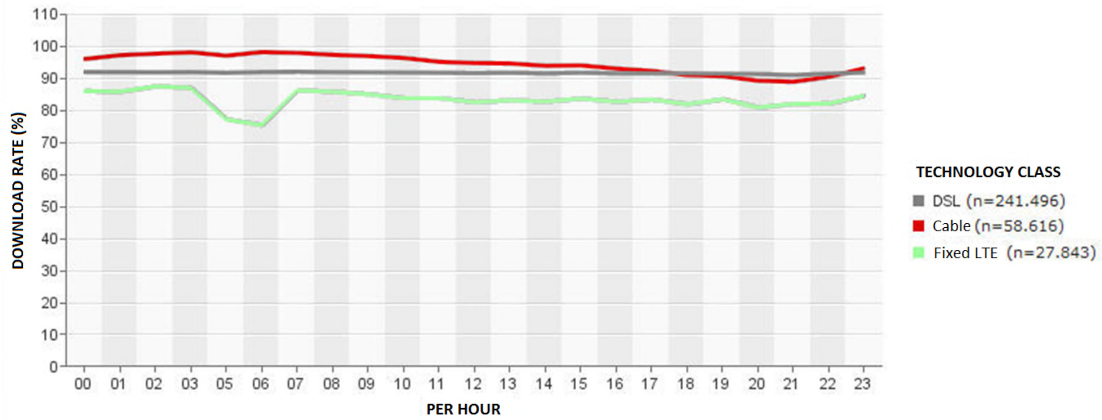

Figure 5.21: Temporal distribution of the download data transfer rates expressed as a percentage of the advertised download data transfer rate, by technology

The analysis by bandwidth class (Figure 5.22) revealed even distribution that exhibted very little deviation regardless of the time of the day. The broadband class > 50 Mbit/s constituted an exception here. The decline in the download data transfer rate during the evening hours can be explained by the large proportion of cable and LTE accesses.

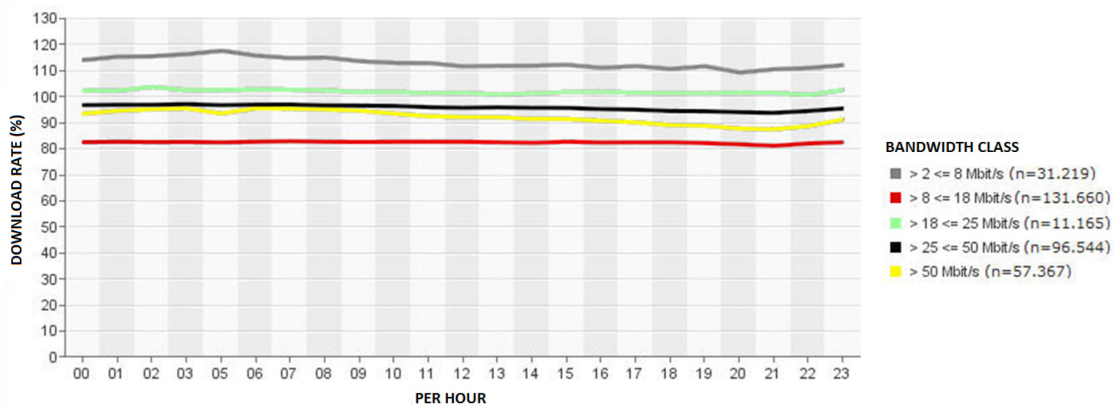

Figure 5.22: Temporal distribution of the download data transfer rates expressed as a percentage of the advertised download data transfer rate, by bandwidth class

Upload

In the case of upload speeds, the upload data transfer rate did not decline in the evening hours (see Figure 5.23).

As with the 2012 study, the fact that the time of day does not have as much influence on upload data transfer rates can be explained by the fact that the upload data transfer rates that are typically advertised to end customers are relatively low.

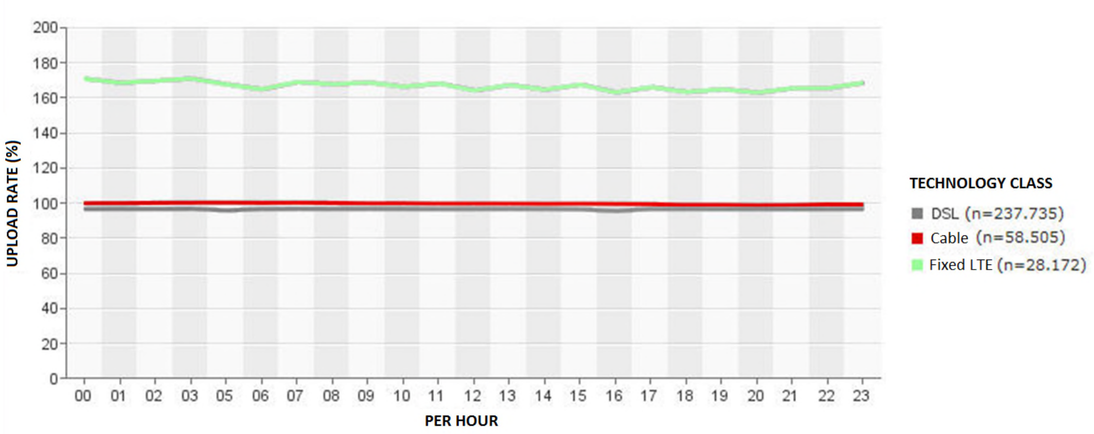

Figure 5.23: Temporal distribution of the upload data transfer rates expressed as a percentage of the advertised upload data transfer rate, by technology

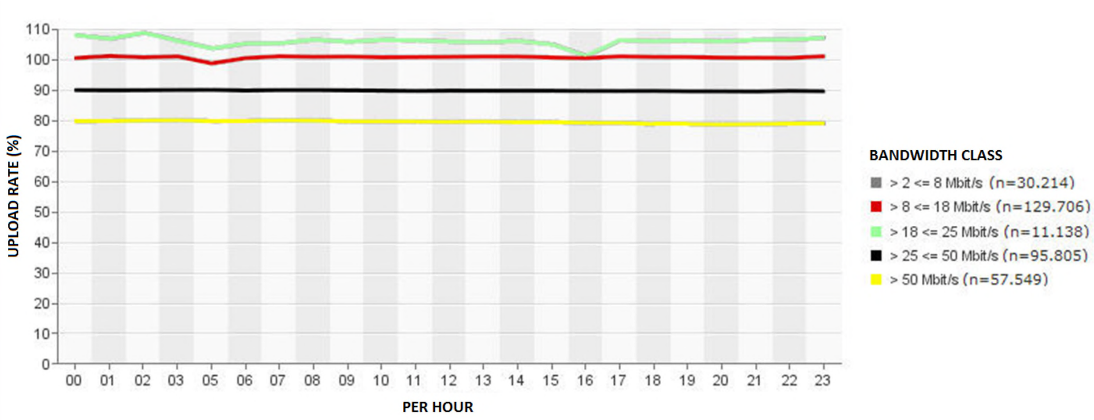

Figure 5.24: Temporal distribution of the upload data transfer rates expressed as a percentage of the advertised upload data transfer rate, by bandwidth class

5.4 Transfer times (measurement platform)

The transfer time measurements were conducted on the nationwide measurement platform.

The average transfer time presented here is the average response time of all 30 individual transfer times for the packets that were observed during a transfer time measurement.

This value was 18.52 milliseconds (ms) for DSL accesses. Cable accesses did better with 16.55 milliseconds (see Table 17). At 39.78 milliseconds, the transfer times measured for fixed LTE accesses were significantly longer. The values ascertained for DSL accesses and fixed LTE accesses improved over the results reported by the 2012 study (2012: 23.68 ms and 44.80 ms respectively) while the transfer times measured for cable accesses were somewhat longer than in the previous year (2012: 15.17 ms).

Table 17: Transfer times by technology

Transfer Time		
Technology	N	Mean
DSL	230.263	18,52 ms
Cable	57.088	16,55 ms
Fixed LTE	31.398	39,78 ms

When examined over the course of the day (Figure 5.25), the picture is similar to that seen in 2012. The measured transfer times for DSL accesses remained more or less constant. An increase of roughly up to 3% was observed during the evening hours. The transfer times of cable accesses were shorter than those of DSL accesses over the course of the entire day. They exhibited a slightly longer transfer time (up to approximately 10%) during the evening hours.

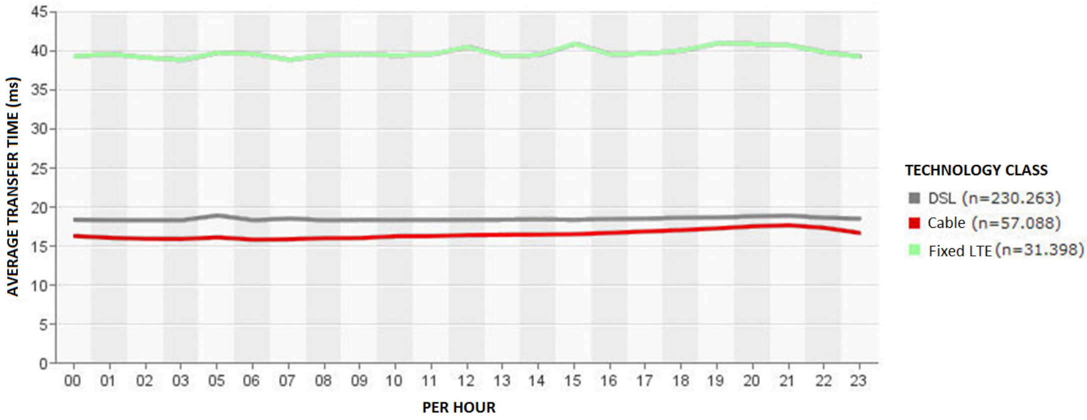

Figure 5.25: Temporal distribution of the transfer time over several hours, by technology

Analysed by bandwidth class (Table 18), transfer time for DSL accesses exhibited relatively little dependence on the broadband class. In the case of cable accesses, transfer time fell from 21.34 ms at > 25 to ≤50 Mbit/s to 15.96 ms in the class > 50 Mbit/s.

A clear dependence on bandwidth class was not observed among fixed LTE accesses. The reasons for this are not yet apparent.

Table 18: Transfer time by bandwidth class

Transfer time			
Technology	Bandwidth in Mbit/s	N	Mean
DSL	2: > 2 to ≤ 8	18.405	17,83 ms
	3: > 8 to ≤ 18	121.728	18,78 ms
	4: > 18 to ≤ 25	3.833	20,84 ms
	5: > 25 to ≤ 50	86.297	18,21 ms
Cable	5: > 25 to ≤ 50	6.344	21,34 ms
	6: > 50	50.744	15,96 ms
Fixed LTE	2: > 2 to ≤ 8	10.920	36,37 ms
	3: > 8 to ≤ 18	4.193	47,48 ms
	4: > 18 to ≤ 25	8.249	44,20 ms
	5: > 25 to ≤ 50	1.789	46,46 ms
	6: > 50	6.247	32,67 ms

5.5 Web browsing (measurement platform)

The scenario 'web browsing' was examined on the nationwide measurement platform. Here the first ten of the most frequently accessed sites according to the Alexa Top Sites list were accessed in order to simulate typical user behaviour (see 2.3).

The times for different phases of the page request were measured for this:

- The *DNS response time* is the time it takes to translate the domain name to the corresponding IP address.
- The *HTTP response time* is the time it takes to initialise the HTTP connection to the websites.
- Lastly, the time it took to completely download the Alexa Top 10 websites was measured as the website download time.

Table 19 shows these times for the respective connection technology.[28] Cable accesses delivered slightly better results than DSL accesses for the categories HTTP reponse time and website download time.

Table 19: DNS response time, HTTP response time and website download time in the scenario 'web browsing', by technology for fixed broadband accesses

Web Browsing				
Technology	N	DNS response time	HTTP response time	Website download time
DSL	2.415.307	32,89 ms	51,65 ms	4,64 s
Cable	617.801	40,80 ms	49,27 ms	4,49 s

Looking at the times by bandwidth class (Table 20), it can be said – as in 2012 – that the website download times of the accesses tested here were dependent to only a very small degree on the respective access's data transfer rate. The measured values for the complete download of the Alexa Top 10 sites via DSL ranged from 4.78 seconds in the bandwidth class > 2 to ≤ 8 Mbit/s to 4.57 seconds in the bandwidth class > 25 bis ≤ 50 Mbit/s.

[28] In light of the data volumes available, the 2013 study did without the web browsing scenario for fixed LTE accesses in favour of the number of measurements for the temporal distribution of the data transfer rates and the transfer times.

Cable accesses generated values of 4.81 seconds in the bandwidth class > 25 to ≤ 50 Mbit/s and 4.45 seconds in the bandwidth class > 50 MBit/s.

The amount of data that has to be transmitted to display the websites is relatively small. Consequently, access-agnostic parameters – such as infrastructures for delivering content in the net (content delivery networks) and infrastructures for hosting content – are more likely to come into play as factors that determine the download time.

Table 20: DNS response time, HTTP response time and website download time in the scenario 'web browsing', by bandwidth class for fixed broadband accesses

Web Browsing					
Technology		N	DNS response time	HTTP response time	Website download time
DSL	2: > 2 to ≤ 8	228.368	34,32 ms	52,32 ms	4,78 s
	3: > 8 to ≤ 18	1.232.717	29,76 ms	52,46 ms	4,66 s
	4: > 18 to ≤ 25	35.139	58,43 ms	49,91 ms	4,59 s
	5: > 25 to ≤ 50	919.083	35,77 ms	50,48 ms	4,57 s
Cable	5: > 25 to ≤ 50	73.368	33,90 ms	48,72 ms	4,81 s
	6: > 50	544.433	41,73 ms	49,34 ms	4,45 s

A website with complex content was chosen from the Alexa Top 10 list for the following presentation of the chronological breakdown of the website download time because loading such websites completely requires more interaction. A different website than the one used in the 2012 study was chosen because the one used last year is no longer in the Alexa Top 10.

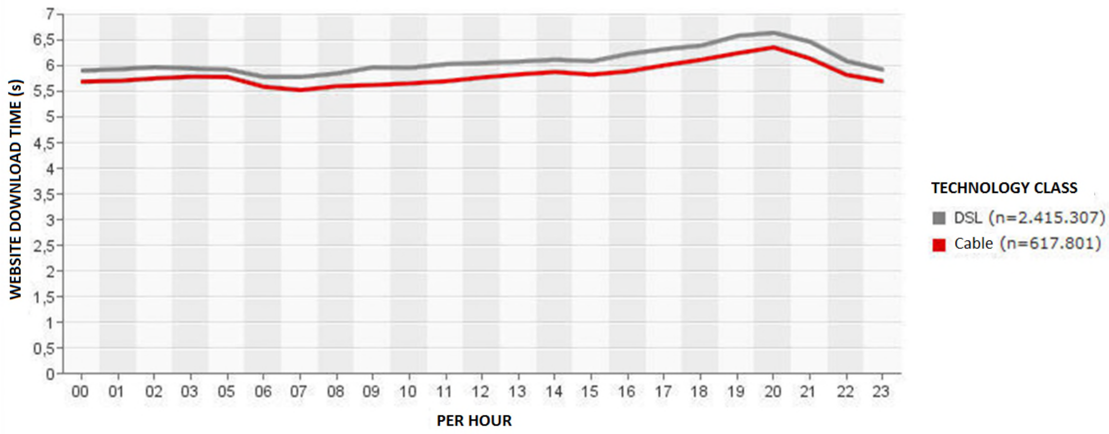

Figure 5.26: Temporal distribution of website download times over several hours, by technology, for a website with complex content

As in the 2012 study, the temporal distribution of the website download time exhibited an increase of roughly up to 15% in the download time in the evening hours. This effect was observed for both DSL and cable acccesses (see Figure 5.26) and was evident for all bandwidth classes (see Figure 5.27).

This could possibly be due to the increased load placed on the infrastructures when delivering content in the net or, in the case of hosting, the increased number of accesses during the evening hours.

The behaviour of the counter test point was intentionally included in the measurement in the 'web browsing' scenario in order to examine performance in terms of web content presentation. For this reason, a distinction must be made between the measured values shown here and the temporal distribution of the measured data transfer rates, which was examined at 5.3. The measurements for the temporal distribution of the measured data transfer rates were conducted under full utilisation of the transmission channel over a sufficiently long period in order to determine the data transfer rate of the particular connection. At the same time, the counter test point for the measurement (data reference system) was also controlled and designed in such a way that there would be no chance of interference through an overload.

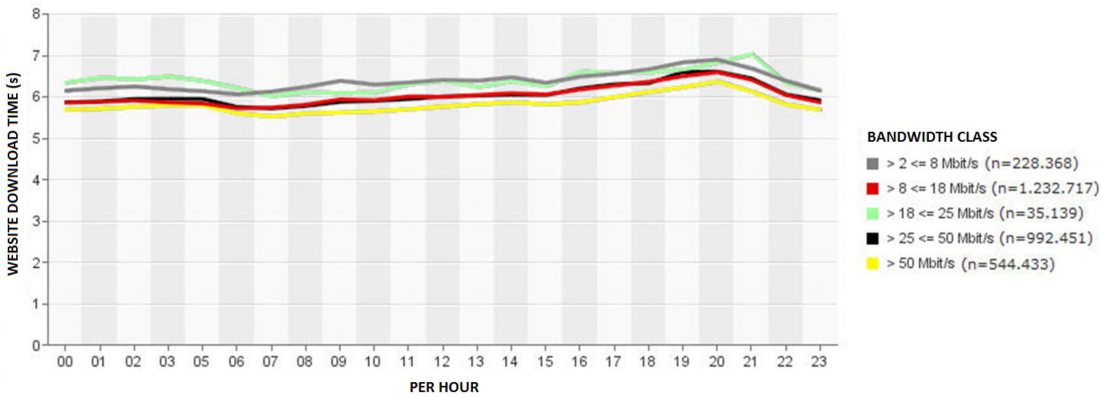

Figure 5.27: Temporal distribution of website download times over several hours, by bandwidth class, for a website with complex content

6 Glossary

Provider

A provider is a party that has concluded a contract with the end customer regarding the provision of an Internet access.

'Up-to' bandwidth

The data transfer rate of an Internet connection in practical use often falls short of the advertised data transfer rate. This can be due to a number of factors such as the length of the subscriber line, the number of users who use the line at the same time, and even the modem settings. For this reason, many telecommunications contracts do not guarantee a set data transfer rate and instead promise only rates of 'up to' a certain limit. The degree to which the actual achievable data transfer rate deviates from the maximum promised rate often remains unclear.

CMTS

A cable modem termination system (CMTS) is a component that is usually located in the cable headend and makes high-speed data services such as Internet or Voice over Cable available to cable users.

Data transfer rate

Speed at which data are transmitted via a (broadband) connection. Measured in megabits per second (Mbit/s). A description of the method used to measure data transfer rates for this study can be found at 2.1.1.

Nationwide measurement platform

The nationwide measurement platform is a measurement concept that was used for the study. It is described at 2.1.2.1.

DNS

The Domain Name System (DNS) is a hierarchical directory service in the Internet that is used to manage namespace, in other words, for answering requests for name to IP address resolution.

Download/Downstream

Direction of a data transfer from the Internet to the end-customer equipment.

DSL

A digital subscriber line (DSL, xDSL) is a digital broadband connection for subscriber terminals that uses simple copper cable in the conventional telephone network. xDSL includes ADSL (asymmetric digital subscriber line), HDSL (high data rate digital subscriber line) and VDSL (very high data rate digital subscriber line).

DSLAM
A digital subscriber line access multiplexer (DSLAM) is part of the infrastructure that is needed in order to use DSL.

Terminal
A technical device that the end customer employs in order to use the Internet access. It can be installed directly at the end customer interface (service access) or connected with it via an end-customer infrastructure.

End customer
Party that has concluded a contract with a provider for the provision of an Internet access. For the purposes of this document, telecommunications service providers who receive telecommunications services from other service providers are not considered to be end customers.

End-customer infrastructure
The whole of the systems and equipment on the end-customer side which are employed to use telecommunication via a telecommunications infrastructure.

End user
Party that has concluded a contract with a provider for the provision of an Internet access. In this document the term 'end user' is used synonymously with the term **end customer** as defined by the DIN 66274 standard.

ETSI
The European Telecommunications Standards Institute is a non-profit institute for the establishment of pan-European standards in the telecommunications field.

FTP
The File Transfer Protocol is a protocol of the ISO/OSI application layer for transmitting files via IP networks.

FTTB
Fibre to the Building: optical fibre cable to the building. Copper cables are used for the onward distribution in the building.

FTTC/FTTN
Fibre to the Curb / Fibre to the Node: optical fibre cable to the distributing box, onward transmission to the subscriber access via copper cable.

FTTH
Fibre to the Home: optical fibre cable into the house / flat.

Fibre optics
Technology for realising broadband accesses using optical fibre trunks. Forms: FTTH, FTTB, FTTC / FTTN

GPRS
General Packet Radio Service is a packet-oriented service for transmitting data in GSM and UMTS networks.

GSM
The Global System for Mobile Communications (GSM) is the second generation digital mobile telephony standard which succeeded the analogue systems of the first generation.

HTTP
The Hypertext Transfer Protocol (HTTP) is a protocol of the ISO/OSI application layer for transmitting data via IP networks. It is primarily used to load websites from the World Wide Web (www).

IP
Internet Protocol is a protocol of the ISO/OSI network layer for the exchange of data via computer networks.

IPTV
Internet Protocol Television (IPTV) is the generic term for audio-visual services such as television and video which are transmitted via IP-based networks.

ISDN
Integrated Services Digital Network (ISDN) is a digital fixed-line network standard for a telecommunications network that integrates services.

ITU-T
The International Telecommunication Union (Telecommunication Standardization Sector) is a specialised agency of the United Nations which deals officially and worldwide with technical aspects of telecommunications.

Cable
Technology for realising broadband accesses via broadband television cable (copper wire, coaxial)

LAN
A Local Area Network (LAN) is a local computer network with a limited range.

Transfer time
Time that a data packet requires to travel from a sender to a recipient, usually stated in milliseconds. A description of the method used to measure data transfer rates for this study can be found at 2.2.

LTE
Long Term Evolution is a fourth-generation digital mobile telephony standard which enables faster data transfer rates than are possible with the third generation standard.

Fixed LTE
LTE access technology is used particularly in rural areas as an alternative to fixed-network access. Users access the Internet via an LTE-capable terminal.

Mbit/s
Megabits per second. Mbit/s is the unit used to measure data transfer rates. In conformance with the International System of Units (SI), one Mbit/s is the equivalent of 1,000 kbit/s or 1,000,000 bit/s.

Mobile broadband access
Broadband access for use at changing locations. Mobile broadband access is realised in different technologies (such as UMTS, LTE).

Modem/Router
Functional group that provides the end-user interface necessary for using the Internet access. Depending on the access technology used and the services offered, it can be a simple network termination point or a complex hardware unit that the service provider makes available (such as a router/modem unit for double and triple play products).

Net neutrality
Net neutrality is the term used to designate unhindered data transmission in the Internet. All data packets are transported unaltered and in the same quality, without regard to their origin, destination or content.

PING
Ping is a computer programme for checking the availability of a host in an IP network. It is also used when measuring transfer time.

SIM
A Subscriber Identity Module is a chip card in a mobile phone that is used to identify the user in GSM and UMTS networks.

SNMP
Simple Network Management Protocol is a protocol for managing, monitoring and controlling network elements.

Fixed broadband access
Broadband access for use at a stationary location. Access can be realised either by wire (e.g. DSL, cable, optical fibre) or on a wireless (e.g. fixed LTE, radio relay, satellite) basis.

Synchronised data rate of the connection
Data rate with which the terminal device is synchronised with the provider's network. The connection's synchronised data rate is the maximum data transfer rate that, under optimal conditions, can be reached but not exceeded. Depending on the design of the provider's product, it can be less than the maximum data rate which the subscriber line would permit based on its quality and, where applicable, its length, depending on the technology used for the connection. It must also be remembered that in the case of some technologies, the resources can be used by several consumers (for example, with cable or mobile telephony accesses).

TCP
The Transmission Control Protocol is the connection-oriented, packet-switching protocol of the ISO/OSI transport layer for controlling data transmission.

Upload/Upstream
Direction of a transmission, from the end-customer's equipment to the network.

UMTS
The Universal Mobile Telecommunications System is a third-generation digital mobile telephony standard with faster data transfer rates than are possible with the second generation.

URL
The Uniform Resource Locator is the identifier of a resource (host) and the network protocol used in computer networks. The URL can be used to locate the resource (is often used as a synonym for Internet address).

Advertised data transfer rate
Data transfer rate that the provider advertises to the end customer or communicates to the end customer in billing or contract documents. This rate is often expressed as an 'up to' bandwidth.

VoIP
Voice over IP is voice transmission via IP-based data networks.

WAN
A Wide Area Network is a computer network that covers a very large geographical area.

WLAN
A Wireless Local Area Network is a local computer network with a limited range which can be accessed on a wireless basis.

Annex

7 Technical description of the measuring procedure

The Annex provides a brief outline of the technical procedures and processes used in the study.

7.1 System used for the measurement platform

The nationwide measurement platform consists of monitoring units at 26 sites (see Figure 7.1) and several centralised server systems which include a business intelligence platform (data analysis), a data warehouse (data storage), data reference systems (counter test points for the data measurements) and a management system.

Distribution of the sites

The distribution of the sites was determined on the basis of the following considerations:

- Coverage of at least all single-digit telephone prefix areas must be ensured.
- The sites had to be located in larger cities to ensure the availability of a large number of providers at one location.

Figure 7.1: Locations of the nationwide measurement platform sites

Distribution of the providers and products

Broadband end-customer connections from national, regional and local providers were examined via the platform. Fixed-line providers and cable TV providers were selected for this, based on their respective market share[29] (see Table 21).

In the area of fixed broadband connections the respective 'best-in-class' products were tested, in other words, the highest-quality connections available at urban locations that are extensively served by providers. A large proportion of the platform locations are to be found in the direct vicinity of the providers' main distribution frame, outdoor DSLAM or CMTS.

[29] VATM Telecommunications Market Analysis Q3/2013

Table 21: Providers of and products for fixed broadband connections examined on the nationwide measurement platform (Source: VATM Telecommunications Market Analysis Q3/2013)

Fixed broadband accesses			
Provider	**Market share**	**Classification**	**Products**
Telekom	43,8%	National	16000/1024 kbit/s, 25064/5056kbit/s, 51300/10000 kbit/s
Vodafone	10,6%	National	6144/640 kbit/s, 16128/800 kbit/s, 50000/10000 kbit/s
United Internet	12,0%	National	6000/512 kbit/s, 16000/1024 kbit/s, 24000/5000 kbit/s, 51300/10000 kbit/s
Telefónica	8,1%	National	6000/1024 kbit/s, 12000/1024 kbit/s, 16000/1000 kbit/s, 16000/1024 kbit/s, 50000/10000 kbit/s
Unitymedia KabelBW	8,5%	Regional	32000/1000 kbit/s, 64000/5000 kbit/s, 100000/2500 kbit/s, 128000/5000 kbit/s
Kabel Deutschland	7,1%	Regional	32000/2000 kbit/s, 100000/6000 kbit/s
EWE	2,5%	Regional	16000/1024 kbit/s
Versatel	1,8%	Regional	16000/800 kbit/s
NetCologne	1,4%	Local	18000/1000 kbit/s, 100000/5120 kbit/s
M-net	0,7%	Local	18000/1000 kbit/s
KielNet	in 'others'	Local	51200/10240 kbit/s
congstar	in 'Telekom'	National	16000/1024 kbit/s
Tele2	in 'others'	Regional	16000/1000 kbit/s

7.1.1 Monitoring units – stationary measurements

Powerful hardware and software that were tailored to this particular purpose were used for the measurement platform. The monitoring units are autonomous units which do not require an on-site operator. When a unit is turned on, it automatically switches to operating mode. Self-tests and integrated system monitoring ensure a high level of operational reliability.

Each of the said sites is equipped with at least one monitoring unit with the following specifications:

- Computer system that uses 19-inch technology or an embedded box PC
- State-of-the-art PC architecture with a sufficiently large processor and memory
- 10/100/1000 Mbit/s Ethernet card
- ISDN card
- Windows XP Embedded operating system
- The operating system's default TCP/IP settings

The monitoring units were connected – like the participants – to the access network, including the provider's router. The fact that publicly-available subscriber lines rather than special test connections were used guaranteed the comparability of the providers.

Restrictions on volume as a result of the measurements were not observed among the access products.

7.2 Measurement setup for end customer measurements

To ensure that the largest possible number of participants could be obtained, the implementation technology had to meet a number of requirements:

- It must not require any special installation in the end customer's infrastructure. This was stipulated in order to avoid making participation more complicated for the end user.
- It must not require a specific type of browser or operating system.
- It must be widely used and robust.

The measurement software used for the 2013 study was not based on Flash, as in the previous study, but rather on Java.

The following aspects were taken into account in this connection:

- The end-customer measurement was conducted using a software application in the form of a *Java PlugIn* in the browser on the end customer's PC. The switch to Java did not lead to any changes in the actual measuring process over the 2012 study.
- Since Java is widely used, end customers could normally use the software application without having to install anything else on their computers, similarly to 2012 when Flash was used.
- In contrast to Flash, Java allows the use of protocols (in particular the Simple Network Management Protocol (SNMP)) which can be used to query the end customer's modem/router via the *Java PlugIn* in the browser on the end customer's PC.
- For security reasons, the measurement software (programme code) was signed with a certificate to ensure the authenticity of the source.[30] Likewise, readouts were conducted only in the end-customer environment (LAN). The Internet was not accessed for this since this would mean an additional security risk.

[30] Digitally signing Java applications protects the code from manipulation and links the provider's identity to the code. This provides end users the assurance that the code comes from zafaco GmbH and is trustworthy.

During the study, personal data was collected, stored and processed when necessary or required for conducting the study. The legal provisions that were currently in effect were complied with throughout these activities. Personal data include the user's IP address and the router ID that are ascertained during the measuring process for validation and statistical monitoring purposes. Under certain circumstances, this information could allow the user to be identified (personal reference).

In accordance with the privacy statement of the Network Quality Initiative, only zafaco and the Bundesnetzagentur have access to the users' IP address and router ID. This data is not made available to third parties. Further, neither zafaco nor the Bundesnetzagentur could identify the users. Only an access provider would be able to infer a user's identity using this information because only providers can match an IP address or router ID to a contract.

End-customer test environment

The most reliable measurement results can be achieved when other data-intensive applications and other terminal devices do not access the Internet access / broadband connection that is to be measured and virus scanners, firewalls and the like have been deactivated.

In principle, the following effects can occur that influence the results of the measurement:

- Additional terminal devices (such as smartphones or tablets) access the Internet and generate parallel data traffic at the same time that the measurement is being conducted.
- The connection of the end-customer PC conducting the measurement is limited by
  - a WLAN connection that has lower data transfer rates than the Internet access does,
  - local LAN configurations which limit the data transfer rate of individual end-customer terminals.
- Processes/applications (such as virus scanners and firewalls) can be directly integrated into the data exchange between the software application and data reference system. This can possibly influence the data transfer rate.

- The operating system, browser version, etc. used on the end customer's terminal can influence the measurement results (for example, implementation of the TCP/IP protocol stack).

The end users were informed of these effects and requested to establish an 'optimal test environment'. They were instructed to close all other applications and connect the terminal to be used for the measurement directly via LAN cable to the access unit made available by the provider. They were also asked to close any parallel processes/applications that might be running in the background.

Lastly, prior to conducting the measurement, the end user was asked whether the above-described type of optimal test environment was in place during the measurement (see2.1.3.1).

Only those measurements for which the customer reported having an optimal test environment underwent the validation process conducted for the overall study. As a result, only those data records that, according to the respective customer, were obtained under optimal test conditions were included in the analysis of the study.

Reading additional values

In contrast to the 2012 study, additional values could be read for certain subsets of routers in the 2013 study:

- Synchronised data rate of the connection

  The term 'synchronised data rate' refers to the data rate with which the modem connects with the provider's access network. The synchronised data rate is the data transfer rate that the subscriber line achieves but cannot exceed under optimal conditions. Depending on the design of the provider's product, the synchronised data rate can be less than the maximum data transfer rate that the subscriber line permits according to its quality and – depending on the connection technology – its length. Account must also be taken of the fact that, for example, in the case of some technologies it is possible that more than one consumer can use resources in the access network at the same time (such as with cable or mobile communication accesses). In addition, the synchronised data transfer rate does not cover the joint – technology-agnostic – use of resources in the concentration network.

  Compared with the 2012 study, the number of manufacturers able to read the line's synchronised data rate was increased by implementing additional query protocols. This value is useful for determining whether the synchronised data rate falls within the range indicated by the end customer as the advertised data transfer rate (see 5.2.1).

- Query of the router interfaces, including their line speed (interface link speed)

  The properties of the end customer's PC and router/modem (LAN/WLAN) that were used for the measurement, including their line speed (interface link speed), could be read from a subset of modems/routers.

  It was consequently possible to ascertain for this subset whether the measurement was conducted via WLAN and the data rate with which the end customer's PC was connected with the modem/router, irrespective of the end user's statement regarding the use of an optimal test environment.

- Transmitted traffic volume in the upstream and downstream direction of the interfaces (interface traffic counter)

  For this subset, the total transmitted traffic volume in the upstream and downstream direction could be read from the byte or packet counter (interface traffic counter) of the WAN interface (the router's connection to the Internet). The readout was conducted only via the LAN interface between the end customer's PC and modem/router. This made it possible to identify data traffic that occurred above and beyond the data traffic during the measurement. This parallel data traffic can be caused by, for example, applications that are running in the background or other terminal equipment.

Using the above-described values, the customer's statement regarding the use of an 'optimal test environment' can be checked in respect of the quality of the connection of the end customer's PC (e.g. WLAN) and parallel data traffic can be included in the calculation of the data transfer rate (see 2.1.3.2.1).

Since these possibilities did not exist for all participants, the effects for this subgroup were examined in a separate analysis (see 5.2.2 and 5.2.3).

It was consequently decided not to treat differently the subset of measurement results for which it was possible to read out other values as well. This procedure ensured methodological consistency between the first quality study and the current second quality study. Treating a subset differently would have also led to bias in the overall study.

7.3 Data reference systems

Eight servers (data reference systems) with a connection of 1 Gbit/s each were used for the data measurements. Optimised, stable routing was achieved by linking the data reference systems with Europe's largest and most important peering points / Internet exchange points.

The server-side configuration was as follows:

- Computer system that uses 19-inch technology
- State-of-the-art PC architecture with a sufficiently large processor and memory

- 10/100/1000 Mbit/s Ethernet card
- Linux operating system
- TCP/IP configuration according to ETSI EG 202 057-4

7.4 Measuring procedure

The measurements were controlled by a centralised management system. A special test schedule with measurements every hour was carried out for each monitoring unit. During the data measurements, connections were generated between the monitoring units and one of eight servers (data reference systems). The test schedule for the automated measurements was set up so that a 20% reserve was maintained, thus precluding an overloading of the data reference systems. In addition, the servers were monitored by a monitoring system. A night-time maintenance window between 4:00 am and 5:00 am was incorporated into every day for scheduled maintenance work.

7.4.1 Measuring the download data transfer rate

The data transfer rate for downloads was measured on the measurement platform and in the course of the end-customer measurements using the same procedure.

In order to reproduce a realistic user situation, the HTTP protocol that is often used by end customers was employed.

Several parallel HTTP data streams were initiated in order to download a 1 GB file from the data reference system to the monitoring unit for each data stream. The transfer of each of the data streams was stopped after a pre-determined period of 20 seconds. It was thus ensured that, even at the maximum observed data transfer rate, data would be transmitted during the entire measurement period and the maximum data transfer rate possible for the respective transmission link could be measured. The effects of TCP congestion control (overload control) were taken into account when determining the window of time for this.

Initiating several parallel data streams also reduces the influence that the monitoring unit's TCP/IP configuration has on the measurement. The higher the data transfer rate to be measured, the stronger this influence is. In the course of extensive (and, since 2002, regular) surveys conducted by zafaco, the use of four data streams has proven to be suitable for the bandwidth range of up to 200 Mbit/s that was covered by this study.

The *HTTP download time* is the amount of time that elapses from the starting time of the last HTTP stream until the time of the first interruption of the four parallel HTTP streams of the standardised HTTP download (see Figure 7.2). Thus, the term 'HTTP download time' refers to the period of time during which all parallel HTTP streams generate load at the same time.

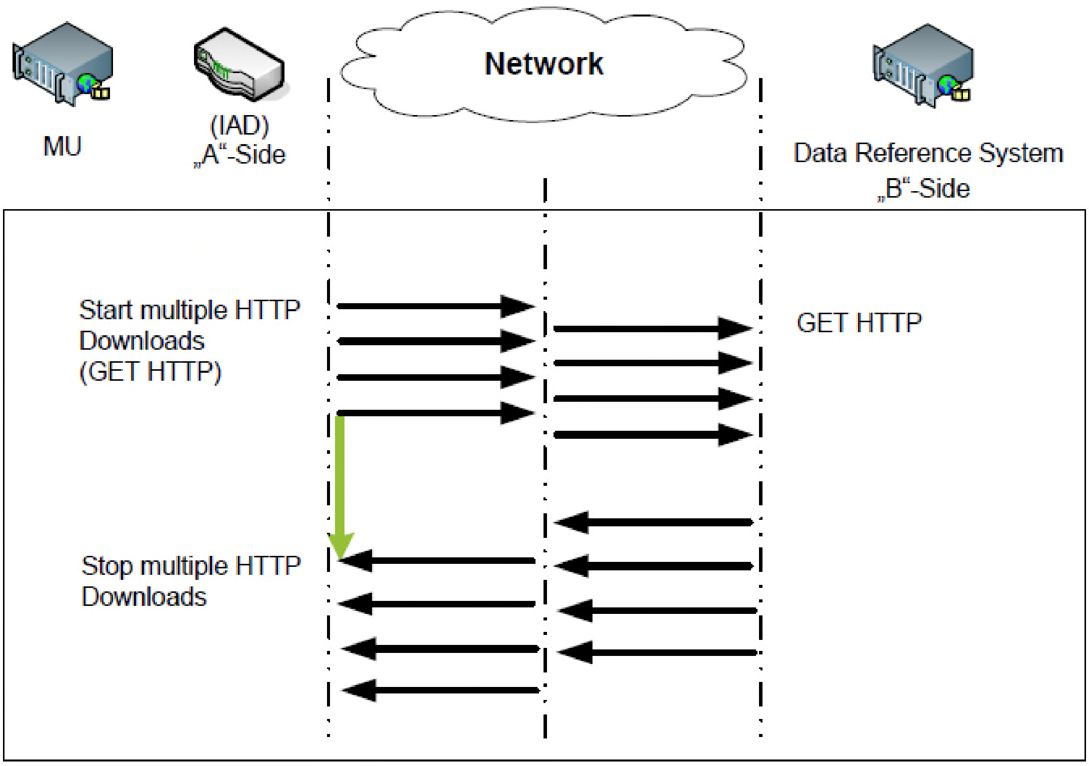

Figure 7.2: Measuring the download data transfer rate

The data volume that was transmitted is calculated by adding the volumes of data loaded by the four individual HTTP streams during the HTTP download time.

The *HTTP download throughput* – and thus the available download data transfer rate in Mbit/s – was calculated on the basis of the data volume and the HTTP download time.[31]

7.4.2 Measuring the upload data transfer rate

The details of the measuring procedure chosen here vary, depending on whether the measurement is conducted on the measurement platform or as part of the end-customer measurements.

When conducting measurements on the measurement platform, the FTP protocol that is widely used for transmitting files was used. The upload data transfer rate was measured by conducting a standardised FTP upload[32] of a sufficiently large[33] file in passive mode[34] which was then interrupted after 20 seconds.

In contrast, the upload data transfer rate was ascertained during the end-user measurements with the help of a standardised HTTP upload[35]. For this, a sufficiently large[4] amount of data was generated and transmitted for a measurement period of at least 20 seconds.

The *upload time* for the FTP upload was calculated as the time that elapsed from the starting time until the time when the FTP stream of the standardised FTP upload was interrupted (see Figure 7.3). For the HTTP upload, the upload time is the time that elapses from the starting time until the upload stream has been completely transmitted.

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[31] In the case of the end-customer measurements, the calculation included the HTTP protocol header, in other words: the information regarding the data transfer rate refers to the throughput of the Internet access service (IP payload).
[32] In accordance with ETSI EG 202 057, Part 4
[33] Here, 'sufficiently large' means that even at the maximum observed data transfer rate it is ensured that data will be transferred during the entire measurement period and that is it possible to measure the maximum possible data transfer rate for this transmission link.
[34] Passive mode is used when the server is unable to establish a connection with the client. This is the case when, for example, the client is located behind a router which changes the client's IP address via NAT or when a firewall restricts access to the client's network from outside the network.
[35] In accordance with ETSI EG 202 057, Part 4

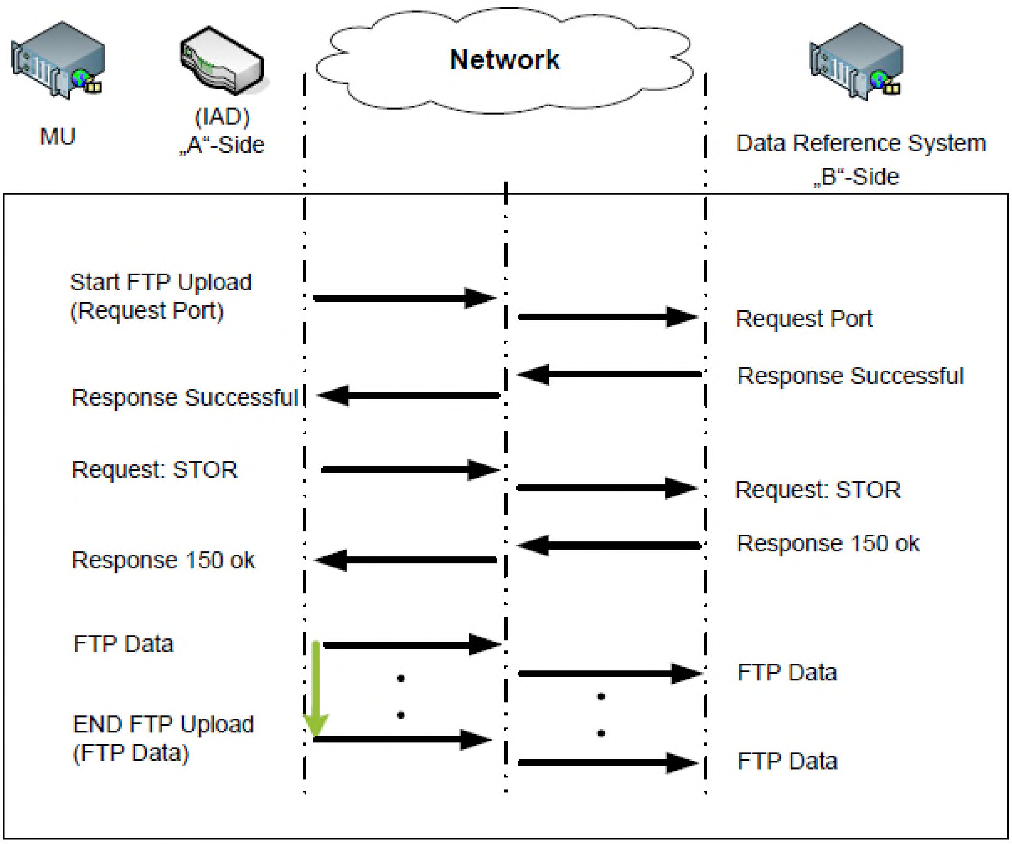

Figure 7.3: Measuring the upload data transfer rate

The *upload throughput* and thus the product's available upload data transfer rate, measured in Mbit/s, were calculated on the basis of the data volume and the upload time.

7.4.3 Measuring the transfer time

The transfer time measurement involves sending a ping request to a data reference system. This request is transmitted by the network nodes along the transmission path and answered by the queried system in the opposite direction. The transfer time is the time that has elapsed between the sending of the request and the receipt of the response.

A transfer time measurement conducted on the measurement platform consists of 30 consecutive ping measurements[36] that are carried out in 1-second intervals from a monitoring unit to the data reference systems.

The transfer time measurement is defined here as the time that elapses (see Figure 7.4) between sending a ping request (ICMP echo request) and the receipt of the response to it (ICMP echo reply).

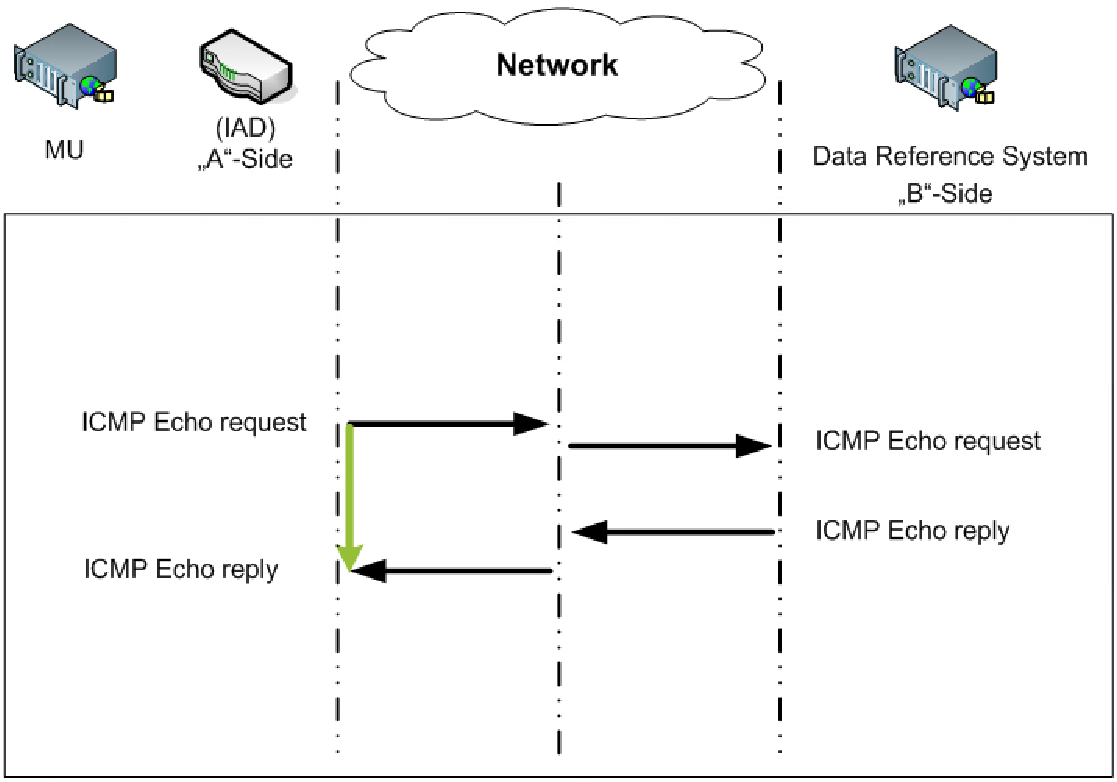

Figure 7.4: Measuring the transfer time

The *average transfer time value* is the average response time in milliseconds for all transfer times in a transfer time measurement.

7.4.4 Measuring the website download time

In order to simulate typical user behaviour, the ten websites which according to the Alexa Top Sites list [37] were visited most often in July 2013

[36] ICMP echo requests with a packet size of 32 bytes
[37] Cf. www.alexa.com/topsites/countries/DE

were accessed (see Table 22). The composition of the list was kept the same during the measurement period.

Table 22: Alexa Top 10 Sites (as of: July 2013)

Alexa Top 10 Websites in Germany // July 2013	
Ranking	**Website**
1.	http://www.google.de
2.	http://www.facebook.com
3.	http://www.youtube.com
4.	http://www.amazon.de
5.	http://www.ebay.de
6.	http://www.google.com
7.	http://www.wikipedia.org
8.	http://www.web.de
9.	http://www.gmx.net
10.	http://www.yahoo.com

In connection with the web browsing use scenario, the time it takes for a website to load completely was ascertained. The end user perceives this process as a single event. From a technical standpoint however different phases can be measured (DNS response time, HTTP response time and website download time). These quality parameters were individually ascertained as outlined below.

DNS response time

This value measures the time it takes in milliseconds to translate domain names to IP addresses.

DNS response time is defined here as the time that elapses between the sending of a DNS request (DNS query) to the terminal and the receipt of the resolved IP address (DNS query response).

HTTP response time

This value is the response time of an HTTP initialisation to the websites of the Alexa Top 10 in milliseconds.

HTTP response time is defined here as the time that elapses between the sending of the initial HTTP request (GET HTTP) until the receipt of the first TCP packet of the HTTP response.

Website download time

This value indicates the amount of time in seconds that is needed to download completely the Alexa Top 10 websites.

The *website download time* is defined here as the time that elapses between the sending of the initial HTTP request (GET HTTP) and the receipt of the last HTTP response (HTTP 200 OK) (see Figure 7.5).

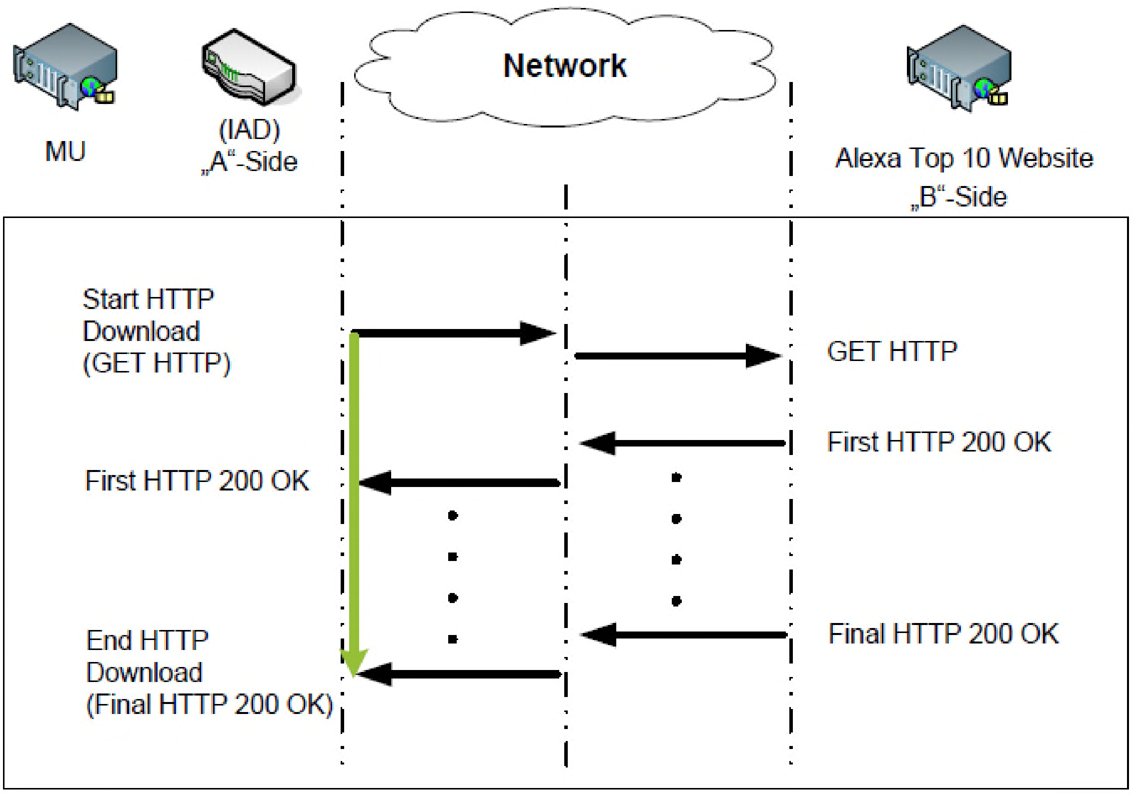

Figure 7.5: Measuring the website download time

A WebKit browser engine[38] that supports JavaScript and Web 2.0 sites was used to record DNS response times, HTTP response times and website download times. It consequently permits accurate observation and recording of the processes that take place when websites are called and loaded. As a result it is possible to precisely determine the individual times for the complete download of websites.

[38] WebKit (http://www.webkit.org/) is an open source HTML rendering engine which is used to display web pages in web browsers.

7.5 Reading modem/router parameters

The Java application used for end customer measurements for the 2013 study makes it possible to read the information listed below from several providers’ modems/routers.

During the study, personal data was collected, stored and processed when necessary or required for conducting the study. The legal provisions that were currently in effect were complied with throughout these activities. Personal data include the user’s IP address and the router ID that are ascertained during the measuring process for validation and statistical monitoring purposes. Under certain circumstances, this information could allow the user to be identified (personal reference).

In accordance with the privacy statement of the Network Quality Initiative, only zafaco and the Bundesnetzagentur have access to the users’ IP address and router ID. This data is not made available to third parties. Further, neither zafaco nor the Bundesnetzagentur could identify the users. Only an access provider would be able to infer a user’s identity using this information because only providers can match an IP address or router ID to a contract.

7.5.1 Synchronised data rate of the connection

The term 'synchronised data rate' refers to the data rate with which the modem connects with the provider's access network. The synchronised data rate is the data transfer rate that the subscriber line achieves but cannot exceed under optimal conditions. Depending on the design of the provider's product, the synchronised data rate can be less than the maximum data transfer rate that the subscriber line permits according to its quality and – depending on the connection technology – its length. Account must also be taken of the fact that, for example, in the case of some technologies it is possible that more than one consumer can use resources within the access network (such as with cable or mobile communication accesses). In addition, the synchronised data transfer rate does not cover the joint – technology-agnostic – use of resources in the concentration network.

Compared with the 2012 study, the number of manufacturers able to read the line’s synchronised data rate was increased by implementing additional query protocols. This value is useful for determining whether the synchronised data rate falls within the range indicated by the end customer as the advertised data transfer rate (see 5.2.1).

7.5.2 Query of the router interfaces, including their line speed (interface link speed)

The properties of the end customer's PC and router/modem (LAN/WLAN) that were used for the measurement, including their line speed (interface link speed), could be read from a subset of modems/routers.

It was consequently possible to ascertain for this subset whether the measurement was conducted via WLAN and the data rate with which the end customer's PC was connected with the modem/router, irrespective of the end user's statement regarding the use of an optimal test environment.

7.5.3 Transmitted traffic volume in the upstream and downstream direction of the interfaces (interface traffic counter)

For this subset, the total transmitted traffic volume in the upstream and downstream direction could be read from the byte or packet counter (interface traffic counter) of the WAN interface (the router's connection to the Internet). The readout was conducted only via the LAN interface between the end customer's PC and modem/router. This made it possible to identify data traffic that occurred above and beyond the data traffic during the measurement. This parallel data traffic can be caused by, for example, applications that are running in the background or other terminal equipment.

Using the above-described measurements, parallel data traffic can be included in the calculation of the data transfer rate.

The data volume transmitted via the WAN interface was ascertained at the start and at the end of the measurement using the traffic counter. The readout was conducted only via the LAN interface between the end customer's PC and modem/router. The difference between the value at the end of the measurement and the value at the start of the measurement represents the data volume that was transferred via the WAN interface during the measurement period. This data volume includes both the data exchanged between the software application and the data reference system during the measurement and, where applicable, any parallel data traffic. The data transfer rate can then be calculated on the basis of the total volume including parallel data traffic.

7.5.4 Readout process

The readout process is started once the customer has agreed to conduct the measurement and the measuring process has begun.

The modem/route is accessed from the end customer’s PC within the customer’s LAN/WLAN. As a first step, the manufacturer and provider are identified. Manufacturer-specific queries are then conducted by a Java Applet from the Java PlugIn.

This is done either via Universal Plug and Play (UPnP)[39], the Simple Network Management Protocol (SNMP)[40] or via http.

[39] UPnP allows devices to be accessed, irrespective of manufacturer, via an IP-based network. The UpnP standard is specified by the UPnP Forum.
[40] The SNMP network protocol developed by IETF is used to monitor and manage network elements such as routers on a centralised basis.

7.6 Technical validation

The measured values and the end-customer information were checked regularly in the course of a multi-step validation process. Data records with implausible values were rejected.

Depending on the values ascertained, the following validation steps were conducted:

Provider

- Reject foreign providers.
- Validate the provider identifier based on the IP address in conjunction with a reverse DNS lookup / whois query.
- Map valid resale scenarios (possible combinations of providers based on end-customer information and service providers based on the technical validation)[41].

Postal code with attribution to geographical area and federal state

- Attribution to federal state and geographical area (urban, semi-urban or rural[42]) based on the population density[43] of the respective postal code area, with verification of the validity of the specified postal code.

Technology

- Translate free text entries into standard designations with the help of regularly updated conversion tables.
- Check whether the specified technology corresponds to combinations of providers and technologies found in the marketplace.

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[41] During the technical validation, the provider is ascertained whose wholesale product the reseller uses in order to offer end customers an Internet access service. In the event that this provider could not be a wholesale provider for the provider indicated by the end customer, this data record is rejected as being implausible.

[42] Classification according to Eurostat

[43] Federal Statistical Office, "List of Municipalities, territorial status: 31 December 2011 (4th quarter)", January 2012

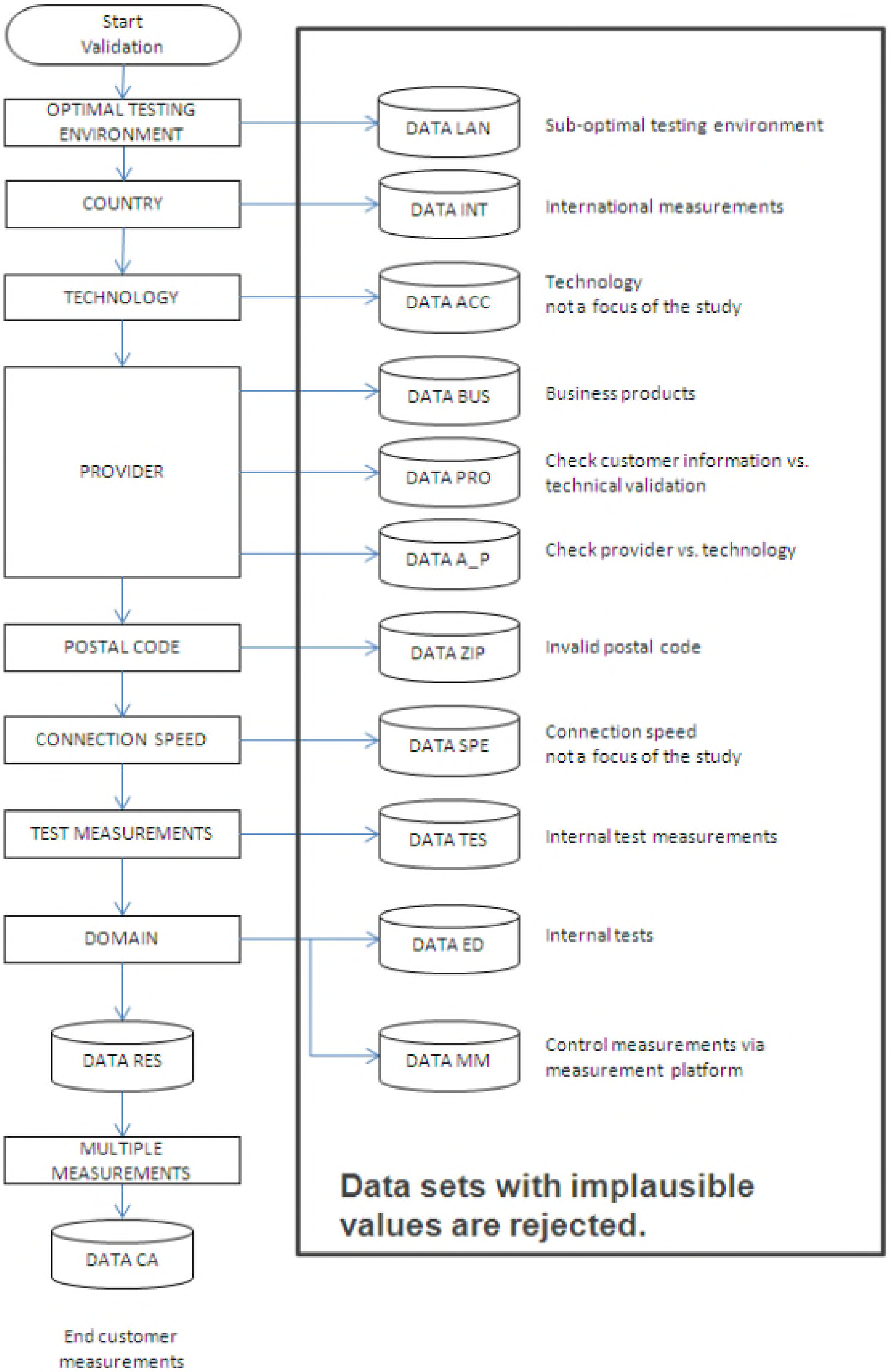

Figure 7.6: Overview of the validation steps in which data records with implausible values are rejected

8 List of figures