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Within the scope of its powers and responsibilities the Czech Telecommunication Office (hereinafter referred to as "Office") measures and evaluates selected parameters of data networks. The measurement and evaluation of selected parameters of electronic communication networks is specified in fixed networks in a guideline entitled:

Methodology for measurement and evaluation of data parameters of electronic communication networks, version 2.0, which is published and applied by the Office in the case of inspection measurements in fixed networks.

The measurements are performed using the Office's own measuring devices (terminals) with clearly defined parameters in fixed networks. The measurement method applied is based on the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol and on standard ITU-T Y.1564 "Ethernet service activation test methodology".

I. Introduction

The purpose of this document (hereinafter referred to as "Methodology") is to describe and unify the procedure for measurement and evaluation of the data parameters of fixed or semi-fixed (FWA) electronic communication networks, namely in terms of the end-user access to the Internet access service and, as the case may be, to other services. The Methodology is related in particular to the following documents: Determination of the basic parameters and measurement of the quality of the Internet access service, Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules, and also the general methodology of Measurement of Data Parameters of Networks Using the TCP Protocol and standard ITU-T Y.1564 including technical specification MEF 23.1. The Methodology further specifies the particular procedures for measurement and subsequent evaluation of the values measured.

A necessary condition for the measurement and evaluation of the data parameters of fixed electronic communication networks is the availability of network sources and the related transparency of network paths (in accordance with net neutrality).

The document fully respects or acknowledges the international recommendations of IETF RFC 1191, RFC 1981, RFC 2544, RFC 2681, RFC 2697, RFC 2923, RFC 3393, RC 4443, RFC 4656, RFC 4821, RFC 4898, RFC 5136, RFC 5357 and RFC 7323, and also international standards ITU-T Y.1563 and Y. 1564 including technical specifications MEF 10.1 and 23.1.

II. Definition of the measuring sides and the network under test

1. Measuring server

Measuring server (MS) shall mean the measuring side which provides the opposite side with services (data) upon request in the case of data download. In general, measuring server is a device connected to the Internet at a defined point. The measuring server should have sufficient performance and independence of the data connection so that sufficient throughput and guarantee of the data parameters is ensured, even in the case of multiple connections of measuring devices at a time. The measuring server is a part of the Measuring System of Electronic Communications (hereinafter referred to as “MSEK”) managed by the Office.

2. Measuring device (terminal)

Measuring device, terminal (MT) shall mean the measuring side which functions as a recipient of the service (data) in the case of data download. Measuring device shall mean a terminal with the respective service software which is capable of performing measurements according to the applicable methodological procedures of the Office and whose computing and network performance is high enough that it does not affect negatively the measurement results. The measuring device must be capable of monitoring and recording basic and extended set of data parameters of fixed electronic communication networks, exporting them in a standardized format suitable for machine processing or other kind of further processing, and subsequently allowing the transfer of the resulting values to the central storage of the MSEK or storing them in internal memory during the measuring process.

3. Network under test

Network under test (NUT) shall mean such sequence of transmission nodes where a connection exists between every two consecutive transmission nodes and, at the same time, the first transmission node is MT and the last transmission node is MS. The electronic communication network measured is a network that is part of the network under test to which the measuring device (terminal) was connected during the measurement.

III. Definition of the set of parameters

When defining the set of parameters, the Office focused mainly on the comprehensibility of the parameters from the point of view of an ordinary user of the Internet access service. The Office also considered which parameters are presented by the service providers in their offers of the Internet access service with regard to the Regulation (EU) 2015/2120 of the European Parliament and of the Council (hereinafter referred to as “Regulation”) and the related Statement of the Czech Telecommunication Office on selected issues relatingto open Internet access and European net neutrality rules (contract-guaranteed download and upload speed, see Article 4(1)(d) of the Regulation).

The Office therefore selected the below-specified parameters in the form of a basic and extended set of possible data parameters, recommended for monitoring of various aspects of quality of the Internet access service. An inseparable part is a set of identification parameters clearly defining the place and time of the measurement of data parameters of fixed electronic communication networks including the information on the measuring device and the Internet access service measured.

1. Set of basic data parameters

The Office has decided, with regard to the relevance for ordinary users (with respect to the commonly concluded subscriber contracts on the provision of Internet access service and the need for comprehensibility), to cover three basic data parameters which determine the quality of Internet access service, namely TCP throughput (upload; $\mathrm{TCP\ aTR_{up}}$), TCP throughput (download; $\mathrm{TCP\ aTR_{down}}$), and delay ($\mathrm{Delay(avg)}$).

1.1. TCP throughput (upload)

TCP throughput (upload), $\mathrm{TCP\ aTR_{up}}$, can be viewed as data transmission speed in the direction from the end-user to the provider of Internet access service corresponding to the transport layer of the ISO/OSI model (L 4) and using the connection-oriented TCP protocol. The process of measurement and determination of the TCP throughput (upload) of the NUT should comply with the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol, whereas the resulting value of $\mathrm{TCP\ aTR_{up}}$ can be written as follows:

$$\mathrm{TCP\ aTR_{up}} = \frac{\mathrm{TCP\ RWND_{up}} \cdot 8}{\mathrm{Delay(avg)_{up}}}; [\mathrm{b/s; B, s}]. \tag{1}$$

1.2. TCP throughput (download)

TCP throughput (download), $\mathrm{TCP\ aTR_{down}}$, can be viewed as data transmission speed in the direction from the provider of Internet access service to the end-user corresponding to the transport layer of the ISO/OSI model (L 4) and using the connection-oriented TCP protocol. The process of measurement and determination of the TCP throughput (download) of the NUT should comply with the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol, whereas the resulting value of $\mathrm{TCP\ aTR_{down}}$ can be written as follows:

$$\mathrm{TCP\ aTR_{down}} = \frac{\mathrm{TCP\ RWND\ _{down}} \cdot 8}{\mathrm{Delay(avg)_{down}}}; [\mathrm{b/s; B, s}]. \tag{2}$$

1.3. Delay

Delay can be viewed as a time elapsed between sending of the first bit of the TCP segment and receipt of the last bit corresponding to the confirmation of the TCP segment. The process of measurement and determination of the delay of the NUT should comply with the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol, whereas the resulting value of delay should be defined in the form of $\mathrm{Delay(avg)}$ or, more specifically:

$$\mathrm{Delay(avg)} = \frac{1}{\mathrm{t}} \sum_{\mathrm{i=0}}^{\mathrm{N-1}} \mathrm{Delay_i}; [\mathrm{s; s, s}], \tag{3}$$

where $\mathrm{Delay_i}$ means individual values of Delay continuously with $1\ \mathrm{s}$ period during the test, and parameter t means the total duration of the test.

2. Set of extended data parameters

The set of extended data parameters is based on the set of basic data parameters and includes, in addition, qualitative data parameters, namely information rate (upload; $\mathrm{IR_{up}}$), information rate (download; $\mathrm{IR_{down}}$), frame delay (FD), inter-frame delay variation (IFDV), and frame loss ratio (FLR). In general, these qualitative data parameters are closely related to the elementary functionality of the network and therefore are relevant when performing an activation analysis (performance test). Unlike the set of basic data parameters which correspond to the transport layer of the ISO/OSI model, the extending qualitative data parameters correspond to the link layer of the ISO/OSI model and therefore are closely related to the structure of the Ethernet II frame, whereas the protocol used during the process of measurement on the transport layer of the ISO/OSI model is the UDP protocol. The qualitative parameters can provide, among other things, key information on the ability of the network to provide the end-users with other advanced services, for example real-time services in the form of IPTV, VoIP, etc.

2.1. Information rate (upload)

Information rate (upload), $\mathrm{IR_{up}}$, is data transmission speed in the direction from the end-user to the provider of Internet access service corresponding to the link layer of the ISO/OSI model (L 2), relying on the structure of the Ethernet II framing. The process of measurement and determination of the information rate (upload) of the NUT should be based on standard ITU-T Y.1564, i.e., measurement of the data transmission speed of Ethernet frames starting with MAC address and ending with FCS.

The maximum achievable value of the information rate IR is limited by the maximum number of frames, FPS, which can be transferred per second, which can be written as follows:

$$\mathrm{FPS} = \frac{\mathrm{NBR}}{(\mathrm{IFG} + \mathrm{Preamble} + \mathrm{MAC\ DST} + \mathrm{MAC\ SRC} + 802.1\mathrm{Q}\ (802.1\mathrm{ad}) + \mathrm{Ethertyp} + \mathrm{Payload} + \mathrm{FCS}) \cdot 8}; [1/\mathrm{s}; \mathrm{b/s}, \mathrm{B}], \quad (4)$$

where NBR means the data transmission speed corresponding to the physical layer of the ISO/OSI model (L 1). The resulting maximum information rate (upload) can be written as follows:

$$\mathrm{IR_{up}}(\max) = \mathrm{MTU} \cdot 8 \cdot \mathrm{FPS}; [\mathrm{b/s}; \mathrm{B}, 1/\mathrm{s}]. \quad (5)$$

2.2. Information rate (download)

Information rate (download), $\mathrm{IR_{down}}$, is data transmission speed in the direction from the provider of Internet access service to the end-user corresponding to the link layer of the ISO/OSI model (L 2), relying on the structure of the Ethernet II framing. The process of measurement and determination of the information rate (upload) of the NUT should be based on standard ITU-T Y.1564, i.e., measurement of the data transmission speed of Ethernet frames starting with MAC address and ending with FCS. The resulting maximum information rate (download) can be written as follows:

$$\mathrm{IR_{down}}(\max) = \mathrm{MTU} \cdot 8 \cdot \mathrm{FPS}; [\mathrm{b/s}; \mathrm{B}, 1/\mathrm{s}]. \quad (6)$$

2.3. Frame delay

Frame delay, FD, is a result of measurement of the time delay of the NUT between the sending and receipt of the Ethernet frame. It is usually a “round-trip” type of measurement due to the use of synchronization only on the side of the measuring device, which corresponds to the time elapsed between the sending of the first bit of the frame from the end-user to the provider of the Internet access service and the receipt of the last bit of the back-sent frame in the direction from the service provider to the end-user. Frame delay (generally the kth frame) of the RTT type can be expressed as follows:

$$\mathrm{FD_k}(\mathrm{RTT}) = \mathrm{t_2} - \mathrm{t_1} \leq 2 \cdot \mathrm{T_{max}}; [\mathrm{s}; \mathrm{s}, \mathrm{s}, \mathrm{s}], \quad (7)$$

where $\mathrm{t_1}$ represents the time of sending of the first bit of the kth frame and $\mathrm{t_2}$ represents the time of receipt of the last bit of the same kth frame on the measuring device, whereas $\mathrm{T_{max}}$ is the maximum value of frame delay which, when exceeded, results in the frame being declared as lost.

2.4. Inter-frame delay variation

Inter-frame delay variation, IFDV, often described also as jitter is a difference between the reference time of delivery of the Ethernet frame ($\mathrm{c_k}$) and the actual time of delivery thereof ($\mathrm{d_k}$) on the side of the provider of Internet access service or on the side of the end-user, i.e., using the “end-to-end” measurement method. Inter-frame delay variation can be written as follows:

$$\mathrm{IFDV}_k = |d_k - c_k|; [s; s, s], \tag{8}$$

where $c_k = d_j + \Delta t$, $k > j$ and Δt is the interval between the sending of the jth and kth Ethernet frame.

2.5. Frame loss ratio

Frame loss ratio, FLR, is the ratio between all undelivered (lost) Ethernet frames and the total number of all Ethernet frames sent to the provider of the Internet access service or to the end-user, i.e., using the "end-to-end" measurement method. Frame loss ratio can be written as follows:

$$\mathrm{FLR} = \frac{\sum_{n=1}^{N} L_n}{\sum_{n=1}^{N} S_n} \cdot 100; [\%; -, -], \tag{9}$$

where L_n represents the n^{th} frame lost and S_n represents the n^{th} frame sent.

3. Set of identification parameters

The set of identification parameters as an inseparable part of the measuring process defines in a clear manner the place and time of the measurement of the data parameters of fixed electronic communication networks including the information on the measuring terminal. The set of identification parameters includes the exact time of measurement which consists of the date and exact time of the start of the measuring process, exact time of the start of the individual tests, and duration of the measuring process and the individual tests, including the exact time of completion of the measuring process, and it also includes the exact position of the measuring terminal defined in the form of a GPS coordinate, plus, if applicable, the specific address location if known. This set also includes information identifying the measuring device and measuring interface which was connected during the measurement process to the fixed electronic communication network measured.

3.1. Exact time of measurement

Exact time of measurement includes the date and exact time of the start and end of the measuring process according to the Methodology, including the exact time of start of the individual tests as well as the duration of the entire measuring process including the individual tests. To determine the exact time, we recommend using an internal or external GPS module of the measuring device used. If the GPS module is not available, it is possible to use internal clock of the measuring device for the determination of the exact time.

The date of the measuring process according to the Methodology must be written in the following format: DD month YYYY, for example 01 January 2018. The required accuracy of the time of the start and end of the measuring process, time of start of the individual tests, and the duration of the entire measuring process including the duration of the individual tests is in seconds, and the resulting information must be in the following format: HH:MM:SS, for example 08:03:24.

3.2. Exact position of the measuring device

The exact position of the measuring device represents a uniquely identified place where the measuring device was placed during the measuring process according to the Methodology. To determine the exact position, we recommend using an internal or external GPS module of the measuring device used. If the GPS module is not available, it is possible to enter the position of the measuring device manually. We also recommend specifying the specific address location if known.

GPS coordinates must be in the following format: xx.xxxxxxxN, yy.yyyyyyyE, for example, 50.1106225N, 14.4996508E. If the identification is known the specific address location of the place of measurement must be provided in the following format: Street No., Postcode Municipality/City, for example, Sokolovská 58/219, 190 00 Praha.

3.3. Identification of the measuring device and interface

Identification of the measuring device and interface represents a set of data identifying uniquely the measuring device formed by an ID of the MT chassis and an ID of the MT measuring module including the information on the measuring interface which was connected during the measurement process to the electronic communication network measured. We recommend providing also an ID of the MS chassis and ID of the MS measuring module for unique identification of the entire measuring chain.

This information includes also the name of the technology measured and the name of the Internet access service measured, name of the provider, the provider's registered office including the identification No. (IČO) as well as the information according to the Regulation (EU) 2015/2120 of the European Parliament and of the Council (hereinafter referred to as "Regulation") and the related Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules (contract-guaranteed download and upload speed, see Article 4(1)(d) of the Regulation).

IV. Measurement process

This section defines the techniques of measurement of data parameters of fixed electronic communication networks in such a manner as to make it possible to verify the actual and, as the case may be, maximum achievable value thereof. The techniques of the measuring process differ according to which set of data parameters is to be monitored in terms of various aspects of quality of the Internet access service or, more precisely, whether it is a basic or extended set of data parameters.

As the measurement of data parameters of fixed electronic communication networks is in general conditional upon correct functioning of the first four layers of the ISO/OSI model, i.e., from the physical up to the transport layer, it is necessary to check prior to the commencement of the measurement the functionality, capacity of the network under test, and other parameters on the second and in particular third layer of the ISO/OSI model. The recommended steps before the start of the measuring process are as follows:

- Basic check, e.g., using the available testing tools which can suggest the expected values. In order to determine the parameters of the measurement it is recommended to check with a packet capturing program, e.g., Wireshark, what is really going on at the network interface (what is the actual $\mathrm{TCP\,RWND}$, whether there are repeated packet transfers, and whether or not $\mathrm{TCP\,RWND}$ is exhausted during the transfer, etc.).
- Check whether the traffic is not prioritized based on IP addresses of the standard (generally known) measuring servers. It is therefore advisable to perform the initial measurement of TCP throughput against reference measuring servers.
- A good approach is also to check the fulfillment of net neutrality rules, i.e., whether the traffic of a certain service is not prioritized. In this case, whether e.g., there is prioritization of the ports which require greater capacity of the network under test. A special case may be prioritization of ports which are used by the measuring devices (terminals). In such case, of course, the result would be substantially distorted.
- If it is very likely that traffic is deliberately prioritized toward standard measuring servers, either based on the IP address, or port, it is necessary to perform a comparative measurement according to the above steps. If the results of the standard measurement and the comparative measurement significantly differ it is necessary to report this in the measurement results accordingly.
- It is advisable to perform a supplemental indicative measurement by means of a publicly available tool for measurement of current quality of Internet access service, e.g., NetMetr (measuring server within MSEK).

1. Measuring tools

There are a number of measuring tools that are capable of performing measurements of the set of basic as well as extended data parameters defined in the Methodology. These measuring tools must be implemented in each of the two measuring sides where one acts as a client and one as a server. The measuring tool must allow selection of the measuring technique, i.e., measuring process according to the general methodology of Measurement of Data Parameters of the Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349 the output of which is a set of basic data parameters, or measuring process based on standard ITU-T Y.1564 the output of which is extending data parameters defined in the Methodology including the measurement procedure.

It is necessary to consider the performance of both measuring sides such as to prevent degradation of the measurement. Due to the qualitative development of the Internet access service it is required that the measuring tool include an interface making it possible to perform measurements up to the maximum speed of $\mathrm{NBR} \leq 1000\ \mathrm{Mb}/s$ (on the side of the measuring server up to $\mathrm{NBR} \leq 10\ \mathrm{Gb}/s$). Due to the performance requirements of the measuring processes of the selected tools when measuring the data parameters with speed $\mathrm{NBR} > 100\ \mathrm{Mb}/s$ it is recommended to use measuring tools with dedicated hardware. When using the end-user's equipment, e.g., for indicative measurements, it is always necessary to consider the nominal performance of the equipment, loading with common applications as well as the age of the equipment. In such cases it is possible that even measurements at speed $\mathrm{NBR} \approx 50\ \mathrm{Mb}/s$ can be beyond the capabilities of the end-user's equipment.

2. Sequence of measurements

The procedure and sequence of the measurements, or the whole measuring process, are different in case of measuring only the set of basic parameters or of extended data parameters.

Where only the set of basic data parameters, i.e., the TCP throughput (upload; $\mathrm{TCP\ aTR_{up}}$), the TCP throughput (download; $\mathrm{TCP\ aTR_{down}}$) and delay ($\mathrm{Delay\ (avg)}$) is measured, the measurement process corresponds to the methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol.

Where a set of extended data parameters is measured, the set of basic data parameters is amended to include qualitative data parameters, namely information rate (upload; $\mathrm{IR_{up}}$), information rate (download; $\mathrm{IR_{down}}$), frame delay (FD), inter-frame delay variation (IFDV) a frame loss ratio (FLR), nevertheless the measurement process with this structure definition is also based on the methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol.

2.1. Measurement of a set of extended data parameters

Measurement in fixed electronic communication networks corresponds - in terms of location of the measuring device (terminal) - to stationary measurement. For all measurements at a stationary point it is recommended to perform repeated measurements with sufficient time and operational diversity.

It is recommended to perform three main independent measurements, including compliance with sufficient time diversity, i.e., at least one measurement at the peak hour and at least one measurement during an off-peak time. With respect to the time intensity of the process of measurement of the extended set of data parameters, it is permissible to perform all three main measurements during the peak hours in the case of fixed electronic communication networks (fixed network under load); in the case of newly built fixed electronic communication networks (fixed network without load) it is possible to perform all three main measurements also during off-peak hours.

One measurement should not exceed the timeframe of 20 minutes during which a sequence of three tests will be performed (basic test, hereinafter referred to as “testB”) according to the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6439 and 1 test (complementary test, hereinafter referred to as “testC”) according to standard ITU-T Y.1564. One testB must guarantee the length of measurement of TCP throughput in the following interval:

$$60\ \mathrm{s} < \mathrm{T_{TCP}} < 120\ \mathrm{s}, \tag{10}$$

whereas $\mathrm{T_{TCP}} = 90\ s$ can be considered a recommended value of the length of measurement of TCP throughput. The reason for this determination is detection of a regularly recurring discrepancy from normally available speed (BDR). With respect to processing of the values gained ($\mathrm{T_{proc}}$) by the measuring tools used the total duration of one test should not exceed $\mathrm{T_{testB}}$:

$$\mathrm{T_{testB}} = \mathrm{T_{TCP}} + \mathrm{T_{proc}} \leq 150\ \mathrm{s}. \tag{11}$$

Standard ITU-T Y.1564 recommends performing the basic performance test with total duration of 15 minutes. Because it is recommended performing 3 main independent measurements within the measuring process, one testC or, more precisely, performance test, must guarantee the duration of measurement of the qualitative data parameters:

$$\mathrm{T_{perf}} \geq 300\ \mathrm{s}. \tag{12}$$

The basic performance test shall be used for verification of the parameters according to MEF 23.1. Standard ITU-T Y.1564 also recommends that testC also include the so-called configuration test of the service. This test represents measurement of qualitative data parameters in dependence on the change of the input value CIR in six steps, namely with 50% CIR, with 75% CIR, with 90% CIR, and with 100% CIR, and also with $\mathrm{CIR} + \mathrm{EIR}$ and $\max \mathrm{NBR}$. Each step should correspond to test duration in the range from 1 to 60 seconds. The Office has decided to use only the first five steps with a duration of 5 seconds for one step ($\mathrm{T_{conf}} = 25$ s). with respect to the processing of the values measured ($\mathrm{T_{proc}}$) by the measuring tools, the total duration of one test should not exceed $\mathrm{T_{testC}}$:

$$\mathrm{T_{testC}} = \mathrm{T_{conf}} + \mathrm{T_{perf}} + \mathrm{T_{proc}} \leq 400\ \mathrm{s}. \tag{13}$$

The resulting measurement process should consist of the following steps (see Figure 1):

- Step 1 – one-way test of the TCP throughput (upload) including the value of $\mathrm{Delay(avg)}$ with total duration of the test $\mathrm{T_{testB}} \leq 150\ \mathrm{s}$,
- Step 2 – a break (saving the previous test results) with duration $\mathrm{T_{break}} \leq 120\ \mathrm{s}$,
- Step 3 – one-way test of the TCP throughput (download) including the value of $\mathrm{Delay(avg)}$ with total duration of the test $\mathrm{T_{testB}} \leq 150\ \mathrm{s}$,
- Step 4 – a break (saving the previous test results) with duration $\mathrm{T_{break}} \leq 120\ \mathrm{s}$,
- Step 5 – bidirectional test of TCP throughput (upload + download) including the value of $\mathrm{Delay(avg)}$ with total duration of the test $\mathrm{T_{testB}} \leq 150\ \mathrm{s}$,
- Step 6 – a break (to save the previous test results) with duration $\mathrm{T_{break}} \leq 120\ \mathrm{s}$,
- Step 7 – bidirectional test of qualitative data parameters according to standard ITU-T Y.1564 with total duration of the test $\mathrm{T_{testC}} \leq 400\ \mathrm{s}$,
- Step 8 – a break until the start of the next sequence of measurements corresponding to the lapse of time (saving the previous test results, preparing for the next test) with duration $\mathrm{T_{break}} \leq 120\ \mathrm{s}$.

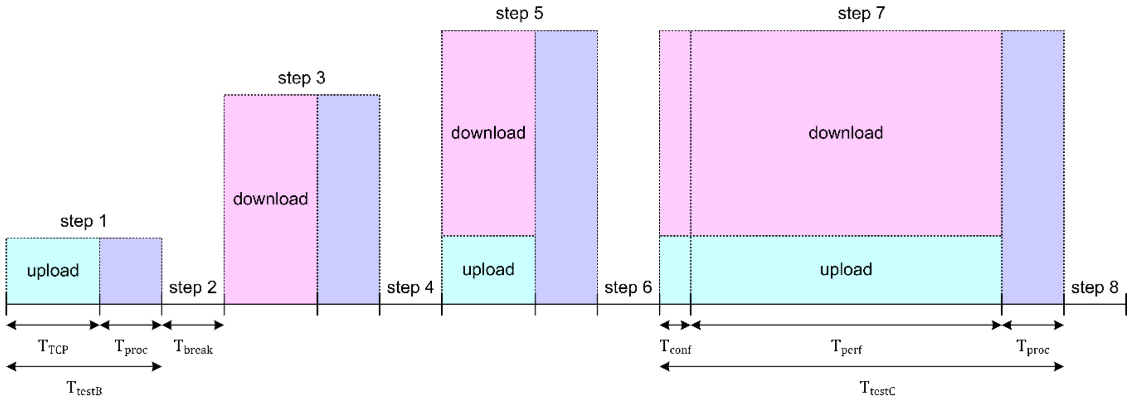

Figure 1: Recommended form of the process of measurement of the extended set of data parameters of fixed electronic communication networks

If the measuring tool does not make it possible to set the order of the sequence of tests as recommended it is possible to change the order without breaching the integrity of the measurement. In the same way, it is possible to omit the bidirectional test of TCP throughput (step 5) or the sequence of breaks between individual tests (steps 2, 4, 6 and 8). The minimum admissible form of the process of measurement of the extended set of data parameters must consist of a one-way upload test (step 1), one-way download test (step 3) of TCP throughput, and a bidirectional test of qualitative data parameters according to standard ITU-T Y.1564 (step 7). The possible combinations of implementation of the minimum admissible form of the process of measurement depend on the measuring tools applied.

2.2. Input parameters of the measurement sequence

The input parameters of the measurement sequence must be based on the parameters presented by the providers of electronic communication services in their offers of the Internet access service with regard to Regulation (EU) 2015/2120 of the European Parliament and of the Council (hereinafter referred to as “Regulation”) and the related Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules (contract-guaranteed download and upload speed, see Article 4(1)(d) of the Regulation), and also on measuring processes specified in the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349, and according to standard ITU-T Y.1564. When defining the input parameters, the characteristics of the access technology were also taken into account.

Pursuant to the Regulation, the Office provided four definitions of speeds in relation to the provision of the Internet access service in fixed networks in the range from the point of delivery of the service to the end-user (DeP 7) up to the MSEK point of access through the peering node NIX.CZ (DeP 1). In the case of download and upload, the following definitions of speeds apply for each direction separately:

- Minimum speed ($\mathrm{R_{min}}$) – the lowest guaranteed speed for download and upload which the relevant provider of Internet access service has undertaken to provide to the end-user by contract. If the speed drops below this value such condition constitutes service outage. It means that the download or upload speed should never drop below this value.
- Maximum speed ($\mathrm{R_{max}}$) – the highest possible speed for download and upload which the relevant provider of Internet access service stated in the contract with the end-user for the provision of the service. The maximum speed must be set realistically and with regard to the technology used, its transfer capabilities, and with regard to the specific conditions of deployment which are limiting for the download and upload speeds. The maximum speed must be achievable in the relevant connection or at the relevant location.

- Normally available speed (BDR) – speed which the end-user can assume and actually achieve for download and upload at the time when he/she is using the service. Normally available speed is defined as the percentage of the amount of downloaded and uploaded data and the respective time period in which the services is provided. Normally available speed can be specified as a different value for peak hours and off-peak hours, but in such case these speeds must be normally achievable in the respective time periods (peak hours, off-peak hours). The provider of the Internet access service must also clearly specify the definition of the time periods of peak hours and off-peak hours with clear numerical values.
- Advertised speed ($\mathrm{R_{inzer}}$) – download and upload speed which the provider of Internet access service uses in its commercial communication, including advertisements and marketing, in connection with publicity, sale or delivery of the service. Advertised speed, including other commercial communication, is also subject to the applicable provisions of consumer and competition law and must not be higher than the maximum speed values stated in the contract.

2.2.1. Input parameters of the sequence of measurement of a set of basic data parameters

The general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol, based on the recommendation of IETF RFC 6349, defines BB, minRTT, $\mathrm{TCP\ RWND}$ and MTU as input parameters. A majority of the available measuring tools makes it possible to set the input parameters BB and MTU; the other parameters can be set by these measuring tools according to the criteria provided in the recommendation of IETF RFC 6349. Some manufacturers of measuring tools incorrectly mention CIR in connection with parameter BB. This identification is misleading because it is prone to incorrect setting of the BB value with the value corresponding to the link layer of the ISO/OSI model (“committed information rate”), but it is actually a physical layer. It is therefore recommended to ask the manufacturer of the measuring tool on which layer of the ISO/OSI model the input parameter BB is set.

In the case of measurement of basic data parameters, the input parameter BB will equal the defined value of the maximum speed for download and upload:

$$\mathrm{BB_{up/down}}\ (\mathrm{L}\ 1) = \mathrm{CIR_{up/down}}\ (\mathrm{L}\ 1) = \mathrm{R_{max_{up/down}}}\ (\mathrm{L}\ 1);\ [\mathrm{b/s; b/s}]. \qquad (14)$$

It is recommended to identify the value of MTU of the NUT measured, if not known (e.g., for the framework IEEE 802.3 + IEEE 802.2 with SNAP extension, $\mathrm{MTU} = 1492\ \mathrm{B}$ or Ethernet II is $\mathrm{MTU} = 1500\ \mathrm{B}$), using the available test tools, for example Wireshark, a packet capturing program, or a tool functioning according to recommendation of IETF RFC 4821 “Packetization Layer Path MTU Discovery”.

2.2.2. Input parameters of the sequence of measurement of qualitative data parameters

When measuring the qualitative data parameters in the form of supplemental parameters to basic parameters within the extended set of data parameters, it is necessary to rely on standard ITU-T Y.1564 which defines, among other things, CIR, $\mathrm{CIR} + \mathrm{EIR}$ and the size of the Ethernet frame FS (from $64\ \mathrm{B}$ to $1526\ \mathrm{B}$) as input parameters. As implied by the identification of CIR, EIR, these are parameters corresponding to the link layer of the ISO/OSI model. Some manufacturers of measuring tools incorrectly label in connection with parameters CIR and EIR the values corresponding to the physical layer of the ISO/OSI model. It is therefore recommended to ask the manufacturer of the measuring tool on which layer of the ISO/OSI model the input parameters CIR a $\mathrm{CIR} + \mathrm{EIR}$ are set.

In the case of measurement of qualitative data parameters, the input parameter CIR should equal the defined value of the normally available speed BDR for download and upload:

$$\mathrm{CIR_{up/down}}\ (\mathrm{L}\ 1) = \mathrm{BDR_{up/down}}\ (\mathrm{L}\ 1);\ [\mathrm{b/s; b/s}], \qquad (15)$$

for elimination of prioritization and also potential distortion of the qualitative parameters of the NUT in question, in particular in a situation where the value $\mathrm{SDR_{avg}}\ (\mathrm{L}\ 1)$ of the measuring process would approximate the value $\mathrm{R_{max}}$ (L 1). Nevertheless, for the purpose of the configuration test it is advisable to set parameter $\mathrm{CIR + EIR}$ as follows:

$$(\mathrm{CIR + EIR})_{\mathrm{up/down}}\ (\mathrm{L}\ 1) = \mathrm{R}_{\mathrm{max}_{\mathrm{up/down}}}\ (\mathrm{L}\ 1);\ [\mathrm{b/s; b/s}], \quad (16)$$

in order to check the ability of the NUT in question to provide the defined values of the maximum download speed and maximum upload speed. The result is information rate IR corresponding to the link layer of the ISO/OSI model for both directions and the defined qualitative data parameters. When determining the value of the frame size FS, it is advisable to rely on the determined value of MTU used in the measurement of basic data parameters or, more precisely:

$$\mathrm{FS = MTU + MAC\ DST + MAC\ SRC + 802.1Q\ (802.1ad) + Ethertyp + FCS; [B; B]}, \quad (17)$$

if the value set for the NUT in question is $\mathrm{MTU = 1500\ B}$ then in the case of $\mathrm{MAC\ DST = 6\ B}$, $\mathrm{MAC\ SRC = 6\ B}$, $\mathrm{802.1Q\ (802.1ad) = 0\ B}$, $\mathrm{Ethertyp = 2\ B}$ and $\mathrm{FCS = 4\ B}$ the result will be $\mathrm{FS} =$ $= \mathrm{1518\ B}$.

2.3. Evaluation of the measurement

With respect to the fact that the evaluations of the measurement according to the respective set of data parameters of fixed electronic communication networks measured can significantly differ also with respect to the exercise of the powers of the Office, detailed information on each case (scenario) will be provided in the relevant annexes to this document.

3. Demarcation points of measurement

The demarcation points of measurement are such points within the network between which the sets of data parameters of the fixed electronic communication network will be measured. In general, a demarcation point can be imagined as an interface of the network node (a specific port of an active element). The Office will perform the measurements according to the methodology directly in the particular demarcation point or, as the case may be, at a near place in the range which does not exceed the distance of the respective demarcation point according to the contract terms. The Office defines the following demarcation points, whereas it is always assumed that the measurement is performed at the Ethernet interface (in particular when carrying out measurements in order to exercise the Office's powers):

- The first demarcation point is defined in the form of access of MSEK (measuring server) to Internet through peering node NIX.CZ, see DeP 1 on Figure 2. Also other place within the network may be defined as the first demarcation point, but only in cases where the situation cannot be resolved by means of demarcation point DeP 1. A typical situation can be, for example, measurement of a dedicated line.
- The second demarcation point can be imagined in the form of an interface of the network node (a specific port of an active element) or, as the case may be, at a near place in the range which does not exceed the distance of particular neighbouring demarcation point according to the contract terms where a measurement according to the methodology will take place by means of the measuring device (terminal). This document defines the positions of the demarcation points DeP 2 to DeP 7, see Figure 2, according to the general structure of the access network and its access to the Internet or, more precisely, to MSEK (DeP 1). It is evident that within the actual structure of access network of a particular provider of Internet access service some demarcation points can be merged or, as the case may be, omitted.

Demarcation points defined this way, see Figure 2, can be used also when it is necessary to monitor data traffic with the use of the SNMP protocol which, among other things, enables continuous collection of data traffic (upload and download) at the relevant interface of the active elements associated with the respective demarcation point. The monitored values of the data traffic correspond in most cases to the link layer of the ISO/OSI model (L 2), i.e., IR.

In a situation where Ethernet interface is not available it is necessary to use a certified converter of the network provider for the measurement. If no such converter is available it is necessary to use a converter which is supplied to the customer upon activation of the service, but if neccessary in particular situation it is possible to use other converter suitable for this service and technology. After connecting and switching-on of such converter, it is necessary to wait a necessary time to achieve synchronization and stabilized state in the network (for example, 5 minutes), preferably to proceed according to consultation with the network operator.

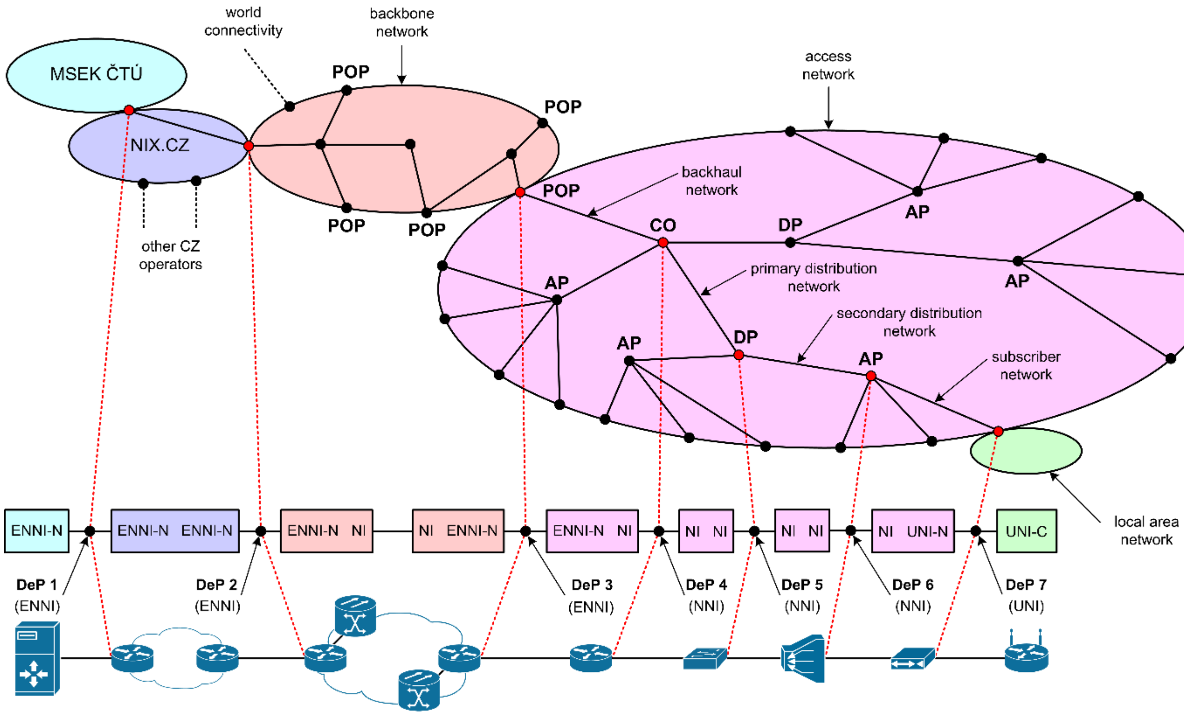

Figure 2: Defined positions of the demarcation points within the general diagram of the access network structure and its connection to the Internet

4. Security considerations

Because the measurement of the extended set of data parameters uses the UDP protocol on the transport layer of the ISO/OSI model, the behavior of the measurement process can be perceived by network operators (providers) as an attempt for DoS or a DDoS attack. Therefore, the measurement of the extended set of data parameters may require coordination with the Internet connection provider.

4.1. Measurements in the networks with IPv6 and NAT

With respect to the possibility to encapsulate the TCP and UDP protocol in an IPv6 packet, significant differences in the measurement of TCP throughput can occur between IPv6 and IPv4 today in the electronic communication network with native IPv6 support. It is therefore advisable to check whether IPv6 connectivity is available, and if so, to perform the measurement even in a situation where the TCP and UDP session will be encapsulated in IPv6 packets.

4.2. Measurements in the environment of private IP addresses and stateful firewalls

If, for some reason, the initiation of network session in the direction from server ("remote") → client ("local") is impossible, it is necessary to use such a measuring tool that enables reverse initiation of the network session when measuring download direction. This situation may occur e.g., in electronic communication networks with NAT or with a set stateful firewall which, for example, blocks the TCP segment with SYN attribute (establishment of session) from the outside.

4.3. Procedure in the event of an error

If a problem (e.g., a problem when establishing a data connection) or an evident error occurs during the measurement it is necessary to proceed adequately. The operator of the measuring terminal should try to determine the cause of the problem, eliminate it if possible and, if applicable, subsequently perform a repeated measurement.

V. Terms, definitions and abbreviations

AP (access point) – means the concentration point on the access network side.

BB (bottleneck bandwidth) – means the lowest value of the capacity of the network under test corresponding to the first layer of the ISO/OSI model

BDR – normally available speed which the end-user can assume and really achieve for download and upload at the time when he/she is using the service

CIR (committed information rate) – guaranteed minimum information rate corresponding to the second layer of the ISO/OSI model

CO (central office) – central location of the provider through which Internet access (backbone network access) is provided

Delay – is the time elapsed between sending of the first bit of the TCP segment and receipt of the last bit corresponding to the confirmation of the TCP segment

$\mathrm{Delay_i}$ – ith value of Delay which is recorded during continuous measurement with a period of 1 second during the test of TCP throughput

Delay(avg) – average value of Delay during the test of TCP throughput

DeP x (demarcation point x) – means a specific demarcation point as a demarcation point between two different network entities (backbone network, access network, local area network, etc.)

DP (distribution point) – distribution point (node) of a distribution network belonging to the set of the access network

EIR – excess information rate or, more precisely, non-guaranteed information rate corresponding to the second layer of the ISO/OSI model and covering the band from the upper limit of CIR to the maximum value of NBR

ENNI (external network to network interface) – interface between two providers of Internet access service

ENNI-N (external network to network interface-network side) – a port on an active network element physically connected to the interfaces between two providers of Internet access service

FS (frame size) – Ethernet frame size

FD (frame delay) – frame delay representing time delay of the NUT between sending and receipt of the Ethernet frame

FD (RTT) – corresponds to the time elapsed between sending of the first bit of the frame from the end-user to the provider of Internet access service and receipt of the last bit of the back-sent frame in the direction from the service provider to the end-user

FLR (frame loss ratio) – ratio between all undelivered (lost) Ethernet frames and the total number of all Ethernet frames sent

FWA (fixed wireless access) – wireless electronic communication network at a fixed location

IFDV – inter-frame delay variation, often also delay variation or jitter, represents a difference between the reference time of delivery of the Ethernet frame ($\mathrm{c_k}$) and the real time of delivery thereof ($\mathrm{d_k}$)

IR – value of the information rate corresponding to the link layer of the ISO/OSI model

L x (layer x) – a specific layer of the ISO/OSI model

$\mathrm{minDelay}$ – means the lowest measured value of Delay during an established session during the initial testing interval

MS – measuring server

MSEK – Measuring system of electronic communications, an information system of the Office

MT – measuring terminal

MTU (maximum transmission unit) – means the maximum size of the IP datagram (TCP segment) which can newly be sent through the given network interface

NBR (net bit rate) – means the data transmission rate corresponding to the physical layer of the ISO/OSI model (L 1) of the respective interface with assumed use of the Ethernet frame

NNI (network to network interface) – an interface between active network elements of the provider of the Internet access service

NI (network interface) – a port on an active network element

NUT – network under test

POP (point of presence) – a demarcation point between two different types of data networks (backbone and access network). POP is above all an infrastructure which makes it possible for remote users to connect to the Internet.

$\mathrm{R_{inzer}}$ – advertised speed, i.e., download and upload speed which the provider of the Internet access service uses in its commercial communication, including advertisements and marketing, in connection with publicity, sale or delivery of the service

$\mathrm{R_{max}}$ – maximum speed, i.e., the highest possible speed for download and upload

$\mathrm{R_{min}}$ – minimum speed, i.e., the lowest guaranteed speed for download and upload

SDR – really achieved speed, i.e., current speed at a given time

$\mathrm{SDR(avg)}$ – average value of the really achieved speed over the time of duration of the test t

Network node – grouping of one or multiple network elements

SNAP (SubNetwork Access Protocol) – an extension of the LLC frame IEEE 802.2 such that it could work with different versions of the Ethernet field $\mathrm{Ethertyp}$ (e.g., with frame type Ethernet II)

t – duration of the test in general (e.g., in the case of testB it corresponds to value $\mathrm{T_{testB}}$)

$\mathrm{TCP\ aTR}$ – actual value of TCP throughput corresponding to the transport layer of the ISO/OSI model

$\mathrm{TCP\ RWND}$ (TCP receive window) – means the size of the TCP window of the data receiver

UNI (user network interface) – interface between the Internet access service provider and the end-user

UNI-C (user network interface-customer side) – a port on an active network element on the side of the end-user of the connection, physically connected to the interface between the Internet access service provider and the end-user

UNI-N (user network interface-network side) – a port on an active network element on the side of the Internet access service provider physically connected to the interface between the provider and the end-user.

VI. Annexes

1. Measurement of the fixed electronic communication networks for the purpose of inspection the data parameters belonging to the set of basic data parameters

Annex 1, version 2.0, valid from 1 October 2018, is intended for measurement of data parameters in normal network traffic which belongs to the set of basic data parameters. The measurement according to annex 1 is intended for exercise of the Office's powers in terms of inspection data parameters of the Internet access service.

1.1. Description of the measurement scenario

The measurement scenario corresponds to the measurement process specified in the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol. The specified measurement scenario is defined by the Office for measuring data parameters of fixed electronic communication networks belonging to the set of basic data parameters for the purpose of inspection them. The measurement scenario as well as the chosen set of basic data parameters are in accordance with the following documents: Determination of the basic parameters and measurement of the quality of the Internet access service and Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules.

1.2. Selection of the measurement method

For the purpose of performing measurements according to the specified measurement scenario, measurement method is chosen as defined in the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349. Pursuant to the Regulation, the Office provided four definitions of speeds in relation to the provision of the Internet access service in fixed networks in the range from the point of delivery of the service to the end-user (DeP 7) up to the point of MSEK access through the peering node NIX.CZ (DeP 1). In the case of download and upload, the definitions of speeds apply for each direction separately. The selected measurement method will be applied by the Office in the case of verification measurements of compliance with the defined speeds, in terms of verification of a service outage and the so-called discrepancies as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters. The measurement method selected by the Office defines performance of measurement on the transport layer of the ISO/OSI model (L 4) by means of the TCP protocol.

In exceptional cases, for example, for the measurement of data parameters of dedicated lines, e.g., MPLS, or when it is necessary to measure at demarcation points DeP < 6, it is possible to use a measurement method defined by standard ITU-T Y.1564 or to perform measurement of qualitative data parameters belonging to the set of extended data parameters defined in this document. Such selected alternative method defines performance of measurement on the link layer of the ISO/OSI model (L 2) with the use of the protocol of the transport layer UDP (L 4), i.e., only applying step 8 of the defined sequence of measurement within this document. The input parameters of the sequence of measurement will depend on the contract terms, and the input parameter $(\mathrm{CIR} + \mathrm{EIR})_{\mathrm{up/down}}$ will not be applied within the configuration test which will only include the first 4 steps (in full accordance with the minimum number of steps according to ITU-T Y.1564).

1.3. Measurement sequence

It is recommended to perform three main independent measurements, including compliance with sufficient time diversity, i.e., at least one measurement at the peak hour and at least one measurement during an off-peak time. With respect to the time intensity of the process of measurement of the basic set of data parameters, it is permissible to perform all three main measurements during the peak hours, i.e., when performing the measurement in normal network traffic. One measurement should not exceed the timeframe of 20 minutes during which a sequence of three tests of the testB category will be performed according to the subsection Measurement sequence of the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol (steps 1 to 6), or, as appropriate, it is possible to use similar procedure according to the subsection Measurement sequence in this document and omit steps 7 and 8.

If the measuring tool does not make it possible to set the order of the sequence of tests as recommended it is possible to change the order without breaching the integrity of the measurement. In the same way, it is possible to omit the bidirectional test of TCP throughput (step 5) or the sequence of breaks between individual tests (steps 2, 4 and 6). The minimum admissible form of the measurement process of the basic set of data parameters must consist of one-way upload test (step 1), one-way download test (step 3) of TCP throughput. The possible combinations of the implementation of the minimum admissible form of the process of measurement depend on the measuring tools applied. Using the so-called “loopback” test during the measurement is not recommended, not even in the case of symmetrical NUTs.

1.4. Demarcation points

The first demarcation point will be, in accordance with subsection Demarcation points of the measurement in this document, the access of MSEK (measuring server) to the Internet through peering node NIX.CZ, see DeP 1 on Figure 2. The second demarcation point can be imagined in the form of an interface of the network node (specific port of an active element) or, as the case may be, at a near place in the range which does not exceed the distance particular neighboring demarcation point according to the contract terms where a measurement according to the methodology will take place by means of the measuring device (terminal). The second demarcation point envisaged within Annex 1 to this document is DeP 7, see Figure 2, i.e., demarcation point between the provider of the Internet access service and the end-user. With respect to the technologies of the access networks and their structure, the second demarcation point can occasionally be also DeP 6, see Figure 2 (e.g., a situation where the concentration point AP is implemented in the form of a router or network switch).

1.5. Setup of the measuring terminal and beginning of the measurement process

After having determined the measurement method, the measurement sequence, and the demarcation points, it is necessary to connect the measuring device physically according to the demarcation point set (DeP 7). Correct connection will subsequently be verified by means of the measuring device where it is necessary to select and set the parameters of the measuring interface. In addition, it is necessary to set other parameters of the higher network layers, if necessary, e.g., $\mathrm{MAC\ SRC}$, $802.1\mathrm{Q}$ $(802.1\mathrm{ad})$, IP address of the measuring terminal if it does not receive it through the DHCP server, and the number of the TCP port of the measuring tool on the measuring device and the measuring server, unless it is pre-set.

In the next stage it is necessary to set the input parameters of the measuring tool on the side of the measuring device. The input parameters of the measuring tool or, more precisely, the measurement sequence, must be based on the parameters presented by the providers of electronic communication services in their offers of the Internet access service with regard to Regulation (EU) 2015/2120 of the European Parliament and of the Council (hereinafter referred to as “Regulation”) and the related Statement of the Czech Telecommunication Office on selected issues of access to open Internet and European net neutrality rules (contract-guaranteed download and upload speed, see Article 4(1)(d) of the Regulation), and also on the measuring processes specified in the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349. The input parameters need to be set according to the measuring tool applied in accordance with subchapter ‘Input parameters of the sequence of measurement of a set of basic data parameters' in this document where it is necessary to pay attention on which layer of the ISO/OSI model and under which name the input parameter BB is set in the measuring tool. In this case, the equation (14) or $\mathrm{BB}_{\mathrm{up/down}}\,(\mathrm{L}\,1) = \mathrm{CIR}_{\mathrm{up/down}}\,(\mathrm{L}\,1) = \mathrm{R}_{\mathrm{max}_{\mathrm{up/down}}}\,(\mathrm{L}\,1)$ must always apply.

Another key parameter is MTU. It is recommended to identify the value of MTU of the NUT measured, if not known, using the available test tools, for example Wireshark, a packet capturing program, or a tool functioning according to recommendation of IETF RFC 4821 "Packetization Layer Path MTU Discovery".

Based on the settings of the input parameters of the measuring tool, including the intervals of the measurement sequence, it is possible to perform the test according to the selected steps, preferably in the recommended order, the result of which is the measured values of the set of basic data parameters. The results of the individual tests of the testB category will be subsequently saved in the form of reports allowing for subsequent machine processing (HTML, CSV, etc.) in the final version of the Measurement Report.

1.6. Evaluation of the measurement process result

When evaluating the results of the process of measurement of the testB category according to Annex 1 hereto, the Office will monitor compliance with the defined speeds, in terms of verification of a service outage and the so-called variations as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters. In the case of minimum speed ($\mathrm{R}_{\mathrm{min}}$), it is the lowest guaranteed speed for download and upload which the relevant provider of the Internet access service is contractually obliged to provide to the end-user. If the speed drops below this value such situation constitutes service outage. The following should therefore apply for download and upload speed:

$$\mathrm{TCP\ aTR} \geq \mathrm{R}_{\mathrm{min}};\ [\mathrm{b/s};\mathrm{b/s}], \tag{18}$$

Otherwise an outage of the Internet access service has occurred.

In its document entitled Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules pursuant to the Regulation, the Office introduces significant and continuous or regularly recurring discrepancy from normally available speed (BDR). Both defined discrepancies are derived from detectable change in performance of the Internet access service. The detected change of performance of the Internet access service (hereinafter referred to as "DZV") in a fixed electronic communication network means a decrease of at least one of the really achieved speeds (hereinafter referred to as "SDR") for download and upload below 50% of the value stated as BDR. The amount of the decrease of SDR below BDR can be expressed as $\mathrm{p}_{\mathrm{SDR}} = 0.5$. The limit of the detectable change in performance can be subsequently determined using the following equation:

$$\mathrm{DZV} = \mathrm{BDR} \cdot \mathrm{p}_{\mathrm{SDR}};\ [\mathrm{b/s};\mathrm{b/s},-]. \tag{19}$$

The Office considers a discrepancy which creates a continuous detectable change in performance of the Internet access service lasting more than 30 minutes to be significant continuous discrepancy from BDR for download and upload. It is therefore possible to write that the following applies to the significant continuous discrepancy from BDR:

$$\mathrm{T}_{\mathrm{DZV}} > 30\ \mathrm{min}, \tag{20}$$

where $\mathrm{T}_{\mathrm{DZV}}$ means the length of the interval of exceeding of the DZV limit corresponding to the time of commencement of the measuring process t_0. With respect to the measurement process itself and its individual steps, the Office will consider the situation where the condition $\mathrm{TCP\ aTR} < \mathrm{DZV}$ will hold for all results of the tests of testB category for download or upload to be an occurrence of significant continuous discrepancy.

The Office considers a discrepancy during which at least three detectable changes in the performance of the Internet access service longer than 1 minute occur within one hour to be regularly recurring discrepancy from BDR for download and upload. If therefore we mark the time of commencement of the test during which the DZV limit was exceeded as $\mathrm{t_x}$, where $\mathrm{x} \in \mathbb{N}^+$, and we also use the determined length of the interval of the test $\mathrm{T_{testB}}$, it will be possible to write that the following applies to the regularly recurring discrepancy from BDR:

$$\exists\ \mathrm{t_1, t_2, t_3}\colon \mathrm{T_{DZV}} > 1\ \mathrm{min} \wedge (\mathrm{t_3} - \mathrm{t_1}) \leq (60\ \mathrm{min} - \mathrm{T_{testB}}). \tag{21}$$

The statement whether a service outage or the so-called discrepancies as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters will be an integral part of the Measurement Report.

2. Measurement of the fixed electronic communication network for the purpose of inspection the data parameters belonging to the set extended data parameters

Annex 2, version 2.0, valid from 1 October 2018, is intended for measurement of data parameters belonging to the set of extended data parameters of fixed electronic communication networks falling in the category of NGA. The measurement according to Annex 2 is applicable for the purpose of verification of data parameters of newly built NGA networks, existing NGA networks, or, as the case may be, fulfilment of the need of the Office to assess the existing fixed networks in terms of qualitative data parameters achieved.

2.1. Description of the measurement scenario

The measurement scenario corresponds to the measurement process specified in the methodological procedure of this document. The specified measurement scenario is defined by the Office for measuring data parameters of fixed electronic communication networks belonging to the set of extended data parameters for the purpose of inspection them. The measurement scenario as well as the chosen set of extended data parameters are in accordance with the following documents: Determination of the basic parameters and measurement of the quality of the Internet access service and Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules.

2.2. Selection of the measurement method

For the purpose of performing measurements according to the specified measurement scenario, the measurement method chosen is based on the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349, supplemented by standard ITU-T Y.1564. Pursuant to the Regulation, the Office provided four definitions of speeds in relation to the provision of Internet access service in fixed networks in the range from the point of delivery of the service to the end-user (DeP 7) up to the point of MSEK access through the peering node NIX.CZ (DeP 1). In the case of download and upload, the definitions of speeds apply for each direction separately. The selected measurement method will be applied by the Office not only in the case of verification measurements of compliance with the defined speeds, in terms of verification of a service outage and the so-called discrepancies as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters, but also in terms of achievement of qualitative data parameters, in comparison with the technical specification MEF 23.1, category of Performance Tier 2 (Regional). The measurement method selected by the Office defines performance of measurement on the transport layer of the ISO/OSI model (L 4) by means of the TCP protocol for the set of basic data parameters and measurement on the link layer of the ISO/OSI model (L 2) by means of the UDP protocol on the transport layer for the measurement of the complementary qualitative data parameters within the set of extended data parameters.

2.3. Measurement sequence

It is recommended to perform three main independent measurements, including compliance with sufficient time diversity, i.e., at least one measurement at the peak hour and at least one measurement during an off-peak time. With respect to the time intensity of the process of measurement of the extended set of data parameters, it is permissible to perform all three main measurements during the peak hours in the case in the case of fixed electronic communication networks (fixed network under load); in the case of newly built fixed electronic communication networks (fixed network without load) it is possible to perform all three main measurements also during off-peak hours. One measurement should not exceed the timeframe of 20 minutes during which a sequence of three tests of the testB category and one test of the testC category, according to the subsection Measurement sequence in this document (steps 1 to 8).

If the measuring tool does not make it possible to set the order of the sequence of tests as recommended it is possible to change the order without breaching the integrity of the measurement. In the same way, it is possible to omit the bidirectional test of TCP throughput (step 5) or the sequence of breaks between individual tests (steps 2, 4, 6 and 8). The minimum admissible form of the measurement process of the extended set of data parameters must consist of a one-way upload test (step 1), one-way download test (step 3) of TCP throughput, and a bidirectional test of qualitative data parameters according to standard ITU-T Y.1564 (step 7). The possible combinations of the implementation of the minimum admissible form of the process of measurement depend on the measuring tools applied. Using the so-called "loopback" test during the measurement is not recommended, not even in the case of symmetrical NUTs.

2.4. Demarcation points

The first demarcation point will be, in accordance with subsection Demarcation points of the measurement in this document, the access of MSEK (measuring server) to the Internet through peering node NIX.CZ, see DeP 1 on Figure 2. The second demarcation point can be imagined in the form of an interface of the network node (a specific port of an active element) or, as the case may be, at a near place in the range which does not exceed the distance of particular neighboring demarcation point according to the contract terms where a measurement according to the methodology will take place by means of the measuring device (terminal). The second demarcation point envisaged within Annex 2 to this document is DeP 7, see Figure 2, i.e., demarcation point between the provider of the Internet access service and the end-user. With respect to the technologies of the access networks and their structure, the second demarcation point can occasionally be also DeP 6, see Figure 2 (e.g., a situation where the concentration point AP is implemented in the form of a router or network switch).

2.5. Setup of the measuring terminal and beginning of the measurement process

After having determined the measurement method, the measurement sequence, and the demarcation points, it is necessary to connect the measuring device physically according to the demarcation point set. Correct connection will subsequently be verified by means of the measuring device where it is necessary to select and set the parameters of the measuring interface. In addition, it is necessary to set other parameters of the higher network layers, if necessary, e.g., $\mathrm{MAC\,SRC}$, $802.1\mathrm{Q}$ (802.1ad), IP address of the measuring terminal if it does not receive it through the DHCP server, and the number of the TCP port of the measuring tool on the measuring device and the measuring server, unless it is pre-set.

In the next stage it is necessary to set the input parameters of the measuring tool (measuring device). The input parameters of the measuring tool or, more precisely, the measurement sequence, must be based on the parameters presented by the providers of electronic communication services in their offers of the Internet access service with regard to Regulation (EU) 2015/2120 of the European Parliament and of the Council (hereinafter referred to as "Regulation") and the related Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules (contract-guaranteed download and upload speed, see Article 4(1)(d) of the Regulation), and also on the measuring processes specified in the general methodology entitled Measurement of Data Parameters of Networks Using the TCP Protocol based on the recommendation of IETF RFC 6349. The input parameters need to be set according to the measuring tool applied in accordance with subchapter 'Input parameters of the sequence of measurement of a set of basic data parameters' in this document where it is necessary to pay attention on which layer of the ISO/OSI model and under which name the input parameter BB is set in the measuring tool. In this case, the equation (14) or $\mathrm{BB}_{\mathrm{up/down}}\,(\mathrm{L}\,1) = \mathrm{CIR}_{\mathrm{up/down}}\,(\mathrm{L}\,1) = \mathrm{R}_{\mathrm{max}_{\mathrm{up/down}}}\,(\mathrm{L}\,1)$ must always apply.

Another key parameter is MTU. It is recommended to identify the value of MTU of the NUT measured, if not known, using the available test tools, for example Wireshark, a packet capturing program, or a tool functioning according to recommendation of IETF RFC 4821 “Packetization Layer Path MTU Discovery”.

Based on the settings of the input parameters of the measuring tool, including the intervals of the measurement sequence, it is possible to perform the test according to the selected steps, preferably in the recommended order (steps 1 to 6), the result of which is the gained values of the set of basic data parameters. The results of the individual tests (testB) will be subsequently saved in the form of reports allowing for subsequent machine processing (HTML, CSV, etc.) in the final version of the Measurement Report.

In the last stage it is necessary to set the input parameters of the measuring device within the measurement of qualitative data parameters in the form of complementary parameters to the basic parameters within the extended set of data parameters. The basis in this case is standard ITU-T Y.1564 which defines, among other things, CIR, $\mathrm{CIR} + \mathrm{EIR}$ and size of the Ethernet frame FS (from $64\,\mathrm{B}$ to $1526\,\mathrm{B}$) as input parameters. As implied by the identification of CIR, EIR, these are parameters corresponding to the link layer of the ISO/OSI model. The input parameters need to be set according to the measuring tool applied in accordance with subchapter ‘Input parameters of the sequence of measurement of qualitative parameters’ in this document where, however, it is necessary to pay attention on which layer of the ISO/OSI model and under which name the input parameters CIR and EIR are set in the measuring tool. In this case, the equation (15) and (16), or $\mathrm{CIR}_{\mathrm{up/down}}\,(\mathrm{L}\,1) = = \mathrm{BDR}_{\mathrm{up/down}}\,(\mathrm{L}\,1)$ and $(\mathrm{CIR} + \mathrm{EIR})_{\mathrm{up/down}}\,(\mathrm{L}\,1) = \mathrm{R}_{\mathrm{max}_{\mathrm{up/down}}}\,(\mathrm{L}\,1)$ must always hold. When determining the value of the frame size FS, it is advisable to use as a basis the determined value of MTU from the previous stage, or $\mathrm{FS} = \mathrm{MTU} + \mathrm{MAC\ DST} + \mathrm{MAC\ SRC} + 802.1\mathrm{Q}\ (802.1\mathrm{ad}) + \mathrm{Ethertyp} + \mathrm{FCS}$.

Based on the settings of the input parameters of the measuring tool, including the intervals of the measurement sequence, it is possible to perform the test according to the selected steps, preferably in the recommended order (steps 7 to 8), the result of which is the gained values of the complementary parameters to the basic parameters within the extended set of data parameters. The results of the individual tests (testC) will be subsequently saved in the form of reports allowing for subsequent machine processing (HTML, CSV, etc.) in the final version of the Measurement Report.

2.6. Evaluation of the measurement process result

When evaluating the results of the measurement process of the testB category according to Annex 2 to this document, the Office will monitor compliance with the defined speeds, in terms of verification of a service outage and the so-called discrepancies as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters. In the case of minimum speed ($\mathrm{R}_{\mathrm{min}}$), it is the lowest guaranteed speed for download and upload which the relevant provider of the Internet access service has undertaken to provide to the end-user by contract. If the speed drops below this value such condition constitutes service outage. The following should therefore apply for download and upload speed:

$$\mathrm{TCP\ aTR}\ \geq \mathrm{R}_{\mathrm{min}};\ [\mathrm{b/s}; \mathrm{b/s}], \qquad (18)$$

Otherwise an outage of the Internet access service has occurred.

In its document entitled Statement of the Czech Telecommunication Office on selected issues relating to open Internet access and European net neutrality rules pursuant to the Regulation, the Office introduces a significant continuous and regularly recurring discrepancy from normally available speed (BDR). Both defined discrepancies are derived from the detected change in the performance of the Internet access service. The detected change of performance of the Internet access service (hereinafter referred to as “DZV”) in a fixed electronic communication network means a decrease of at least one of the really achieved speeds (hereinafter referred to as “SDR”) for download and upload below 50% of the value stated as BDR. The amount of the decrease of SDR below BDR can be expressed as $\mathrm{p_{SDR}} = 0.5$. The limit of the detectable change in performance can be subsequently determined using the following equation:

$$\mathrm{DZV} = \mathrm{BDR} \cdot \mathrm{p_{SDR}}; [\mathrm{b/s}; \mathrm{b/s}, -]. \tag{19}$$

The Office considers a discrepancy which creates a continuous detectable change in performance of the Internet access service lasting more than 30 minutes to be a significant continuous discrepancy from BDR for download and upload. It is therefore possible to write that the following applies to the significant continuous discrepancy from BDR:

$$\mathrm{T_{DZV}} > 30\ \mathrm{min}, \tag{20}$$

where $\mathrm{T_{DZV}}$ means the length of the interval of exceeding of the DZV limit corresponding to the time of commencement of the measuring process $\mathrm{t_0}$. With respect to the measurement process itself and its individual steps, the Office will consider the situation where the condition $\mathrm{TCP\ aTR} < \mathrm{DZV}$ will hold for all results of the tests (testB) for download or upload to be an occurrence of a significant continuous discrepancy.

The Office considers a discrepancy during which at least three detectable changes in the performance of the Internet access service longer than 1 minute occur within one hour to be a regularly recurring discrepancy from BDR for download and upload. If, therefore we mark the time of commencement of the test during which the DZV limit was exceeded as $\mathrm{t_x}$, where $\mathrm{x} \in \mathbb{N}^+$, and we also use the determined length of the interval of the test $\mathrm{T_{testB}}$, it will be possible to write that the following applies to the regularly recurring discrepancy from BDR:

$$\exists\ \mathrm{t_1}, \mathrm{t_2}, \mathrm{t_3}: \mathrm{T_{DZV}} > 1\ \mathrm{min} \wedge (\mathrm{t_3} - \mathrm{t_1}) \leq (60\ \mathrm{min} - \mathrm{T_{testB}}). \tag{21}$$

The statement whether a service outage or the so-called discrepancies as indicators of the fact that the performance of the service does not achieve the contractually agreed parameters will be an integral part of the Measurement Report.

When evaluating the results of the measurement process of the testC category according to Annex 2 to this document, it is also necessary to assess the measured qualitative data parameters belonging to the set of extended data parameters of fixed electronic communication networks. The measurement according to Annex 2 is applicable for the purpose of verification of data parameters of NGA networks, or, as the case may be, fulfilment of the need of the Office to assess the existing fixed networks in terms of the qualitative data parameters achieved. Due to the location of the measuring server as a part of MSEK with Internet access through the peering node NIX.CZ, see DeP 1 on Figure 2, and due to the area of the Czech Republic, the Office has decided to recommend using for the evaluation of the results of the measurement process of qualitative data parameters the values provided in the technical specification MEF 23.1, Performance Tier 2 (Regional), corresponding to distances of < 1200 km, whereas the values of the specific CoS in the form of usable quality classes are provided in tab. 1, tab. 2 and tab. 3.

Tab. 1: Category of Performance Tier 2 (Regional), class CoS High according to MEF 23.1

Qualitative data parameter	Required value
FD – frame delay[1]	≤ 25 ms
IFDV – inter-frame delay variation	≤ 8 ms
FLR – frame loss ratio	≤ 0.01 %

[1] Frame delay FD is defined in the technical specification MEF 23.1 as a resulting value of a measurement of the “end-to-end” type. In the case of the measuring process of the Office according to appendix 2, the double value thereof will be monitored, or FD (RTT).

Tab. 2: Category of Performance Tier 2 (Regional) class CoS Medium according to MEF 23.1

Qualitative data parameter	Required value
FD – frame delay	≤ 75 ms
IFDV – inter-frame delay variation	≤ 40 ms
FLR – frame loss ratio	≤ 0.01 %

Tab. 3: Category of Performance Tier 2 (Regional) class CoS Low according to MEF 23.1

Qualitative data parameter	Required value
FD – frame delay	≤ 125 ms
IFDV – inter-frame delay variation	N/S
FLR – frame loss ratio	≤ 0.1 %

Tables No. 1, No. 2 and No. 3 will be used by the Office for its internal purposes of classification of networks according to their data parameters. The statement whether the set criteria of the category of Performance Tier 2 (Regional) of selected classes CoS according to MEF 23.1 were fulfilled during the measuring process will be an integral part of the Measurement Report.