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Draft BEREC Guidelines on Very High Capacity Networks

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1 Introduction

1. These BEREC Guidelines, designed in accordance with Article 82 of the European Electronic Communications Code (EECC),[1] are drafted to provide guidance to NRAs '*on the criteria that a network is to fulfil in order to be considered a very high capacity network, in particular in terms of down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation*' (Art. 82). NRAs shall take these Guidelines into utmost account.[2] The Guidelines shall contribute to the harmonisation of the definition of the term 'very high capacity networks' in the EU.

2. Article 3 of the EECC specifies its general objectives, including '*promot[ing] connectivity and access to, and take-up of, very high capacity networks'*. Furthermore, according to recital (28) of the EECC, '*it is necessary to give appropriate incentives for investment in new very high capacity networks that support innovation in content-rich internet services and strengthen the international competitiveness of the Union. Such networks have enormous potential to deliver benefits to consumers and businesses across the Union*.'

3. This objective of promoting the widespread deployment and take-up of very high capacity networks is at the core of the EU's ambition towards a gigabit society.[3] Therefore, the concept of very high capacity networks is used also in other initiatives taken by the EU institutions to support this ambition.[4]

4. The term 'very high capacity networks' is defined in Article 2(2) of the EECC and is relevant for several provisions in the EECC, as for example:

   - the conditions under which NRAs shall not impose certain obligations on wholesale-only undertakings depend on access to a very high capacity network (Art. 61(3)) in connection with Art. 80);
   - the geographical surveys of network deployments may include a forecast of the reach of very high capacity networks (Art. 22(1));
   - NRAs may invite undertakings and public authorities to declare their intention to deploy very high capacity networks in designated areas (Art. 22(3));

[1] Directive (EU) 2018/72 of the European Parliament and the Council establishing the European Electronic Communications Code, OJ L 321/36 of 17 Dec. 2018

[2] As set out in Article 4(4) of Regulation (EU) 2018/1971 of the European Parliament and the Council of 11 December 2018 establishing the Body of European Regulators for Electronic Communications (BEREC) and the Agency for Support for BEREC (BEREC Office), amending Regulation (EU) 2015/2120 and repealing Regulation (EC) No 1211/2009, OJ L 321/1 of 17 Dec. 2018 and Article 61(7) of the EECC.

[3] See in particular the communication from the Commission 'Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society'. The ambitious strategic objectives set by the Commission, which are supported by the Council and European Parliament, are recalled in Recital 24 of the Code.

[4] See, for example, the Connecting Europe Facility (CEF2) and the European Fund for Strategic Investment (EFSI) programmes which are proposed for the next Multiannual Financial Framework (MFF).

5. Other articles and recitals of the EECC which also refer to very high capacity networks are listed in annex 1.

2 Definition of the term ‘very high capacity network’ in the EECC

6. Article 2(2) of the EECC defines the term ‘very high capacity network’ as follows:

   ‘*’Very high capacity network’ means*

   - *either an electronic communications network which consists wholly of optical fibre elements at least up to the distribution point at the serving location,*
   - *or an electronic communications network which is capable of delivering, under usual peak-time conditions, similar network performance in terms of available downlink and uplink bandwidth, resilience, error-related parameters, and latency and its variation’*. [bullet points added by BEREC]

7. Recital (13) further clarifies:

   ‘[…] While in the past the focus was mainly on growing bandwidth available overall and to each individual user, other parameters such as latency, availability and reliability are becoming increasingly important. The current response towards that demand is to bring optical fibre closer and closer to the user, and future 'very high capacity networks' require performance parameters which are equivalent to those that a network based on optical fibre elements at least up to the distribution point at the serving location can deliver.

   In the case of ***fixed-line connection****, this corresponds to network performance equivalent to that achievable by an* ***optical fibre installation up to a multi-dwelling building****, considered to be the serving location.*

   In the case of ***wireless connection****, this corresponds to network performance similar to that achievable based on an* ***optical fibre installation up to the base station****, considered to be the serving location.*

   Variations in end-users’ experience which are due to the different characteristics of the medium by which the network ultimately connects with the network termination point should not be taken into account for the purposes of establishing whether a wireless network could be considered as providing similar network performance.

   In accordance with the principle of technology neutrality, other technologies and transmission media should not be excluded, where they ***compare with that baseline scenario in terms of their capabilities****. […]’ [emphasis and paragraphs added by BEREC].*

8. Therefore, according to the provisions in the EECC, an electronic communications network which consists wholly of optical fibre elements at least up to the distribution point at the serving location is considered a very high capacity network (part 1 of Art 2(2)). Any electronic communications network capable of delivering, under usual peak-time

conditions, an equivalent network performance is also considered a very high capacity network (part 2 of Art. 2(2)).

9. Recital 13 established the link between these two parts of the definition of very high capacity networks in Article 2(2) by developing the concept of equivalence of network performance and providing a baseline scenario based on two different topologies: (i) fibre roll out (at least) up to a multi-dwelling building in the case of a fixed-line connection and (ii) fibre roll out up to the base station in the case of a wireless connection. This ensures the principle of technology neutrality based on the equivalence of the performance of the networks.

10. Moreover, Article 2(2) of the EECC determines the parameters to be considered in order to establish that a network offers an equivalent performance to that of the baseline scenario, namely ‘available downlink and uplink bandwidth, resilience, error-related parameters and latency and its variation’.

11. Article 82 of the EECC entrusts BEREC to issue guidelines on the criteria to consider a network as a very high capacity network, in particular in terms of the above-mentioned specific parameters.

12. In conclusion, very high capacity networks according to Art. 2(2) are:

    a. Any network providing a fixed-line connection with fibre roll out at least up to the multi-dwelling building;

    b. Any network providing a wireless connection with fibre roll out up to the base station;

    c. Any network which provides a fixed-line connection and is capable of delivering under usual peak-time conditions a network performance equivalent to what is achievable by a network providing a fixed-line connection with fibre roll-out up to the multi-dwelling building (**performance thresholds 1**); and

    d. Any network which provides a wireless connection and is capable of delivering under usual peak-time conditions a network performance equivalent to what is achievable by a network providing a wireless connection with fibre roll out up to the base station (**performance thresholds 2**).

13. Very high capacity networks are of importance since they are capable of providing end-user services with a particularly high quality of service (QoS). The EECC promotes the rollout of very high capacity networks to benefit end-users (Art. 3(2)a EECC). Therefore, the equivalent performance of the baseline scenario (see paragraphs 9, 12c and 12d) is considered with regards to the achievable end-user QoS of very high capacity networks. Moreover, the EECC defines a very high capacity network as a certain type of electronic communications network and not only as a limited part of a network. Therefore, for the

purposes of determining the network performance of equivalent networks, it is necessary to consider the network up to the end-user where the public network ends.[5]

14. For these reasons, the performance thresholds 1 and 2 need to be determined as follows:

    a. Performance thresholds 1: The end-user QoS which is achievable under usual peak-time conditions by a network providing a fixed-line connection with a fibre roll out up to the multi-dwelling building.

    b. Performance thresholds 2: The end-user QoS which is achievable under usual peak-time conditions by a network providing a wireless connection with a fibre roll out up to the base station.

15. Performance thresholds 1 focus on fibre roll out up to the multi-dwelling building and not on fibre to the home (FTTH), since according to Recital 13 of the EECC, fibre roll out up to the multi-dwelling building should be the baseline scenario for the determination of the equivalent network performance to be considered as a very high capacity network. Other networks which do not qualify as very high capacity networks based on part 1 of Article 2(2) of the EECC (only) need to be capable to provide an end-user QoS achievable with fibre to the multi-dwelling building - and not the higher end-user QoS achievable with FTTH.

3 Criteria for the definition of 'very high capacity networks'

16. In accordance with the EECC (see section 2) and based on data collected from network operators (see section 4 and annex 2 to 4), BEREC has determined that any network which fulfils one (or more) of the following four criteria is a very high capacity network:

Criterion 1: Any network providing a fixed-line connection with a fibre roll out at least up to the multi-dwelling building.

Criterion 2: Any network providing a wireless connection with a fibre roll out up to the base station.

[5] Considering network performance only up to the access node and not up to the end-user would have the following consequences: In case of the baseline scenario (a network with fibre up to the multi-dwelling building), the network up to the access node in (or at) the building is entirely based on fibre and therefore the network performance, is correspondingly high. In case a traditional network without any next generation access needs to be examined whether or not it qualifies as a very high capacity network, the network up to the access node which is located at the MDF location (LEX) is *also* entirely based on fibre. Therefore, the network performance would be similarly high as in case of the baseline scenario and consequently, it would qualify as a very high capacity network. This result is clearly not intended by the EECC.

Criterion 3: Any network providing a fixed-line connection which is capable of delivering, under usual peak-time conditions, services to end-users with the following quality of service (**performance thresholds 1**):

a.	Downlink data rate	≥ 1000 Mbps
b.	Uplink data rate	≥ 200 Mbps
c.	IP packet error ratio (Y.1540)	≤ 0.05%
d.	IP packet loss ratio (Y.1540)	≤ 0.0025%
e.	Round-trip IP packet delay (RFC 2681)	≤ 10 ms
f.	IP packet delay variation (RFC 3393)	≤ 2 ms
g.	IP service availability (Y.1540)	≥ 99.9% per year

Criterion 4: Any network providing a wireless connection which is capable of delivering, under usual peak-time conditions, services to end-users with the following quality of service (**performance thresholds 2**).

a.	Downlink data rate	≥ 150 Mbps
b.	Uplink data rate	≥ 50 Mbps
c.	IP packet error ratio (Y.1540)	≤ 0.01%
d.	IP packet loss ratio (Y.1540)	≤ 0.005%
e.	Round-trip IP packet delay (RFC 2681)	≤ 25 ms
f.	IP packet delay variation (RFC 3393)	≤ 6 ms
g.	IP service availability (Y.1540)	≥ 99.81% per year

17. Note to criterion 1 and criterion 2
    a. Criterion 1 and criterion 2 result from the EECC (see section 2).[6]
    b. Note that a network which qualifies as a very high capacity network according to criterion 1 does not necessarily fulfil criterion 3.
    c. Note that a network which qualifies as a very high capacity network according to criterion 2 does not necessarily fulfil criterion 4.
18. Note to criterion 3 and criterion 4
    a. For the qualification as a very high capacity network, it is sufficient that a network is capable to provide a service which meets the performance thresholds 1 in case of fixed-line connection or performance thresholds 2 in case of wireless connection. Therefore, it is neither necessary that the network actually offers such

[6] Since Article 82 of the EECC requires that the Guidelines define all criteria that a network has to fulfil in order to be considered a very high capacity network, they are also included in these Guidelines.

a service nor that all services provided by the network have to meet the performance thresholds 1 or performance thresholds 2.

b. The performance thresholds 1 and performance thresholds 2 refer to the path from the end-user[7] to the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point) and in case of round-trip parameters back to the end-user (see paragraphs 52 and 53).

c. The threshold data rates of performance thresholds 1 and performance thresholds 2 are data rates at the level of the IP packet payload.

d. The threshold data rates of performance thresholds 1 are the data rates at the point where the fixed subscriber access line (e.g. twisted pair, coax cable) ends in the end-user's living space.

e. In case of particularly long distances (e.g. several hundred kilometres) between the end-user and the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point), the threshold round-trip IP packet delay increases for every 100 km by 1 ms.

f. The performance thresholds 2 refer to outdoor locations only and to the average value within the coverage area considered (see paragraphs 73 and 74).

19. The wording of the EECC in Recital 13, as well as the different thresholds of performance set out in criteria 3 and 4 suggest that 'very high capacity network' does not represent a unified concept. In this sense, very high capacity networks can be divided in two categories, which typically have different performance characteristics. These Guidelines refer to these categories as (i) 'fixed very high capacity networks', which meet criterion 1 or criterion 3 (or both), and (ii) 'wireless very high capacity networks', which meet criterion 2 or criterion 4 (or both).

20. A 'wireless very high capacity network' (i.e. a network that meets criteria 2 or 4, or both), may also meet the performance thresholds of criterion 3 and, if this is the case, it may be considered equivalent to a 'fixed very high capacity network'. This may apply in particular to wireless networks providing services that compete in the same market with services provided by fixed networks (such networks and services are often marketed under the term 'Fixed Wireless Access' or 'FWA').

21. In the following section and annex 2 to 4, the Guidelines explain in detail how BEREC determined the performance thresholds 1 and performance thresholds 2.

22. Finally, the Guidelines provide information on how the criteria 1 to 4 need to be applied (see section 5).

[7] Without taking into account limitations caused by the customer premises equipment respectively mobile equipment.

23. According to Art. 82 of the EECC, '*BEREC shall update the guidelines by 31 December 2025*'. Since it was not yet possible to take 5G fully into account for the release of these Guidelines, as it has not yet reached mature deployment and significant penetration, BEREC intends to update criterion 4 (performance thresholds for wireless network) as soon as possible and not later than 2023.

24. The Guidelines provide criteria for the consideration of a network as a very high capacity network, where this is relevant for the application of the EECC. They should not be interpreted as a view on the appropriateness of such consideration as a criterion for any other policy instrument, including public funding.

4 Determination of the performance thresholds 1 and 2

25. This section together with annex 2 and 4 describes how BEREC determined the performance thresholds 1 and 2.

26. The performance thresholds 1 and 2 need to be determined as defined in paragraph 14, according to the analysis of the relevant legal provisions in the EECC (see section 2, in particular paragraphs 12 and 13).

27. This section describes further the basis for the determination of the performance thresholds 1 and 2 and the determination of the performance thresholds 1 and 2 is done in annex 3 and annex 4.

4.1 Networks considered

28. The performance thresholds 1 refer to a fixed network with fibre roll out up to the multi-dwelling building (see paragraph 14a). End-user services provided by such a network are typically based on copper or coax access. Therefore, the determination of the performance thresholds 1 is based on fixed networks with fibre roll out up to the multi-dwelling building and either copper or coax-based access.

29. The performance thresholds 2 refer to a wireless network with fibre roll out up to the base station (see paragraph 14b). End-user services provided by such a network are typically based on a mobile network (not e.g. on a public WLAN network). Therefore, the determination of the performance thresholds 2 is based on mobile networks with fibre roll out up to the base station.

4.2 'Achievable' end-user QoS

30. The performance thresholds 1 and 2 refer to the '*achievable'* end-user QoS (see paragraph 14). Therefore, they are determined based on the 'best' technology with regard to the achievable end-user QoS.

31. These Guidelines enter into force from 2021 onwards and, therefore, the focus is as much as possible on technologies which will be deployed in networks in this time period.

32. Network operators know the end-user QoS which is achievable in their networks based on technologies they have already deployed. This is also a QoS which end-users can

effectively experience. For such technologies, they are able to provide data on the achievable end-user QoS.

33. Network operators, however, do not know which end-user QoS will be achievable in their networks based on technologies they will deploy in the future. Network operators, therefore, are not able to provide data on the achievable end-user QoS for such technologies. Vendors do also not know which end-user QoS is achievable in practice with technologies they are still developing and which have not yet been deployed in real networks. Therefore, it is not possible to determine the QoS that end-users will experience with technologies that will be deployed in networks only in the future.

34. The determination of the performance thresholds 1 and 2 therefore is based on the 'best' technology with regard to the achievable end-user QoS already deployed in networks (at least pilot deployments or field trials).[8] In order to be as much future oriented as possible, the focus is on the newest technologies used, even if they are only deployed by a small number of operators in the EU.

35. For this reason, the following technologies are considered.

    a. In case of fixed networks with copper access, G.fast on twisted pair.

    b. In case of fixed networks with coax access, the most advanced DOCSIS technology (e.g. DOCSIS 3.1).

    c. In case of mobile networks, LTE Advanced (4G) with carrier aggregation and MIMO[9], however, only carrier aggregation with the highest aggregated spectrum and MIMO with the highest number of parallel data streams used in mobile networks.

36. 5G will be deployed after these Guidelines enter into force. However, 5G had not yet been deployed in networks to a relevant extent at the time when it was necessary to collect the data for the development of these Guidelines. Therefore, it is not possible to determine the performance thresholds 2 (wireless networks) based on these technologies. However, in order to take 5G into account as much as possible, the performance thresholds 2 are determined based on the highest values (and not e.g. on the average of the values) of the achievable end-user QoS, according to the answers from the network operators. Therefore, in practice, save for exceptional cases of LTE Advanced (4G), BEREC expects that 4G and earlier generations of mobile networks are not able to meet performance thresholds 2.

4.3 'Peak-time conditions'

37. The performance thresholds 1 and 2 have to be determined '*under usual peak-time conditions*' (see paragraph 14). Therefore, realistic conditions prevailing in networks which correctly reflect end-user experiences need to be considered. For this reason, the

[8] At the time when the data were collected (see section 4.6)
[9] Multiple-Input and Multiple-Output

determination of the performance thresholds 1 and 2 focus on the service with the highest end-user QoS, a typical use of the network and the current service portfolio. This implies that several end-users simultaneously use the network during peak-time.

38. Since the performance thresholds 1 and 2 need to be based on the *achievable* (and not *currently achieved*) end-user QoS (see paragraph 14), they are determined based on the service with the highest end-user QoS (data rate) *possible* with the 'best' technology deployed in the network.[10] This is a hypothetical situation and it is assumed that the subscribers which are currently subscribed to the service with the highest data rate get the service with the highest data rate possible instead (see paragraphs 100.b, 100.f and 104.d).

4.4 'Typical' end-user QoS

39. The achievable end-user QoS may vary between different end-users depending on e.g. the length of the access media, quality of the access media, interferences and noise. The determination of the performance thresholds 1 and 2 therefore is based on the achievable end-user QoS which end-users *typically* experience (e.g. mean).

40. The EECC does not define the situation for which performance thresholds 1 and 2 need to be determined in more detail. Therefore, it is not possible to determine performance thresholds 1 and 2 for a more specific situation.

4.5 QoS parameters

41. The EECC (Art. 2(2) and Art. 82) demands that the performance thresholds 1 and 2 need to be determined in terms of '*downlink and uplink bandwidth, resilience, error-related parameters, latency and its variation*' (see paragraph 10).

General applicability

42. The performance thresholds 1 apply to *any* network which provides a fixed-line connection and the performance thresholds 2 apply to *any* network which provides a wireless connection (see paragraphs 14a and 14b). Therefore, the QoS parameters of the performance thresholds 1 and 2 need to be applicable to any network, even to networks which are not yet deployed but will be deployed when these Guidelines are in force.

43. Today, nearly all communications networks are based on the Internet Protocol (IP). Therefore, the QoS parameters of the performance thresholds 1 and 2 are based on IP.

Entire communications network

44. The EECC (Art. 2(2)) defines that a very high capacity network is a certain type of communications network. This definition is not limited to a certain part of the network

[10] At the time of data collection.

hierarchy (e.g. only to the access network) but instead encompasses the entire communications network. Therefore the QoS parameters of performance thresholds 1 and 2 need to be applicable to an entire network.

Downlink and uplink bandwidth

45. The first two QoS parameters are the downlink and the uplink data rate.[11] Since the QoS parameters need to be based on IP (see paragraph 42), the performance thresholds 1 and 2 are based on the downlink and uplink data rate of the IP packet payload.

Latency and its variation

46. For latency and its variation, it is necessary also to consider IP-based QoS parameters. Typically, one-way delay is more difficult to measure than round-trip delay and further from an end-user perspective, round-trip delay is of primary interest. Therefore, the performance thresholds 1 and 2 are based on the round-trip IP packet delay (RFC 2681) and the IP packet delay variation (RFC 3393).[12]

Error-related parameters

47. For error-related parameters, the IP-based parameters IP packet error ratio (Y.1540) and the IP packet loss ratio (Y.1540) were considered. In the first phase of the call for initial stakeholder input (see section 4.6 paragraphs 47 and 49), the stakeholders were explicitly asked whether in their view other error-related parameters are more appropriate.

48. Several stakeholders suggested to use the QoS parameters errored seconds (ES), severe errored seconds (SES) and unavailable seconds (UAS). However, these QoS parameters are access network specific and not applicable to an entire communications network. Since the EECC defines a very high capacity network as an entire network and not as only an access network (see paragraph 37), it was not possible to use these QoS parameters.

49. Apart from this, the stakeholders did not provide a clear indication that other error-related QoS parameters are more appropriate. Therefore, the performance thresholds 1 and 2 are based on the IP packet error ratio (Y.1540) and the IP packet loss ratio (Y.1540).[13]

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[11] The Guidelines use the term ‘data rate’ instead of ‘bandwidth’ in order to avoid in case of wireless networks to confuse ‘bandwidth’ with the meaning data rate (e.g. 50 Mbps) with ‘bandwidth’ with the meaning spectrum (e.g. 50 MHz).

[12] This is in conformance with the BEREC report ‘Net Neutrality Regulatory Assessment Methodology’ (BoR(17)178, section 3.2, p. 9). In annex X ‘Quality of service parameters’, the EECC refers to the standard ITU-T Y.2617 with regard to latency (delay) and jitter. However, this is a one-way delay and a rather new standard. In order to enable network operators to provide data, it was necessary to use a standard which is already used since many years. No stakeholder suggested to use Y.2617 instead of RFC 2681 and/or RFC 3393.

[13] In annex X ‘Quality of service parameters’, the EECC refers to the relatively new ITU-T standard Y.2617 with regard to packet loss ratio. In order to enable network operators to provide data, it was necessary to use a

Resilience

50. For resilience, the IP service availability (Y.1540) was considered and in the first phase of the call for initial stakeholder input, the stakeholders were also explicitly asked whether in their view another resilience parameter is more appropriate. The stakeholders did not provide a clear indication that a different parameter is more appropriate for resilience. Therefore, the performance thresholds 1 and 2 are based on the IP service availability (Y.1540).

51. The IP service availability refers to the time period of a year and not solely to the peak-time as it is the case with the other QoS parameters and demanded by the EECC (Art. 2(2), see paragraph 6). The reason is that availability parameters usually refer to a certain time period (and not solely to the peak-time). In response to the first phase of the call for initial stakeholder input (see paragraphs 47 and 49), stakeholders pointed out that they need to know the time period to which the IP service availability refers to otherwise they are not able to provide data. Therefore, in order to collect sufficient data, it was necessary to define the time period and to use the common one-year time period.

Path of the QoS parameters

52. The EECC demands that an entire network needs to be considered (see paragraph 43). The performance thresholds 1 and 2 focus more on the access network since core networks are usually based on fibre. However, this does not preclude that the backhaul and the core networks should be designed in conditions compatible with the access network QoS.

53. For these reasons, the QoS parameters of the performance thresholds 1 and 2 refer to the path from the end-user to the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point) and in case of round-trip parameters back to the end-user.

4.6 Data collection

54. BEREC launched a call for initial stakeholder input in three phases in order to collect the necessary data for the determination of the performance thresholds 1 and 2 based on questionnaires. BEREC welcomes all contributions received and thanks all stakeholders for their inputs.

55. BEREC informed the public at the public debriefing on outcomes of the 38th BEREC ordinary meetings on 13 March 2019 in Brussels on this call for initial stakeholder input

standard which has already been in use for many years. No stakeholder suggested to use Y.2617 instead of Y.1540. Y.2617 does not define a packet error ratio. Therefore, the ITU-T standard Y.1540 needs to be used for the IP packet error ratio. As it would not be appropriate to use different standards for the error-related parameters, Y.1540 also needs to be used for the IP packet loss ratio.

and sent the 'call for initial stakeholder input' documents and the questionnaires to the following stakeholders:[14]

a. Network operators (sent by NRAs);

b. Associations of network operators at EU level;[15] and

c. Major vendors of equipment for fixed access networks based on G.fast[16] and DOCSIS[17] (etc.) and for mobile networks.[18]

56. In the first phase of this call for initial stakeholder input, launched in March 2019, the stakeholders were asked to comment on the draft questionnaires. Based on the input received, BEREC revised the questionnaires, launched the second phase of the call for initial stakeholder input in May 2019 and asked the network operators and vendors to complete the final questionnaires (except the FTTH questionnaire). In order to avoid putting too much burden on the operators at the same time, the network operators were asked to fill in the FTTH questionnaire in a separate and third phase of the call for initial stakeholder input after summer time at the end of August 2019.

57. Annex 2 provides information on the questionnaires used to collect the data and the number of questionnaires received from the stakeholders.

5 Application of the criteria 1 to 4

58. The criteria a network has to fulfil in order to be considered a 'very high capacity network' (see paragraph 16) need to be applied as described in this section. It is sufficient that an NRA considers that a network fulfils one of the four criteria in order to qualify as a very high capacity network and it does not need to meet more than one criterion.

5.1 Application of the criterion 1

59. According to criterion 1 (see paragraph 6), any network providing a fixed-line connection qualifies as very high capacity network if fibre is rolled out at least up to the multi-dwelling building and it does not need to fulfil further criteria.

60. For example, criterion 1 is fulfilled in case of fixed networks where fibre is rolled out up the multi-dwelling building or up to a single-family house,[19] and therefore, in case of fibre to the building (FTTB) and also in case of fibre to the home (FTTH).

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[14] https://berec.europa.eu/eng/events/berec_events_2019/186-public-debriefing-on-outcomes-of-the-38th-berec-ordinary-meetings

[15] ETNO, ECTA, FTTH Council Europe, Cable Europe, EuroISPA and GSMA

[16] Nokia, Huawei, Adtran, Calix, MVM Tel, Zyxcel

[17] Arris, Cisco, Casa Systems, Huawei, Harmonic, Sumavision, DEV Systemtechnik GmbH, Ascent Communication Technology Ltd

[18] Nokia, Huawei, Ericsson, ZTE

61. BEREC is of the view, that in case fibre is rolled out up to the multi-dwelling building it is desirable that technologies which are deployed inside the building correspond to the performance potential of FTTB, although this is not a legal requirement (see paragraphs 16 and 59).

62. Fixed networks with a fibre roll out up to a node (not to a building) and even if only a few single-family houses are connected to this node do not fulfil criterion 1. Such networks, however, would qualify as very high capacity network if they fulfil criterion 3.

5.2 Application of the criterion 2

63. According to criterion 2 (see paragraph 6), any network providing a wireless connection with a fibre roll out up to the base station qualifies as a very high capacity network and it does not need to fulfil further criteria.

64. Criterion 2 refers to wireless networks, therefore, mobile networks with fibre roll out up to the base station fulfil this criterion but also e.g. a public WLAN (WiFi) network with fibre roll out up to the access point.[20]

65. BEREC is of the view, that in case fibre is rolled out up to the base station it is desirable that wireless access technologies which are deployed correspond to the performance potential of fibre to the base station, although this is not a legal requirement (see paragraphs 16 and 63).

5.3 Application of the criterion 3

66. Any network which provides a fixed-line connection and is capable of delivering under usual peak-time conditions services to end-users with a QoS defined by performance thresholds 1 qualifies as a very high capacity network (see paragraph 6).

67. For the qualification as a very high capacity network, it is sufficient that the network is capable to provide a service which meets the performance thresholds 1. Therefore, it is neither necessary that the network actually offers such a service nor that all services provided by the network have to meet the performance thresholds 1 (see paragraph 7.a).

68. The area covered by the network which provides a fixed-line connection needs to be divided in appropriate sub-areas (e.g. multi-dwelling building, group of single-family houses, area of an access node). For each sub-area, it needs to be determined whether

[19] Or offices and industrial buildings

[20] The WLAN (WiFi) access point is considered to be the base station. On the other hand, satellite networks are very different from terrestrial wireless networks in terms of characteristics and architecture and there does not appear to exist an equivalent to the concept of base station as used in terrestrial wireless networks. Therefore, it is not possible to apply criterion 2 to satellite networks. But satellite networks can be considered a very high capacity network if they meet criterion 4.

the performance thresholds 1 are met.[21] If a sub-area meets performance thresholds 1, then the part of the network that covers this sub-area qualifies as a very high capacity network.

69. A sub-area meets performance thresholds 1, if, under usual peak-time conditions, the end-users in this sub-area will typically experience at least the QoS of the performance thresholds 1 at the point where the subscriber access line ends in its living space (not including limitations from the customer premises equipment). For example, if end-users in this sub-area would measure the data rate of the service with an internet speed test during peak-time, then they would typically measure at least 1,000 Mbps in downlink and 200 Mbps in uplink (at the level of the IP packet payload) in case their customer premises equipment does not limit the data rate.

70. Criterion 3 refers to '*any* network which provides a fixed-line connection' and consequently applies technologically neutral to *all* networks which provide a fixed-line connection. Therefore, criterion 3 applies for example to networks with an access network based on

    a. (Usual) twisted pair with DSL technology (e.g. G.fast);

    b. Coax cable with DOCSIS technology (e.g. DOCSIS 3.1); and

    c. Twisted pair cable of category 5 or higher with Ethernet technology (e.g. Gigabit Ethernet).

71. As mentioned in paragraph 20, a 'wireless very high capacity network' (i.e. a network that meets criteria 2 or 4, or both), may also meet the performance thresholds of criterion 3 and, if this is the case, it may be considered equivalent to a 'fixed very high capacity network'.

5.4 Application of the criterion 4

72. Any network which provides a wireless connection and is capable of delivering under usual peak-time conditions services to end-users with a QoS defined by performance thresholds 2 qualifies as a very high capacity network (see paragraph 6).

73. For the qualification as a very high capacity network, it is sufficient that the network is capable to provide a service which meets the performance thresholds 2. Therefore, it is neither necessary that the network actually offers such a service nor that all services provided by the network have to meet the performance thresholds 2 (see paragraph 18.a).

74. The area covered by the network which provides a wireless connection needs to be divided in appropriate sub-areas (e.g. coverage area of a base station or group of base

[21] In case the network operator does not (yet) offer a service which meets performance thresholds 1, then the proof whether performance thresholds 1 are met may be based e.g. on measurements with test implementations in the network.

stations). For each sub-area, it needs to be determined whether the performance thresholds 2 are met.[22] If a sub-area meets performance thresholds 2, then the part of the network that covers this sub-area qualifies as a very high capacity network.

75. A sub-area meets performance thresholds 2, if, under usual peak-time conditions, in this sub-area an end-user will experience on average at least the QoS of the performance thresholds 2 at outdoor locations.[23] For example, if the data rate in this sub-area will be measured during peak-time with a drive test, then the average value of the measured data rate would be at least 150 Mbps in downlink and 50 Mbps in uplink (at the level of the IP packet payload) in case the mobile equipment used in the drive test sufficiently supports the technology used in the wireless network.

76. Criterion 4 refers to ‘any network which provides a wireless connection’ and therefore applies technologically neutral to all networks which provide a wireless connection (e.g. mobile networks, public WLAN (WiFi) networks, satellite networks).

[22] In case the network operator does not (yet) offer a service which meets performance thresholds 2, then the proof whether performance thresholds 2 are met may be based e.g. on measurements with test implementations in the network.

[23] Since an average QoS is considered, different characteristics of the air (e.g. due to different whether conditions), that is the medium by which the mobile equipment of the end-user is connected with the wireless network, are not taken into account as it is required by Recital 13 of the EECC (see paragraph 7).

Annex 1: Articles and recitals of the EECC which refer to very high capacity networks

77. This Annex provides an overview of the articles and also of some recitals of the EECC where the term 'very high capacity networks' is used.

Art. 1

78. Art. 1 mentions as an aim of the directive to implement an internal market in electronic communications networks and services that results in the deployment and take-up of very high capacity networks, sustainable competition, interoperability of electronic communications services, accessibility, security of networks and services and end-user benefits.

Art. 2

79. Art. 2 defines the term very high capacity network as described in section 2.1.

80. Recital (13) provides further information on the definition of the term 'very high capacity networks' (see section 2.1).

Art. 3

81. Art. 3 mentions as an objective to promote connectivity and access to, and take-up of, very high capacity networks, including fixed, mobile and wireless networks, by all citizens and businesses of the Union.

82. Recital (24) further says that 'Progress towards the achievement of the general objectives of this Directive should be supported by a robust system of continuous assessment and benchmarking by the Commission of Member States with respect to the availability of very high capacity networks in all major socio-economic drivers such as schools, transport hubs and major providers of public services, and highly digitised businesses, the availability of uninterrupted 5G coverage for urban areas and major terrestrial transport paths, and the availability to all households in each Member State of electronic communications networks which are capable of providing at least 100 Mbps, and which are promptly upgradeable to gigabit speeds. […]'.

Art. 22

83. Geographical surveys of network deployments may include a forecast of the reach of very high capacity networks (Art. 22(1)).

84. Authorities may designate an area where no undertaking or public authority is planning to deploy a very high capacity network or significantly upgrade or extend its network to a performance of at least 100 Mbps download speeds. Authorities shall publish the designated areas. (Art. 22(2))

85. Authorities may invite undertakings and public authorities to declare their intention to deploy very high capacity networks in designated areas. Where this invitation results in a declaration by an undertaking or public authority of its intention to do so, the relevant authority may require other undertakings and public authorities to declare any intention

to deploy very high capacity networks, or significantly upgrade or extend its network to a performance of at least 100 Mbps download speeds in this area. (Art. 22(3))

86. Recital (62) provides the following information with regard to this. Such surveys should include '[…] both deployment of very high capacity networks, as well as significant upgrades or extensions of existing copper or other networks which might not match the performance characteristics of very high capacity networks in all respects, such as roll-out of fibre to the cabinet coupled with active technologies like vectoring.'

87. Recital (63) further says that: '[…] Where an undertaking or public authority declares an intention to deploy in an area, the national regulatory or other competent authority should be able to require other undertakings and public authorities to declare whether or not they intend to deploy very high capacity networks, or significantly upgrade or extend their network to a performance of at least 100 Mbps download speeds in this area. […]'

<u>Art 61</u>

88. NRAs shall not impose symmetrical obligations going beyond the first concentration point on a wholesale-only operator if it makes available a viable and similar alternative means of reaching end-users by providing access to a very high capacity network to any undertaking on fair, non-discriminatory and reasonable terms and conditions. NRAs may extend that exemption to other providers offering, on fair, non-discriminatory and reasonable terms and conditions, access to a very high capacity network. (Art. 61(3) in connection with Art. 80)

<u>Art 73</u>

89. When imposing obligations of access to, and use of, specific network elements and associated facilities, NRAs should take into account, amongst other factors, the risks involved in making the investment, with particular regard to investments in, and risk levels associated with, very high capacity networks. (Art. 73)

<u>Art 74</u>

90. In determining whether price control obligations would be appropriate, NRAs shall take into account the need to promote competition and long-term end-user interests related to the deployment and take-up of next-generation networks, and in particular of very high capacity networks. (Art. 74)

<u>Art 76</u>

91. Art. 76 deals with the regulatory treatment of new very high capacity network elements and foresees lighter regulation for new very high capacity networks that consists of optical fibre elements up to the end-user premises or base station under certain conditions related to co-investment.

92. It should be noted that while Article 76 carries the term very high capacity networks in its title the provision only applies to very high capacity networks that 'consist of optical fibre elements up to the end-user premises or base station' (Art. 76(1)). Networks which do not consist of optical fibre elements up to the end-user premises or base station, but which are nonetheless capable of delivering similar performances, would therefore not

be relevant for the provisions of Article 76. Therefore, the performance thresholds that the BEREC Guidelines set are not relevant for Art. 76.

<u>Art 105</u>

93. The maximum contractual commitment periods, which is limited to 24 months according to Art. 105(1) shall not apply to the duration of an instalment contract where the consumer has agreed in a separate contract to instalment payments exclusively for deployment of a physical connection, in particular to very high capacity networks according to Art. 105(2).

Annex 2: Questionnaires

94. This annex provides an overview of the questionnaires based on which data were collected from network operators (section 1), the number of completed questionnaires received (section 2) and information on the questionnaires for vendors (section 3).

1. Questionnaires for network operators

95. The determination of the performance thresholds 1 (see paragraph 12c) is based on fixed networks with fibre roll out up to the multi-dwelling building and on the in-building cable infrastructure the following technologies are considered (see paragraphs 21 and 28):

    a. G.fast on (usual) twisted pair;[24] and

    b. The most advanced DOCSIS technology (e.g. DOCSIS 3.1) on coax cable (shared medium).

96. The determination of the performance thresholds 2 (see paragraph 12d) is based on mobile networks with fibre roll out up to the base station (see paragraph 22) and LTE Advanced (4G) with carrier aggregation and MIMO[25], however, considers only carrier aggregation with the highest aggregated spectrum and MIMO with the highest number of parallel data streams deployed in a mobile network.

97. Therefore, data were collected based on the following questionnaires:[26]

    a. Questionnaire for fixed network operators with fibre to the building (FTTB) and G.fast on the in-building copper twisted pair (at least pilot/field trial);

    b. Questionnaire for operators of a hybrid fibre coax (HFC) network with fibre rolled out up to the building and DOCSIS on the in-building coax network; and

    c. Questionnaire for mobile network operators with LTE Advanced.

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[24] G.fast on in-building point-to-point coax cable has also been considered, however, this infrastructure is only very rarely deployed in Europe and no operator answered this questionnaire.

[25] Multiple-Input and Multiple-Output

[26] In addition, data were also collected based on two further questionnaires. (1) Questionnaire for fixed network operators with fibre to the building (FTTB) and G.fast on the in-building coax network (at least pilot/field trial). However, G.fast on in-building point-to-point coax cable is only very rarely deployed in Europe and no operator answered this questionnaire. (2) Questionnaire for operators of a hybrid fibre coax (HFC) network with fibre to the last amplifier (FTTLA) and DOCSIS on the coax network. The data collected with this questionnaire would have been used as an approximation for HFC networks with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network (questionnaire referred to in paragraph 96.b). However, since a sufficient high number of operators filled in the questionnaire referred to in paragraph 96.b, this was not necessary.

98. For reference purposes only, data were also collected with the following questionnaires:

a. Questionnaire for fixed network operators with fibre to the building (FTTB) and Ethernet on the in-building twisted pair cable of category 5 or higher (see annex 5, section 1); and

b. Questionnaire for fixed network operators with FTTH (see annex 5, section 2).

99. Information from these questionnaires is only used for reference purposes since Ethernet on the in-building twisted pair cable of category 5 or higher is only rarely available/used in most EU countries (see paragraphs 224 to 226) and FTTH is a stronger requirement for a very high capacity network than mentioned in the EECC (fibre to the multi dwelling building in case of fixed networks, see paragraph 15).

Main question

100. The questionnaires have all the same structure and they are fully analogous. The main question is 'What end-user QoS is achievable in your network based on fibre to the multi-dwelling building (in case of fixed networks) / base station (in case of mobile networks) … with regard to certain QoS parameters'. The only difference is that each questionnaire asked this question for a different network, the network considered by the questionnaire.

101. This main question needs to be answered for two different scenarios and under certain conditions. In case of scenario 1, the conditions are as follows:

a. Under usual peak-time conditions;

b. For the service with the highest data rate (down+up) as currently provided in the network (the network considered by the questionnaire);

c. The other services are provided with the same end-user QoS as it is currently the case;

d. Limitations of the end-user QoS caused by the CPE/ME[27] should not be taken into account; and

e. In case of mobile networks also: only consider the part of your mobile network with fibre to the base station, the highest aggregated spectrum (e.g. 60 MHz) and the highest number of parallel MIMO data streams (e.g. 4x4 MIMO).

In case of scenario 2, the conditions are the same except b which is:

f. For a service with the highest data rate possible based on the most advanced technology deployed (or at least in a field trial stage) in your network (the network considered by the questionnaire). This service is provided to the end-users which are currently subscribed to the service with the highest data rate from scenario 1.[28]

[27] CPE stands for customer premises equipment and ME for mobile equipment

[28] The end-users which use the service with the highest data rate (scenario 1) now get the service with the highest data rate possible (scenario 2) instead.

In case of LTE and scenario 2, condition e is the same, however, since also field trials are considered (see f above) it may refer to a different LTE technology, the LTE technology used in the field trial.

102. The network operators were asked to provide estimated values of the achievable end-user QoS in peak-time and to provide typical values (e.g. mean, range, no 'up to' values) since the end-user QoS depends on the circumstances of the individual end-users (e.g. the length of the access media, quality of the access media, interferences and noise). The network operators were asked to provide such values for certain QoS parameters (see section 4.5).

103. Altogether, the main question asked for the typically achievable data rate (and other QoS parameters) under the conditions mentioned above (paragraph 93) i.e. for the data rate (and other QoS parameters) which an end-user of the service with the highest data rate currently provided (scenario 1) or possible (scenario 2) will typically experience in peak-time,[29] if the CPE/ME fully supports the technology in the network (no limitations by CPE/ME).

104. The main difference between scenario 1 and 2 is as follows. Scenario 1 considers the service with the highest data rate (down+up) currently provided in the network. The operator may also test further developments of the access technology (e.g. the move from G.fast 106 MHz to G.fast 212 MHz or from DOCSIS 3.0 to DOCSIS 3.1) in a field trial or pilot deployment, then this would be the access technology considered in scenario 2 and the main question asks for an estimate of how the data rate (and the other QoS parameters) would change compared to scenario 1 (maintaining the other conditions e.g. peak-time, no limitation of the CPE/ME etc.).

Clarifications on the main question for mobile networks

105. The answers received from mobile network operators showed that the word 'achievable' and scenario 1 and scenario 2 in the main question were understood differently. Therefore, it was necessary to make the following clarifications.

a. The achievable data rate is the data rate which an end-user would measure with an internet speed test. The main question asks for the average value of this data rate during peak-time and over the whole coverage area of scenario 1 and 2 (see below). Therefore, this area includes not only locations near the base stations but also those locations further away (but still covered by the best LTE technology in terms of aggregated spectrum, MIMO order, modulation etc.). In addition, the conditions of the main question apply (see paragraph 93).

b. For example, if measurements from drive tests are available, for scenario 1 the answer to the main question would be an average of all measured speeds during peak time in the area with the best LTE technology.

[29] E.g. if he measures the speed with an internet speed test

c. The achievable data rate is not:
   (i) The data rate of the real traffic in the network which depends on how end-users use their service.
   (ii) The maximum possible (or maximum measured) data rate in a cell or a certain coverage area (e.g. end-user/mobile equipment near the base station).

d. Scenario 1 and scenario 2 were illustrated by means of an example as follows:
   (i) Scenario 1: In case in the current LTE network the highest aggregated spectrum is 50/20 MHz, the highest number of parallel MIMO data streams is 2x2/2x2 and the highest modulation 265/64 QAM and the product with the highest data rate is 500/50 Mbps, then this is scenario 1. Then the average value of the achievable data rate as defined above of this product (not other/all products) in the coverage area where 50/20 MHz, 2x2/2x2 MIMO and 256/64 QAM are available together shall be provided taking also into account the other conditions of the main question (see paragraph 93).
   (ii) Scenario 2: In case the same operator also has a field trial with an aggregated spectrum of 60/40 MHz, 4x4/2x2 MIMO and 265/64 QAM, then this is scenario 2. Then the answer to the main question would be an estimate of how the data rate (and the other QoS parameters) would change compared to scenario 1 (maintaining the other conditions e.g. peak-time, no limitation of the mobile equipment etc.) in the coverage area of this LTE technology (where CA 60/40 MHz, 4x4/2x2 MIMO and 256/64 QAM are available together).

Additional questions

106. The operators were also asked on which parameters their answers to the main question are based on. These additional questions depend on the technology considered and, therefore, differ slightly between the questionnaires. Examples are: on which access technology, which frequency spectrum, which modulation, which number of twisted pairs per end-user service (e.g. 1, 2-bonded), which number of end-users in the multi-dwelling building who share the same coax resources, which category of twisted pair cable.

107. The other additional questions mainly focus on the experience the network operator has with the access technology to which the main question refers to.

a. The status of the deployment (field trial, pilot deployment, regular operation);

b. Since when the technology has been deployed in the network;

c. The number of end-users who are currently provided with services based on the technology (in case of fixed networks); and

d. The number of base stations which are currently connected with fibre and equipped with the technology (in case of mobile networks).

2. Number of completed questionnaires

108. Table 1 provides an overview of the number of questionnaires received per type of questionnaire. Operators filled in 150 questionnaires for fixed networks and 86 (57%) of

them were taken into account in the analysis. The questionnaire for mobile network operators was completed by 54 operators. They understood the main question differently and an email with clarifications was sent to them (see paragraph 97). 32 (59%) operators responded to this email and the questionnaires of 20 (63%) of them were taken into account in the analysis.

Table 1: Number of completed questionnaires per type of questionnaire

Type of questionnaire	Total	Taken into account
Fixed network with fibre to the multi-dwelling building and G.fast on the in-building copper twisted pair	9	8
Hybrid fibre coax (HFC) network with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network	25	19
Fixed network with fibre to the multi-dwelling building and Ethernet on the in-building twisted pair cable (Cat. 5 or higher)	41	33
Questionnaire for fixed network operators with FTTH	75	26
Mobile network with LTE Advanced	54/32	20
Total	204/182	106

Source: BEREC

109. 64 questionnaires for fixed network operators were not taken into account for the following reasons:

a. In case of both scenarios, not a more advanced technology but instead “old” technology is used (e.g. DOCSIS 1.1 and not at least DOCSIS 3.0);

b. Operator provided data for a technology which has never been deployed in its network, neither field trail, nor pilot deployment nor regular operation;

c. In case of both scenarios, the main question has not been answered with regard to the achievable data rate or the achievable data rate is obviously implausible[30]

d. The answers inform that they do not fulfil the conditions of question 2 (see paragraph 93);

e. The main question has been answered for scenario 1 only and not for scenario 2; and

f. The answers are unclear.

110. 22 questionnaires for mobile network operators were not taken into account since these operators did not respond to the email with the clarifications (see paragraph 97)

[30] In case of two questionnaire responses, the achievable data rate of both scenarios is solely 1.2/0.2 Mbps or 1.14/0.11 Mbps. In the case of responses to the FTTH questionnaire and PON, the typically achievable data rate is higher or close to the total data rate (capacity) of the PON technology.

and, therefore, it is unclear whether they understood and answered the main question correctly.

111. 12 questionnaires for mobile network operators were not taken into account although they responded to the email with the clarifications for the following reasons:

a. The answers inform that they do not fulfil the conditions of question 2 (see paragraph 93);

b. The main question has only been answered partly for scenario 1 and not for scenario 2; and

c. The operator informed that the data refer to sites with specific conditions and, therefore, the data is not representative.

112. Table 2 provides an overview of the number of completed fixed network questionnaires received per country. 150 fixed network questionnaires have been filled in by operators of 26 European countries and 86 questionnaires of operators of 21 European countries have been taken into account in the analysis.

Table 2: Number of completed fixed network questionnaires per country (taken into account/total)

Country	Questionnaire	Country	Questionnaire	Country	Questionnaire
Austria	2/3	Finland	5/6	Norway	4/6
Belgium	2/4	Greece	0/4	Poland	2/7
Bulgaria	11/17 (7/7)*	Hungary	4/5	Portugal	0/3
Croatia	3/7	Ireland	-	Romania	2/2
Cyprus	2/4	Italy	0/4	Spain	0/3
Czech Republic	5/7	Latvia	7/9 (6/7)*	Sweden	-
Germany	9/15	Lithuania	1/2	Switzerland	1/1
Denmark	7/12	Luxembourg	-	Slovenia	3/5
Estonia	2/4	Malta	-	Slovakia	12/16 (4/7)*
France	0/1	Netherlands	1/1	United Kingdom	1/2

* Figures for questionnaire Ethernet on in-building twisted pair cable of category 5 or higher
Source: BEREC

113. Bulgaria, Latvia and Slovakia are represented rather strongly. However, this is limited to only one questionnaire, the questionnaire with regard to Ethernet on the in-building twisted pair cable of category 5 or higher. 41 operators completed this questionnaire and 21 (51%) of them were operators from Bulgaria (7), Latvia (7) and Slovakia (7). This technology and in-building infrastructure is not very common in the EU, however, these three countries may be an exception.

114. Table 3 provides an overview of the number of completed questionnaires for mobile network operators received per country.

115. The mobile network questionnaire has been filled in by 54 operators of 24 European countries, 32 operators of 19 European countries responded to the clarifications and the

questionnaires of 20 operators of 13 European countries have been taken into account in the analysis.

Table 3: Number of completed questionnaires for mobile network operators per country (taken into account/total[31])

Country	Questionnaire	Country	Questionnaire	Country	Questionnaire
Austria	2/3	Finland	0/1	Norway	1/2
Belgium		Greece	1/2	Poland	
Bulgaria	0/1	Hungary	1/1	Portugal	1/2
Croatia	1/2	Ireland		Romania	2/2
Cyprus		Italy		Spain	1/2
Czech Republic	0/1	Latvia	1/1	Sweden	
Germany		Lithuania	0/1	Switzerland	
Denmark	3/3	Luxembourg		Slovenia	3/3
Estonia	0/1	Malta		Slovakia	2/2
France	1/1	Netherlands	0/1	United Kingdom	

Source: BEREC

3. Questionnaires for vendors

116. Vendors do not operate networks and do not offer electronic communications services, therefore, it is not possible to ask vendors also the main question that the network operators were asked (see paragraphs 92 to 97). For this reason, the questionnaires for vendors focus on general information and on the access network. The information from the vendors is used to better understand the answers from the network operators, however, the determination of the performance thresholds 1 and 2 is not directly based on the answers from the vendors.

117. Information were collected from vendors based on the following questionnaires:

a. Questionnaire for vendors of equipment for fixed networks with G.fast;

b. Questionnaire for vendors of equipment for hybrid fibre coax networks; and

c. Questionnaire for vendors of equipment for mobile networks.

118. The questionnaire for vendors of equipment for fixed networks with G.fast was filled in partly by two vendors. A further vendor filled in this questionnaire partly, however, it recommends BEREC not to set the guidelines based on the measurement information it provided.

[31] The total number of completed questionnaires refer to the questionnaires that operators filled in and where they also responded to the email with clarifications (see paragraph 107).

119. The questionnaire for vendors of equipment for hybrid fibre coax networks was filled in by one vendor and partly by another vendor. Another vendor did not answer the questions but provided some basic information on hybrid coax networks.

120. The questionnaire for vendors of equipment for mobile networks was filled in by one vendor and partly by another vendor.

Annex 3: Determination of performance thresholds 1 (fixed networks)

121. This annex determines the performance thresholds 1 (see paragraph 14a) based on the data collected from fixed network operators (see annex 2).

122. For the determination of the performance thresholds 1, fixed networks with fibre roll out up to the multi-dwelling building, in-building copper and coax access (see paragraph 21) and the use of the following access technologies are considered (see paragraphs 28a and 28b).

a. G.fast on (usual) twisted pair; and

b. Most advanced DOCSIS technology (e.g. DOCSIS 3.1) on coax;

123. The performance thresholds 1 are set for the following QoS parameters (see section 4.5):

a. Downlink data rate (Mbps);

b. Uplink data rate (Mbps);

c. IP packet error ratio (Y.1540) (%);

d. IP packet loss ratio (Y.1540) (%);

e. Round-trip IP packet delay (RFC 2681) (ms);

f. IP packet delay variation (RFC 3393) (ms); and

g. IP service availability (Y.1540) (% per year).

124. The performance thresholds 1 need to consider the end-user QoS which is achievable and not the end-user QoS which is currently achieved (see paragraph 14a). Therefore, the determination of the performance thresholds 1 focuses on scenario 2 (not scenario 1) of the main question in the questionnaires (see paragraphs 93 and 96).

125. BEREC received answers to the relevant questionnaires from several operators and therefore a range of values for each of the QoS parameters a.-g. mentioned above. Since the performance thresholds should reflect parameters which are typically achievable, the median of these values is used as a basis to determine the performance thresholds 1. The median is more appropriate than the arithmetic average since it is more robust against outliers. The maximum is not used, since this may only be achievable under exceptional circumstances and therefore does not reflect typically achievable values.

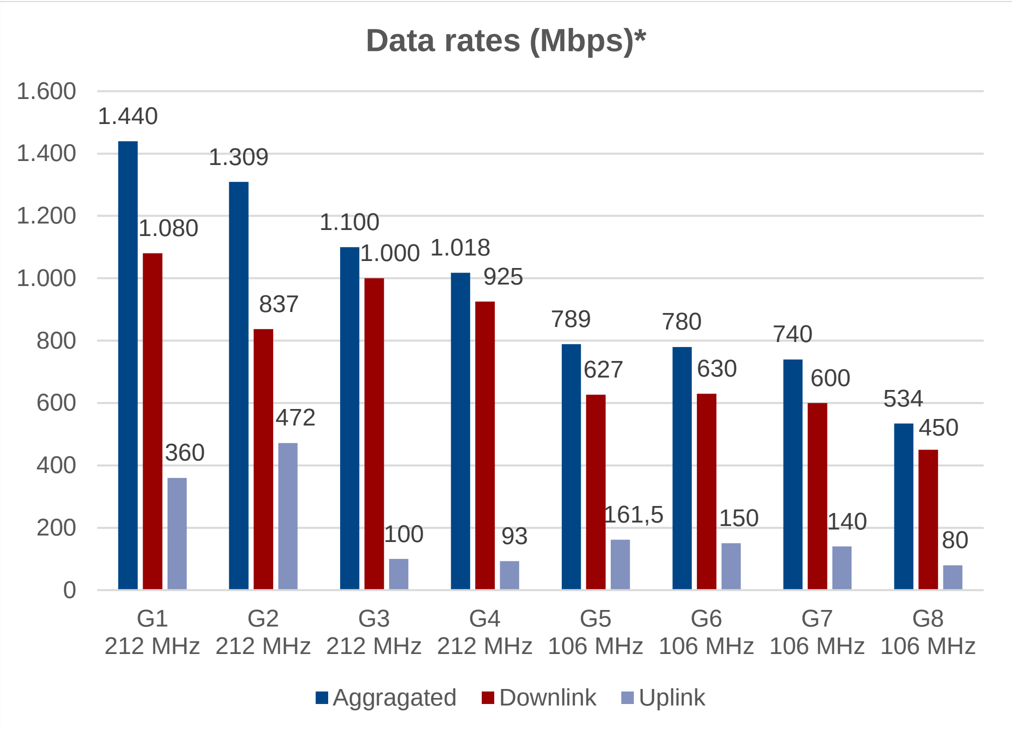
1. Downlink and uplink data rate

126. This section determines the threshold downlink data rate and the threshold uplink data rate of the performance thresholds 1 based on fixed networks with fibre roll-out up to the multi-dwelling building and the two access technologies considered (see paragraph 114).

a. Fixed networks with fibre to the multi-dwelling building and G.fast on the in-building copper twisted pair

127. Figure 1 shows the typically achievable data rates in fixed networks based on fibre to the multi-dwelling building with G.fast deployment on the in-building twisted pair and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers received from eight operators. Since the achievable data rates are considered, it is assumed that G.fast uses the full spectrum (i.e. also the VDSL spectrum) starting with 2.2 MHz. The data rates shown are data rates at the level of the IP packet payload (see paragraph 38).

128. These are data rates which an end-user will typically experience during peak-time if his CPE fully supports the G.fast technology of the network (see paragraph 95). Four of these eight operators use the frequency spectrum up to 212 MHz, the other four up to 106 MHz.



*) Of the IP packet payload
Note: The start frequency of both profiles, 212 MHz and 106 MHz, is 2.2 MHz (except operator G3 17.8 MHz)
Source: BEREC

Figure 1: Typically achievable data rates during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast deployment on the in-building twisted pair

129. In case of G.fast, the aggregated data rate (i.e. the sum of downlink and uplink data rate) is relevant, since the downlink and uplink data rates are configurable but the sum of both must not exceed the aggregated data rate.

130. Figure 1 shows that the typically achievable aggregated data rates during peak-time are clearly higher in case of the use of the 212 MHz profile compared to the use of the 106 MHz profile.

131. Since the performance thresholds 1 have to be based on the 'best' technology with regard to the achievable data rate (see paragraph 23), only the data rates provided for G.fast with 212 MHz are relevant for the determination of the performance thresholds 1.

132. In case of G.fast 212 MHz (start frequency 2.2 MHz) the typically achievable aggregated data rates during peak-time are between 1,018 Mbps and 1,440 Mbps according to information provided by four operators. In three cases, this information is based on experiences from field trials. One operator (G3) already offers a product based on G.fast 212 MHz. Operator G5 expects that products with 1,000/200 Mbps will be possible based on G.fast 212 MHz according to his experiences with this technology in a lab environment (it has not yet implemented it in field trial).

133. At the time of the data collection, most operators only had field trials or experiences from lab tests with G.fast 212 MHz but this is likely to change during the period in which the guidelines are applicable.

134. The data provided by vendors are similar:

   a. One vendor (V1) informed about an aggregated line data rate of 1,600 Mbps measured in a lab environment under certain conditions[32] with G.fast 212 MHz (start frequency 2.2 MHz) and on general target values for G.fast 212 MHz (start frequency 2.2 MHz) based on common network operator requirements of 1,000/250 Mbps (down/up).[33]

   b. Another vendor (V2) measured an aggregated line data rate of 1,328 Mbps (1,060 Mbps down, 268 Mbps up) in case of G.fast 212 MHz in a test based on a certain twisted pair cable.[34]

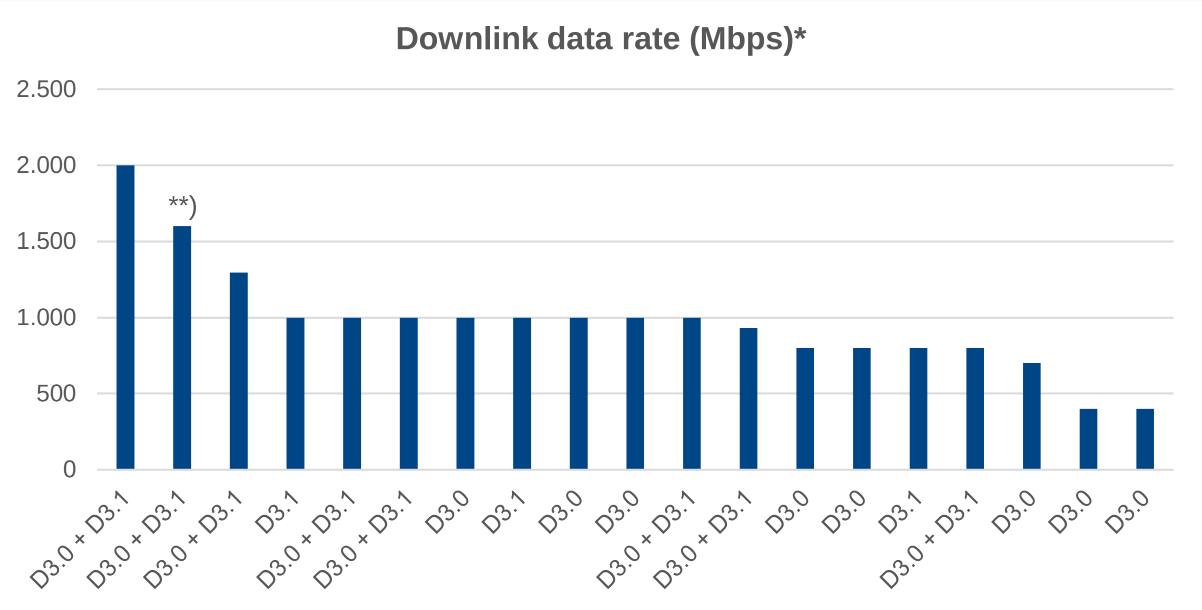
135. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 117) and the median of the typically achievable aggregated data rate of the four operators with G.fast 212 MHz is 1,200 Mbps. The downlink and uplink data rate are configurable (see paragraph 121) and therefore e.g. 1,000 Mbps in downlink and 200 Mbps in uplink.

[32] Star quad cable, diameter 0.5 mm, length 100 m, 3 dB margin
[33] No further information was provided on these target values and the common network requirements.
[34] 200 pairs cable of a certain network operator, diameter 0.5 mm and length 100 m

b. Hybrid fibre coax (HFC) networks with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network

Downlink data rate

136. Figure 2 and Table 4 show the typically achievable downlink data rates during peak-time in a hybrid fibre coax (HFC) network with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers received from 19 operators. The data rates shown are data rates at the level of the IP packet payload (see paragraph 38).



*) Of the IP packet payload
**) 1,600 Mbps in two years based on engineering estimation, 800 Mbps on current field trial
Source: BEREC

Figure 2: Typically achievable downlink data rate during peak-time in HFC networks with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network

137. These are data rates, which an end-user will typically experience during peak-time if his CPE fully supports the DOCSIS technology of the network (see paragraph 95). In downstream direction, 11 operators use DOCSIS 3.1, eight of them together[35] with DOCSIS 3.0, and eight operators use only DOSICS 3.0.

138. DOCSIS 3.1 is a further development of the DOCSIS technology and designed to provide higher data rates compared to DOCSIS 3.0. Since the performance thresholds 1 have to be based on the 'best' technology with regard to the achievable data rate (see

[35] For example, both DOCSIS 3.1 and DOCSIS 3.0 are used to provide a service (channel bonding).

paragraph 23), only the data rates provided for DOCSIS 3.1 are relevant for the determination of the performance thresholds 1.

139. The typically achievable data rate during peak-time depends not only on the DOCSIS technology but in addition on many other parameters, for example, the spectrum used for DOCSIS, the size of the coax network in terms of connected end-users, the services to the end-users have subscribed to, the user behaviour in terms of how intense the end-users use their services and to what extent they use their services simultaneously in peak-time. Therefore, some variation in the data rates can be expected and is plausible.

140. The typically achievable downlink data rate during peak-time of the 11 operators who uses DOCSIS 3.1 (some of them together with DOCSIS 3.0) is between 800 Mbps and 2,000 Mbps.

141. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 124) and the median of the typically achievable downlink data rate of the 11 operators who uses DOCSIS 3.1 is 1,000 Mbps.

Table 4: Typically achievable data rate during peak-time in HFC networks with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network

Op.	**Data rate (Mbps)**		**DOCSIS**		**Op.**	**Data rate (Mbps)**		**DOCSIS**	
	Down	**Up**	**Down**	**Up**		**Down**	**Up**	**Down**	**Up**
D1	2,000	750	D3.0 + D3.1	D3.0 + D3.1	D11	1,000	50	D3.0 + D3.1	D3.0
D2	1,600**)	50	D3.0 + D3.1	D3.0	D12	930	50	D3.0 + D3.1	D3.0
D3	1,295	185	D3.0 + D3.1	D3.0 + D3.1	D13	800	100	D3.0	D3.0
D4	1,000	22-200	D3.1	D3.1	D14	800	100	D3.0	D3.0
D5	1,000	100-150	D3.0 + D3.1	D3.0 + D3.1	D15	800	35	D3.1	D3.0
D6	1,000	500	D3.0 + D3.1	D3.0 + D3.1	D16	800	30	D3.0 + D3.1	D3.0
D7	1,000	200	D3.0	D3.0	D17	700	120	D3.0	D3.0
D8	1000	100	D3.1	D3.1	D18	400	200	D3.0	D3.0
D9	1000	50	D3.0	D3.0	D19	400	120	D3.0	D3.0
D10	1000	50	D3.0	D3.0					

*) Of the IP packet payload, **) 1,600 Mbps in two years based on engineering estimation, 800 Mbps on current field trial
Source: BEREC

142. Table 5 shows the total downlink capacity of a coax network based on DOCSIS 3.1 and DOCSIS 3.0, according to information from vendors. The total downlink capacity is shared by all end-users in the multi-dwelling building who share the same coax resources. The typically achievable data rate of the product with the highest data rate is therefore significantly lower (e.g. approximately the half). This shows that the data of the vendors correspond largely with the data of the network operators.

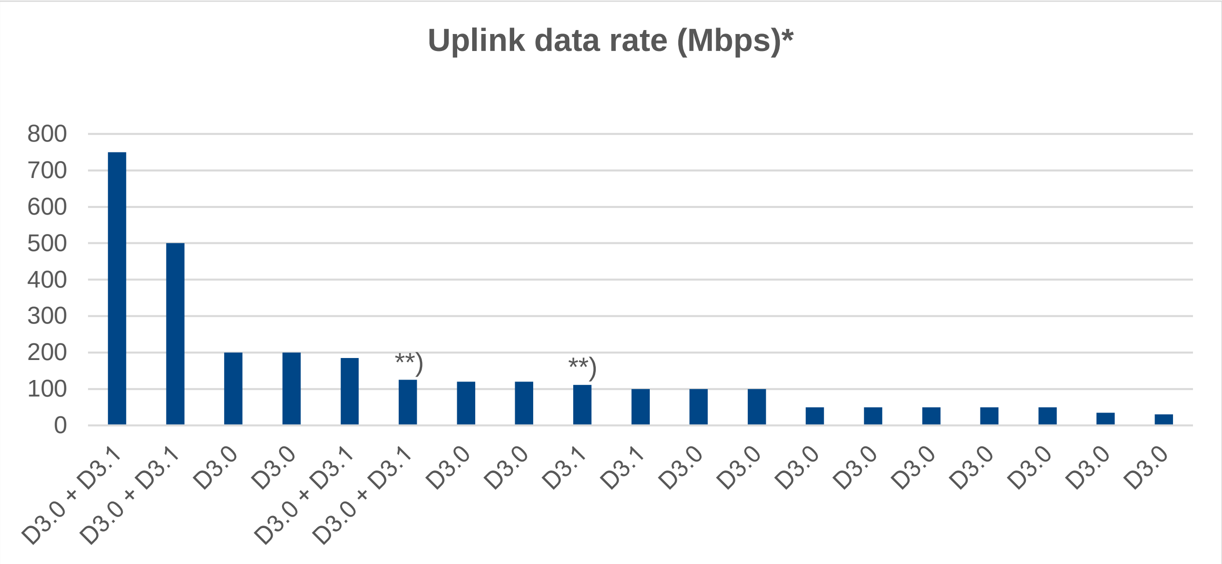
Table 5: Total downlink capacity of a coax network based on DOCSIS 3.0 and DOCSIS 3.1

DOCSIS	DOCSIS spectrum	Total downlink capacity (Mbps)	Vendor
DOCSIS 3.0	24 channels each 8 MHz = 192 MHz	1,200	V3
DOCSIS 3.0	32 channels each 8 MHz = 256 MHz	1,400	V4
		1,600	V2, V3
DOCSIS 3.1	1 OFDM channel with 192 MHz	1,800	V3
DOCSIS 3.1	2 OFDM channels each 192 MHz = 384 MHz	3,100	V4
		3,600	V2, V3

Source: BEREC

Uplink data rate

143. Figure 3 and Table 4 show the typically achievable uplink data rates during peak-time in a hybrid fibre coax (HFC) network with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers received from the same 19 operators. The data rates shown are also data rates at the level of the IP packet payload (see paragraph 38).



*) Of the IP packet payload, **) range (see Table 4)
Source: BEREC

Figure 3: Typically achievable uplink data rate during peak-time in HFC networks with fibre rolled out up to the multi-dwelling building and DOCSIS on the in-building coax network

144. These are also data rates, which an end-user will typically experience during peak-time if his CPE fully supports the DOCSIS technology of the network (see paragraph 95). In upstream direction, six operators use DOCSIS 3.1, four of them together[36] with DOCSIS 3.0, and 13 operators use only DOSICS 3.0.

145. For the determination of the performance thresholds 1, only the data rates provided for DOCSIS 3.1 are relevant (see paragraph 130) and some variation in the data rates can be expected and is plausible (see paragraph 131).

146. The typically achievable uplink data rate during peak-time of the six operators who uses DOCSIS 3.1 (some of them together with DOCSIS 3.0) in uplink direction is between 100 Mbps and 750 Mbps.

147. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 117) and the median of the typically achievable uplink data rate is 160 Mbps.

148. Table 6 shows the total uplink capacity of a coax network based on DOCSIS 3.1 and DOCSIS 3.0, according to information from vendors. The total uplink capacity is shared by all end-users in the multi-dwelling building who share the same coax resources. The typically achievable data rate of the product with the highest data rate is significantly lower (e.g. approximately the half) since it is shared between the end-users in the multi-dwelling building who share the same coax resources (see paragraph 134). Therefore, the data of the vendors correspond largely with the data of the network operators.

Table 6: Total uplink capacity of a coax network based on DOCSIS 3.0 and DOCSIS 3.1

DOCSIS	DOCSIS spectrum	Total uplink capacity (Mbps)	Vendor
DOCSIS 3.0	4 channels each 6.4 MHz = 25.6 MHz	120	V2, V3
DOCSIS 3.0	8 channels each 6.4 MHz = 51.2 MHz	240	V3
DOCSIS 3.1	48 MHz	360	V3
DOCSIS 3.1	2*92 MHz = 184 MHz	1,200	V2
DOCSIS 3.1	192 MHz	1,440	V3

Source: BEREC

c. Determination of the threshold data rates of the performance thresholds 1

149. The performance thresholds 1 need to be based on the ‘best’ technology with regard to the achievable end-user QoS with a focus as much as possible on technologies which will be deployed in networks from 2021 onwards when these Guidelines will be in force (see paragraphs 23 and 24).

[36] For example, both DOCSIS 3.1 and DOCSIS 3.0 are used to provide a service (channel bonding).

150. Therefore, for the determination of the threshold data rates of performance thresholds 1 the following technologies are considered:

a. G.fast 212 MHz on in-building twisted pair (see paragraph 122); and

b. DOCSIS 3.1 on in-building coax network (see paragraph 130).

151. In case of G.fast 212 MHz, the typically achievable aggregated data rate during peak-time relevant for the determination of performance thresholds 1 is 1,200 Mbps (see paragraph 127). In case of DOCSIS 3.1, the typically achievable downlink and uplink data rate during peak-time relevant for the determination of performance thresholds 1 is 1,000 Mbps in downlink and 160 Mbps in uplink (see paragraphs 133 and 139), i.e. an aggregated data rate of 1,160 Mbps.

152. The aggregated data rate of performance thresholds 1 need to be based on the *achievable* aggregated data rate (see paragraph 14a) and, therefore, on G.fast 212 MHz where the aggregated data rate is slightly higher compared to DOCSIS 3.1. For this reason, the threshold aggregated data rate of performance thresholds 1 is set to 1,200 Mbps.

153. In case of G.fast, downlink and uplink data rate are configurable as long as the sum do not exceed the aggregated data rate (see paragraph 121). In case of most operators of G.fast 212 MHz and also in case of many operators of DOCSIS 3.1, the typically achievable downlink data rate during peak-time is 1,000 Mbps. Therefore, **the threshold downlink data rate of performance thresholds 1 is set to 1,000 Mbps and the threshold uplink data rate of performance thresholds 1 is set to 200 Mbps.**

154. The threshold data rates are data rates at the level of the IP packet payload (see paragraphs 34 to 38) and at the point where the fixed subscriber access line (e.g. twisted pair, coax cable) ends in the end-user's living space.

155. Fixed networks with fibre to the multi-dwelling building and G.fast 212 MHz on the in-building twisted pair or DOCSIS 3.1 on the in-building coax network qualify as a very high capacity network since fibre is rolled out up to the multi-dwelling building (see paragraph 6) and do not need to meet the threshold data rates of performance thresholds 1.

2. Other QoS parameters

156. This section determines the thresholds of the other QoS parameters of the performance thresholds 1 (see paragraphs 115.c to 115.g).

157. The threshold aggregated data rate of performance thresholds 1 (1,200 Mbps) is defined based on G.fast 212 MHz (see paragraph 144). Only very few G.fast 212 MHz operators, if any, provided data for the other QoS parameters.

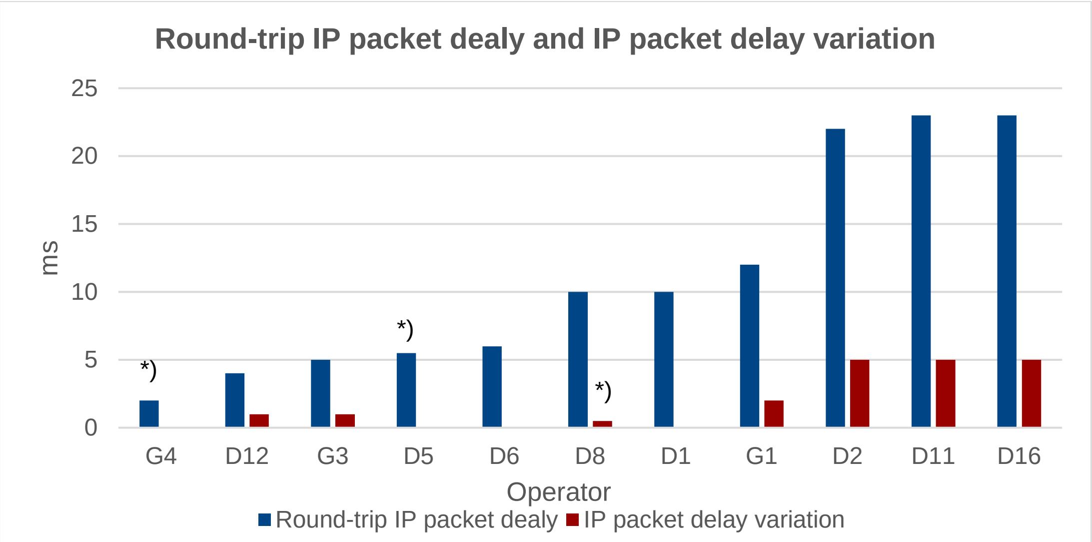
158. The aggregated data rate of DOCSIS 3.1 relevant for the determination of performance thresholds 1 (1,160 Mbps) is only slightly lower (see paragraph 143). Therefore, in order to broaden the data basis, the other QoS parameters of performance thresholds 1 are defined based on both G.fast 212 MHz and DOCSIS 3.1.

159. Not all network operators who provided data for the data rates were able to provide also data for the other QoS parameters. In response to the first phase of the call for initial stakeholder input (see paragraphs 47 and 49), network operators informed that they provide services to end-users without any service level agreement (SLA) and, therefore, do not monitor and have data for other QoS parameters. However, the EECC demands that the Guidelines define also thresholds for other QoS parameters (see paragraphs 1 and 6). In order to enable as much operators as possible to provide data for the other QoS parameters, the final questionnaires foresee also the possibility to provide estimated values of the QoS parameters.

160. All QoS parameters analysed in this section refer to the path from the end-user to the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point) and in case of round-trip parameters back to the end-user (see paragraph 46).

a. Round-trip IP packet delay and IP packet delay variation

161. Figure 4 and Table 7 show the typically achievable round-trip IP packet delay and IP packet delay variation during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers received from 11.



*) Range (see Table 7)
Source: BEREC

Figure 4: Typically achievable round-trip IP packet delay and IP packet delay variation during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

162. The round-trip IP packet delay is mainly caused by the time the nodes on the path need to process the data flow (node processing and queuing delay) and the time the transmission of the data needs from one node to the next node (propagation delay).[37] The processing of the data flow is e.g. access network specific in case of the access node (DPU in case of G.fast, CMTS in case of DOCSIS) and the common data flow forwarding in case of e.g. Ethernet switches and IP routers.

163. Therefore, the round-trip IP packet delay depends on the dimensioning of the network nodes and on the distance the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraph 152). For these reasons, some variation in the IP packet delay can be expected and is plausible.

164. For a distance of 100 km the transmission of the data needs approximately 0.5 ms and, therefore, the round-trip IP packet delay increases with every 100 km by approximately 1 ms.[38]

Table 7: Typically achievable round-trip IP packet delay and IP packet delay variation during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

Operator	Round-trip IP packet delay (RFC 2681) (ms)	IP packet delay variation (RFC 3393) (ms)
G4	<4	No information
D12	4	1
G3	5	1
D5	1-10	No information
D6	6	No information
D8	10	<1
D1	10	No information
G1	12	2
D2	22	5
D11	23	5
D16	23	5
Median	*10*	*2*

Source: BEREC

165. The IP packet delay variation is a measure for the variation of the IP packet delay and is mainly caused by the processing of the data flow in the network nodes (node processing and queuing delay) and, therefore, depends also on the dimensioning of the network nodes.

[37] See ITU-T Y.2617 (06/2016), section 6.1, p. 3. A further type of delay, the so-called serialisation delay, is in case of high data rates negligible. For example, in case a standard Ethernet frame (size 1,526 byte) is transmitted with a data rate of 1 Gbps this type of delay is solely 0.012 ms.

[38] See http://www.m2optics.com/blog/bid/70587/Calculating-Optical-Fiber-Latency

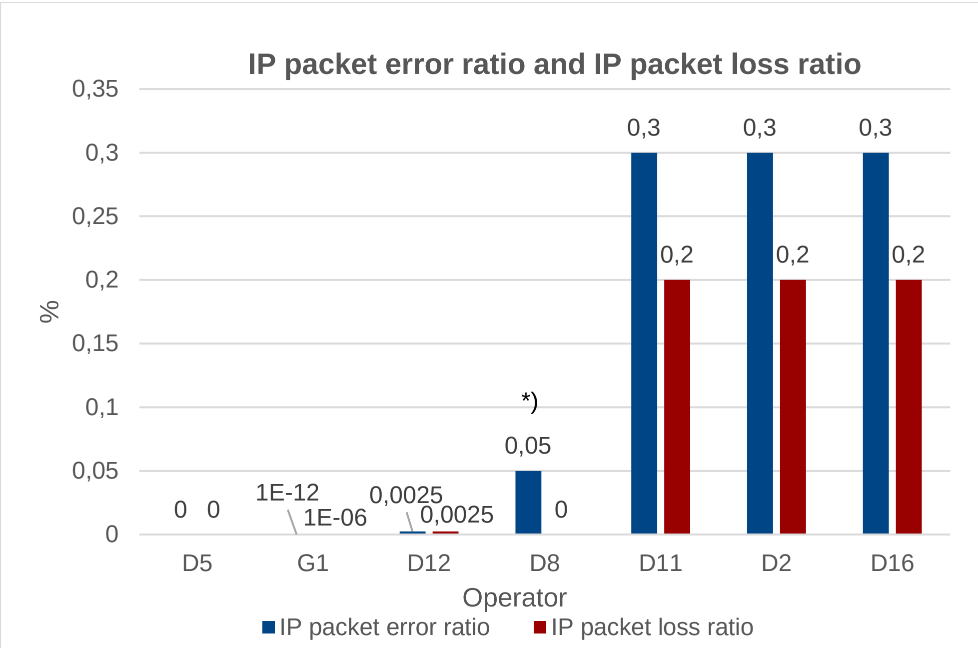
166. The typically achievable round-trip IP packet delay varies between less than 4 ms and up to 23 ms and the median is 10 ms. The typically achievable IP packet delay variation varies between less than 1 ms and up to 5 ms and the median is 2 ms.

167. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 117). Therefore, **the threshold round-trip IP packet delay of the performance thresholds 1 is set to 10 ms and the threshold IP packet delay variation to 2 ms.**

168. In case of particular long distances (e.g. several hundred kilometres) between the end-user and the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point), the threshold round-trip IP packet delay increases for every 100 km by 1 ms (see paragraph 156).

b. IP packet error ratio and IP packet loss ratio

169. Figure 5 and Table 8 show the typically achievable IP packet error ratio and IP packet loss ratio during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers of seven operators.



*) Range (see Table 8)
Source: BEREC

Figure 5: Typically achievable IP packet error ratio and IP packet loss ratio during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

170. IP packets may get lost in the queuing and the processing of the data flow in the network nodes. This processing and also the transmission of IP packets may also result in IP packet errors. The IP packet loss ratio, i.e. the ratio of the lost IP packets to the

transmitted IP packets, therefore depends on the dimensioning of the network nodes and the IP packet error ratio, i.e. the ratio of the errored IP packets to the sum of error-free and errored IP packets, on the processing and transmission quality.

171. For these reasons, some variation in the IP packet loss ratio and the IP packet error ratio can be expected and is plausible.

172. The typically achievable IP packet error ratio varies between 0%[39] and 0.3% and the median is 0.05%. The typically achievable IP packet loss ratio varies between 0% and 0.2% and the median is 0.0025%.

Table 8: Typically achievable IP packet error ratio and IP packet loss ratio during peak-time in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

Operator	IP packet error ratio (Y.1540) (%)	IP packet loss ratio (Y.1540) (%)
D5	0[39]	0[39]
G1	10E-12	10E-6
D12	0.0025	0.0025
D8	<0.1	0[39]
D11	0.3	0.2
D2	0.3	0.2
D16	0.3	0.2
Median	*0.05*	*0.0025*

Source: BEREC

173. With regard to the coax-based access network, the IP packet error ratio and the IP packet loss ratio seem to be rather low, according to the following information from vendors.

(i) One vendor (V4) informed that most operators typically operate their DOCSIS networks above the error-generation region. This, coupled with forward error correction capabilities built into DOCSIS 3.0 and DOCSIS 3.1, typically mean that there are normally no detectable errors for normal operation, especially at typical traffic channel loading levels at which most HFC network providers operate.

(ii) The lowest typically achievable IP packet error ratio during peak-time is according to two vendors (V2, V3) less than 10E-6 % and the lowest typically achievable IP packet loss ratio during peak-time is less than 10E-6 % according to one vendor (V2) and less than 10E-3 % according to another vendor (V3).

[39] Estimations of the achievable IP packet error ration and IP packet loss ratio were possible (see paragraph 151) and a value of 0% maybe be an estimation for a value very close to 0%.

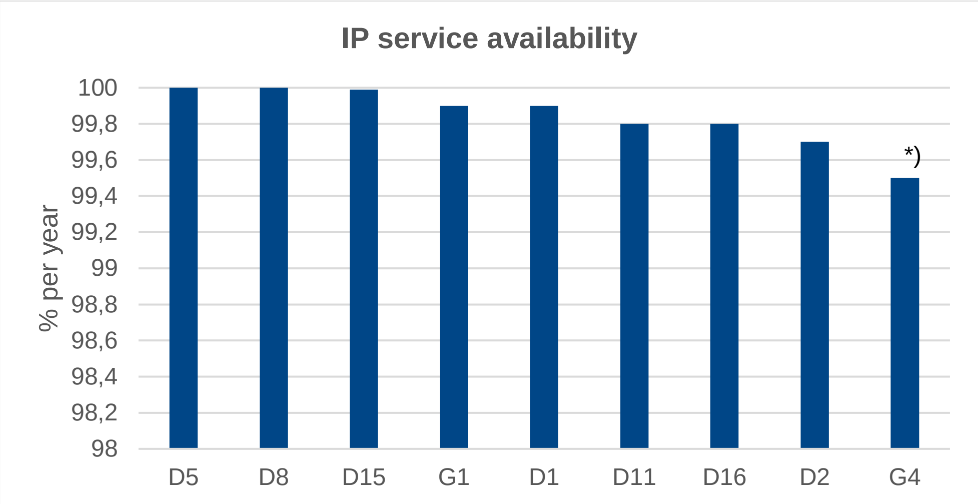
174. One vendor (V2) provided measurement data for the IP packet error ratio and the IP packet loss ratio on the G.fast 212 MHz access network based on a certain type of twisted pair cable.[40] According to these measurements, the IP packet error ratio and the IP packet loss ratio during peak-time is 10E-5 %.

175. This shows that the access network does not necessarily contribute strongly to the IP packet error ratio and IP packet loss ratio reported by the network operators which refer not only to the access network but instead to the path from the end-user to the first point in the network where the end-user traffic is handed over to other public networks (see paragraphs 46 and 152).

176. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 117, Table 8). Therefore, **the threshold IP packet error ratio of the performance thresholds 1 is set to 0.05% and the threshold IP packet loss ratio to 0.0025%.**

c. IP service availability

177. Figure 6 and Table 9 show the typically achievable IP service availability in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 116) based on the answers received from nine operators.



*) Range (see Table 9)
Source: BEREC

Figure 6: Typically achievable IP service availability in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

[40] 200 pairs cable, diameter 0.5 mm, length 100 m

178. The typically achievable IP service availability (i.e. the ratio of the time when the IP service is available to the total scheduled IP service time), varies between higher than 99% and 100%[41] per year and the median is 99.9% per year.

179. One vendor (V3) provided the information that in the coax access network based on DOCSIS 3.1 and DOCSIS 3.0 the highest typically achievable IP service availability is 99.99% per year. This shows that also in case of the IP service availability, the access network does not necessarily contribute strongly to the values reported by the network operators which refer not only to the access network but instead to the path from the end-user to the point in the network where the end-user traffic is handed over to other public networks (see paragraphs 46 and 152).

Table 9: Typically achievable IP service availability in fixed networks based on fibre to the multi-dwelling building with G.fast 212 MHz or DOCSIS 3.1 on the in-building infrastructure

Operator	IP service availability (Y.1540) (% per year)
D5	100[41]
D8	100[41]
D15	99.99
G1	99.9
D1	99.9
D11	99.8
D16	99.8
D2	99.7
G4	>99
Median	*99.9*

Source: BEREC

180. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 117, Table 9). Therefore, **the threshold IP service availability of the performance thresholds 1 is set to 99.9% per year.**

[41] Estimations of the achievable IP service availability were possible (see paragraph 150) and a value of 100% maybe be an estimation for a value very close to 100%.

Annex 4: Determination of performance thresholds 2 (wireless networks)

181. This annex determines the performance thresholds 2 (see paragraph 14b) based on the data collected from mobile network operators (see annex 2).

182. The determination of the performance thresholds 2 is based on mobile networks with fibre roll out up to the base station (see paragraph 22) and the use of LTE Advanced (4G) with carrier aggregation and MIMO with a focus on the carrier aggregation with the highest aggregated spectrum and MIMO with the highest number of parallel data streams (see paragraph 28c).

183. The performance thresholds 2 are as the performance thresholds 1 set for the following QoS parameters (see section 4.5):

a. Downlink data rate (Mbps);

b. Uplink data rate (Mbps);

c. IP packet error ratio (Y.1540) (%);

d. IP packet loss ratio (Y.1540) (%);

e. Round-trip IP packet delay (RFC 2681) (ms);

f. IP packet delay variation (RFC 3393) (ms); and

g. IP service availability (Y.1540) (% per year).

184. The performance thresholds 2 need to consider the end-user QoS which is achievable and not the end-user QoS which is currently achieved (see paragraph 14b). Therefore, the determination of the performance thresholds 2 focuses on scenario 2 (not scenario 1) of the main question in the questionnaires (see paragraphs 93 and 97).

185. The determination of the performance thresholds 2 need to be focused as much as possible on technologies which will be deployed in networks from 2021 onwards when these Guidelines will be in force (see paragraphs 24). 5G will be deployed after these Guidelines enter into force and is designed to provide higher data rates than 4G. Therefore, the determination of the threshold data rates of the performance thresholds 2 is based on the highest values (90% percentile) of the data rates reported by the network operators (see paragraph 29) and not on the mean value (median).

186. The standardisation of 5G also works on low latency and high-reliability communication, but in this case the data rates are significantly lower.[42] The threshold round-trip IP

[42] See e.g. 3GPP TS 22.261 V16.4.0 (2018-06) p. 33-35, 3GPP TS 22.289 V16.1.0 (2019-03), 3GPP TS 22.186 V16.2.0 (2019-06), and 3GPP TS 22.104 V17.1.0 (2019-09). In a few cases of low latency and/or high reliability, the data rates are also high, but in these cases the (stationary) mobile service is only available in a very small area.

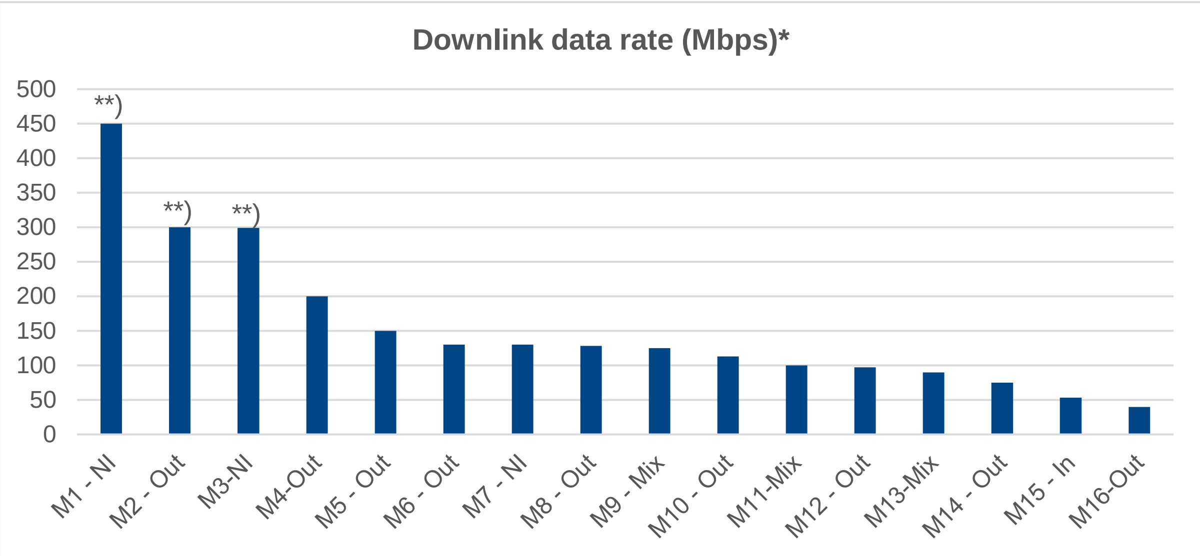
packet delay and the threshold IP service availability of the performance thresholds 2, however, need to be met together with the threshold data rates of the performance thresholds 2 and, therefore, in case of high data rates. For this reason, the threshold round-trip IP packet delay, the threshold IP service availability and the threshold values of the other QoS parameters are solely based on the median of the data provided by the mobile network operators.

1. Downlink and uplink data rate

187. This section determines the threshold downlink data rate and the threshold uplink data rate of the performance thresholds 2 based on mobile networks with fibre roll-out up to the base station and the best LTE Advanced technology used in a mobile network (see paragraph 174).

Downlink data rate

188. Figure 7 and Table 10 show the average value of the achievable downlink data rates in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network under the conditions given in the questionnaire (see paragraph 93 scenario 2) based on the answers received from 16 operators. The



*) Of the IP packet payload, **) Data considered to be implausible (see paragraphs 184 to 187)
Out … outdoor only, Mix … mix of outdoor and indoor, In … indoor only, NI … no information
Source: BEREC

Figure 7: Average value of the achievable downlink data rate during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

achievable downlink data rate is the data rate which an end-user would for example measure with an internet speed test and the average value considers measurements during peak-time and over the whole coverage area of the best LTE Advanced technology (in terms of aggregated spectrum, MIMO order, modulation etc., see paragraph 97). The downlink data rates shown are data rates at the level of the IP packet payload (see paragraph 38).

Table 10: Average value of the achievable downlink data rate during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

Operator	Locations	Average data rate (Mbps)*		Aggregated spectrum (MHz)		MIMO	
		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
M1**)	NI	450	100	90	40	4x4	1x4
M2**)	Out	300	70	80	40	4x4	4x4
M3**)	NI	299	120	50	40	2x2	1x1
M4	Out	200	50	60	40	4x4	1x1
M5	Out	150	35	50	20	4x4, 2x2	4x4
M6	Out	130	40	50	50	4x4	4x4
M7	NI	130	30	60	20	4x4	1x1
M8	Out	128	51	80	80	4x4, 2x2	2x2
M9	Mix	125	70	60	40	4x4	2x2
M10	Out	113	28	50	30	4x4	4x4
M11	Mix	100	30	35	15	4x4	4x4
M12	Out	97	39	100	100[43]	2x2	1x1
M13	Mix	90	40	40	30	2x2	2x2
M14	Out	75	40	25	20	2x2	2x2
M15	In	53	29	70	20	2x2	2x2
M16	Out	40	40	80	20	4x4	4x4
M17	Mix	0-450***)	0-75***)	55	20	4x4	2x2

*) Of the IP packet payload, **) Data considered to be implausible (see paragraphs 184 to 187), ***) Range of the achievable data rate (not an average value)
Out … outdoor only, Mix … mix of outdoor and indoor, In … indoor only, NI … no information
Modulation is in case of all 17 operators (M1-M17) 256 QAM in downlink and 64 QAM in uplink
Source: BEREC

189. The average value of the achievable data rate during peak-time depends on many parameters as for example

a. The LTE Advanced technology used (aggregated spectrum, MIMO order, modulation, transmit power, geometrical parameters of the antenna, etc.);

[43] Uplink carrier aggregation is not supported by the devices used for the measurements

b. The number of the end-users who share the same LTE resources, the data rate (tariff) of the services they have subscribed to, and the behaviour of these end-users during peak-time e.g. how intense they use their services;

c. The environmental conditions, e.g. the impact of the site on the signal propagation characteristics, interferences, reflections etc.

Therefore, some variation in the data rates can be expected and is plausible

190. The average value of the achievable downlink data rate is based on outdoor locations only in case of nine operators, on a mix of indoor and outdoor locations in case of four operators, on indoor locations only in case of one operator and three operators did not provide this information.

191. One further operator (M17) provided the range in which the values of the achievable data rate vary and not the average value of the achievable data rate (see Table 10). Since this range is very wide, it is not possible in BEREC's view to base the determination of the performance thresholds 2 on these data.

192. The average value of the achievable downlink data rate during peak-time varies between 40 Mbps and 450 Mbps. In case of three operators (M1 to M3), this data rate is significantly higher (300 Mbps, 450 Mbps) compared to the other operators.

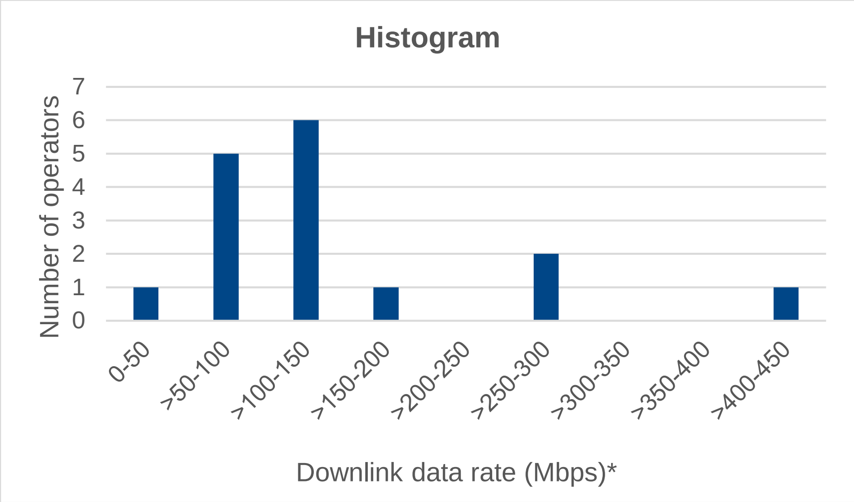
193. Measurement data of NRA internet speed tests (see annex 6) show that in current LTE networks (including LTE-Advanced) during peak-time the downlink data rate is typically (median) 20 Mbps and the highest values (95% percentile) are 70 to 100 Mbps. The use of a 'better' LTE technology (more spectrum, more parallel MIMO data streams etc.) may increase these data rates. However, it is considered unlikely that an *average* value of the downlink data rate over the LTE coverage area is achievable which is three times as high (300 Mbps, 450 Mbps) than the highest currently downlink data rates (70 to 100 Mbps).

194. For these reasons, an average value of the achievable downlink data rate of 300 Mbps (M2, M3) or 450 Mbps (M1) is considered to be implausible and not taken into account in the determination of the performance thresholds 2.

195. Download data rates of 300 Mbps and 450 Mbps can also be considered as outliers as shown by Figure 8.

196. Without considering the implausible data rates (M1 to M3), the average value of the downlink data rate during peak-time varies between 40 Mbps and 200 Mbps, the median is 113 Mbps and the 90% percentile is 150 Mbps.

197. The threshold downlink data rate of the performance thresholds 2 needs to be based on the 90% percentile of the values reported by the network operators (see paragraph 177). Therefore, **the threshold downlink data rate of the performance thresholds 2 is set to 150 Mbps** and it refers to the data rate at the level of the IP packet payload (see paragraphs 34 to 38) and to outdoor locations only, since most of the data provided by the mobile network operators are based on outdoor locations only (see Table 10).

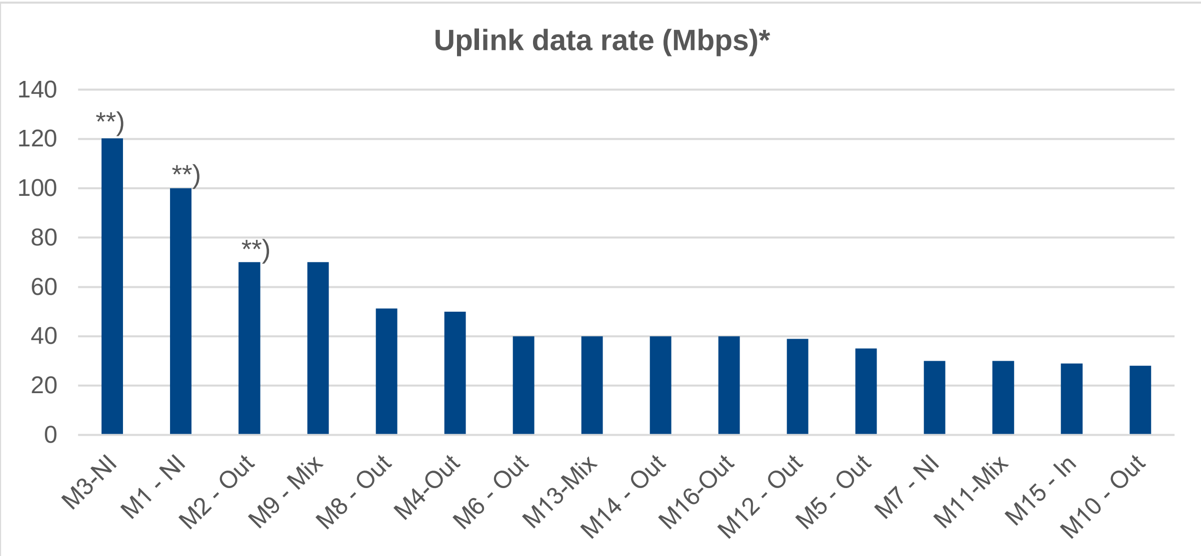


*) Of the IP packet payload
Source: BEREC

Figure 8: Histogram of the average value of the achievable downlink data rate during peak-time of Figure 7

Uplink data rate

198. Figure 9 and Table 10 show the average value of the achievable uplink data rates in a mobile network with fibre roll-out up to the base station and the best LTE Advanced



*) Of the IP packet payload, **) Data considered to be implausible (see paragraphs 184 to 187 and 191)
Out … outdoor only, Mix … mix of outdoor and indoor, In … indoor only, NI … no information
Source: BEREC

Figure 9: Average value of the achievable uplink data rate during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

technology used in this network under the conditions given in the questionnaire (see paragraph 93 scenario 2) based on the answers received from the same 16 operators. The uplink data rates shown are also data rates at the level of the IP packet payload (see paragraph 38).

199. The data provided by the operators with an implausibly high downlink data rate (M1 to M3) are also not considered for the determination of the threshold uplink data rate of the performance thresholds 2 (there is uncertainty about the validity of the entire data provided by these operators). Without these operators, the average value of the achievable uplink data rate during peak-time varies between 28 Mbps and 70 Mbps, the median is 40 Mbps and the 90% percentile is 50[44] Mbps.

200. The threshold uplink data rate of the performance thresholds 2 needs to be based on the 90% percentile of the values reported by the network operators (see paragraph 177). Therefore, **the threshold uplink data rate of the performance thresholds 2 is set to 50 Mbps** and it refers also to the data rate at the level of the IP packet payload and to outdoor locations only (see paragraph 189).

2. Other QoS parameters

201. This section determines the thresholds of the other QoS parameters of the performance thresholds 2 (see paragraphs 175.c to 175.g). The data that are considered to be implausible (M1 to M3) are not taken into account (see paragraphs 184 to 187 and Table 10).

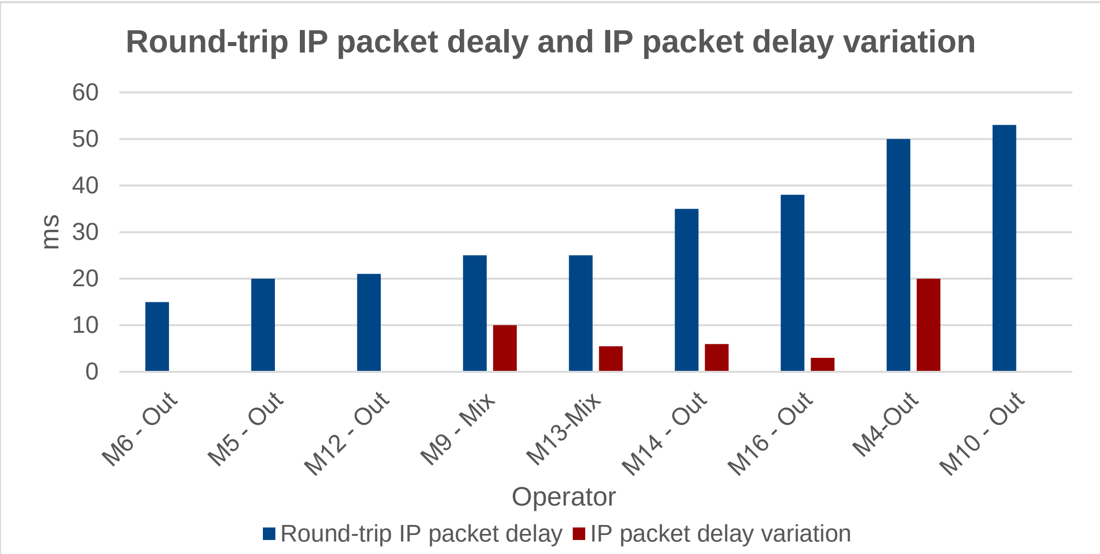
202. Not all network operators who provided data for the data rates were able to provide also data for the other QoS parameters. In response to the first phase of the call for initial stakeholder input (see paragraphs 47 and 49), network operators and in particular mobile network operators informed that they provide services to end-users without any service level agreement (SLA) and, therefore, do not monitor and have data for other QoS parameters. However, the EECC demands that the Guidelines define also thresholds for other QoS parameters (see paragraphs 1 and 6). In order to enable as much operators as possible to provide data for the other QoS parameters, the final questionnaire foresees also the possibility to provide estimated values of the QoS parameters.

203. All QoS parameters analysed in this section refer to the path from the end-user to the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point) and in case of round-trip parameters back to the end-user (see paragraph 46).

[44] Rounded value

a. Round-trip IP packet delay and IP packet delay variation

204. Figure 10 and Table 11 show the average value of the achievable round-trip IP packet delay and IP packet delay variation in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 176) based on the answers received from nine and five operators respectively. The average value considers measurements during peak-time and over the whole coverage area of the best LTE Advanced technology (in terms of aggregated spectrum, MIMO order, modulation etc., see paragraph 97).



Out … outdoor only, Mix … mix of outdoor and indoor
Source: BEREC

Figure 10: Average value of the achievable round-trip IP packet delay and IP packet delay variation during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

205. The round-trip IP packet delay is caused by the node processing delay (including the queuing delay), the propagation delay (approximately 1 ms per 100 km) and in case of lower data rates also of the serialisation delay (see paragraphs 154 and 156). The node processing is e.g. access network specific in case of the access node (LTE base station) and the common data flow forwarding in case of e.g. Ethernet switches and IP routers.

206. Therefore, the round-trip IP packet delay depends on the capacity of the network nodes compared to processing of the data flow that is necessary and on the distance the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraph 195). For these reasons, some variation in the IP packet delay can be expected and is plausible.

207. The IP packet delay variation is a measure for the variation of the IP packet delay and is mainly caused by the processing of the data flow in the network nodes (node

processing and queuing delay) and, therefore, also depends on the dimensioning of the network nodes.

Table 11: Average value of the achievable round-trip IP packet delay and IP packet delay variation during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

Operator	Location	Round-trip IP packet delay (RFC 2681) (ms)	IP packet delay variation (RFC 3393) (ms)
M6	Out	15	No information
M5	Out	20	No information
M12	Out	21	No information
M9	Mix	25	10
M13	Mix	25	5.5
M14	Out	35	6
M16	Out	38	3
M4	Out	50	20
M10	Out	53	No information
Median		*25*	*6*

Out … outdoor only, Mix … mix of outdoor and indoor
Source: BEREC

208. The average value of the achievable round-trip IP packet delay varies between 15 ms and 53 ms and the median is 25 ms. The average value of the achievable IP packet delay variation varies between 5.5 ms and 20 ms and the median is 6 ms (see Table 11).

209. The determination of the threshold round-trip IP packet delay and the threshold IP packet delay variation of the performance thresholds 2 are based on the median of the values reported by the network operators (see paragraph 178). Therefore, **the threshold round-trip IP packet delay of the performance thresholds 2 is set to 25 ms and the threshold IP packet delay variation of the performance thresholds 2 to 6 ms.**

210. In case of particular long distances (e.g. several hundred kilometres) between the end-user and the first point in the network where the traffic of the end-user services is handed over to other public networks (e.g. nearest peering point), the threshold round-trip IP packet delay increases for every 100 km by 1 ms (see paragraphs 156 and 197).

b. IP packet loss ratio

211. Table 12 shows the average value of the achievable IP packet loss ratio in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 176) based on the answers received from four operators. The average value considers measurements during peak-time and over the whole coverage area of the best LTE Advanced technology (in terms of aggregated spectrum, MIMO order, modulation etc., see paragraph 97).

212. IP packets may get lost in the queuing and the processing of the data flow in the network nodes. The IP packet loss ratio, i.e. the ratio of the lost IP packets to the

transmitted IP packets, therefore depends on the dimensioning of the network nodes. For this reason, some variation in the IP packet loss ratio is plausible.

213. The average value of the achievable IP packet loss ratio varies between <10E-7% and 0.1% and the median is 0.005%.

214. A vendor (V2) provided the information that the achievable IP packet loss ratio is in case of 4G sites with an aggregated spectrum of 40 MHz up to 100 MHz, 4x4 MIMO, under usual peak-time conditions and based on the use of a certain equipment in the range of 10E-6 up to 10E-2 and, according to field tests, can be even lower than 10E-6.

Table 12: Average value of the achievable IP packet loss ratio during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

Operator	Location	IP packet loss ratio (Y.1540) (%)
M9	Mix	<10E-7
M4	Out	10E-6
M13	Mix	0.01
M14	Out	0.1
Median		*0.005*

Out … outdoor only, Mix … mix of outdoor and indoor
Source: BEREC

215. Another vendor (V5) informed that the lowest IP packet loss ratio in downlink direction typically achievable is 0.03% in the case of 4G and an aggregated downlink spectrum of 60 MHz up to 100 MHz, downlink MIMO between 4x4 up to 8x8 and under usual peak-time conditions. In uplink direction the lowest the IP packet loss ratio typically achievable is 0.001% in the case of 4G and an aggregated uplink spectrum of 20 MHz up to 80 MHz, uplink MIMO between 2x2 up to 4x4 and under usual peak-time conditions.

216. The IP packet loss ratio reported by the network operators is in a similar range or slightly higher, which is plausible since the IP packet loss ratio reported by the network operators do not only refer to the access network but instead to the path from the end-user to the first point in the network where the end-user traffic is handed over to other public networks (see paragraphs 46 and 195).

217. The determination of the threshold IP packet loss ratio of the performance thresholds 2 is based on the median of the values reported by the network operators (see paragraph 178). Therefore, **the threshold IP packet loss ratio of the performance thresholds 2 is set to 0.005%.**

c. IP packet error ratio

218. Three operators (M4, M9, M13) provided information on the average value of the achievable IP packet error ratio in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 176). Operator M9 reported an average value of less of than 10E-7% for the achievable IP

packet error ratio, while operators M4 and M13 reported values of 10E-6% and 0.01% respectively for this same parameter.

219. Therefore, in order to broaden the data basis, the average value of the IP packet error ratio of the product with the highest data rate currently provided in the mobile network under the conditions given in the questionnaire (see paragraph 93 scenario 1) is included in the determination of the threshold IP packet error ratio of the performance thresholds 2. Table 13 shows this average value of the IP packet error ratio of 5 operators.

Table 13: Average value of the IP packet error ratio during peak-time of the product with the highest data rate currently provided in the mobile network

Operator	Location	IP packet error ratio (Y.1540) (%)
M9	Mix	<10E-7
M4	Out	1.00E-06
M1	NI	0.01
M13	Out	0.01
M18	Mix	0.01
Median		*0.01*

Out … outdoor only, Mix … mix of outdoor and indoor, NI … no information
Source: BEREC

220. The processing of the data flow in the network nodes and the transmission of IP packets may cause IP packet errors. The IP packet error ratio, i.e. the ratio of the errored IP packets to the sum of error-free and errored IP packets, therefore depends on the processing and transmission quality. For these reasons, some variation in the IP packet error ratio can be expected and is plausible.

221. The average value of the IP packet error ratio during peak-time of the product with the highest data rate currently provided varies between less than 10E-7% and 0.01% and the median is 0.01%. The average value of the achievable IP packet error ratio reported by operators M4, M9 and M13 is in the same range.

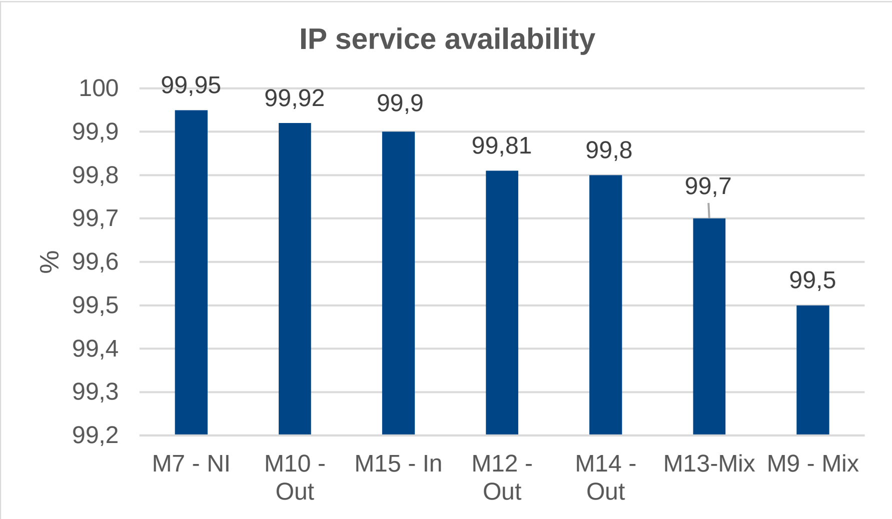
222. A vendor (V2) provided the information that the achievable IP packet error ratio is in case of 4G sites with an aggregated spectrum of 40 MHz up to 100 MHz, 4x4 MIMO, during peak-time and based on the use of a certain equipment in the range of 10E-6 up to 10E-2 and, according to field tests, both can be even lower than 10E-6.

223. The IP packet error ratio reported by the network operators is in a similar range or slightly higher, which is plausible since the IP packet error ratio reported by the network operators do not only refer to the access network but instead to the path from the end-user to the first point in the network where the end-user traffic is handed over to other public networks (see paragraphs 46 and 195).

224. The determination of the threshold IP packet error ratio of the performance thresholds 2 is based on the median of the values reported by the network operators (see paragraph 178). Therefore, **the threshold IP packet error ratio of the performance thresholds 2 is set to 0.01%**.

d. IP service availability

225. Figure 11 and Table 18 show the average value of the achievable IP service availability in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network and under the conditions given in the questionnaire (see paragraph 93 scenario 2 and paragraph 176) based on the answers received from seven operators. The average value considers measurements during peak-time and over the whole coverage area of the best LTE Advanced technology (in terms of aggregated spectrum, MIMO order, modulation etc., see paragraph 97).



Out … outdoor only, Mix … mix of outdoor and indoor, In … Indoor only, NI … no information
Source: BEREC

Figure 11: Average value of the achievable IP service availability during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

Table 14: Average value of the achievable IP service availability during peak-time in a mobile network with fibre roll-out up to the base station and the best LTE Advanced technology used in this network

Operator	**Location**	**IP service availability (Y.1540) (% per year)**
M7	NI	99.95
M10	Out	99.92
M15	In	99.9
M12	Out	99.81
M14	Out	99.8
M13	Mix	99.7
M9	Mix	99.5
Median		*99.81*

Out … outdoor only, Mix … mix of outdoor and indoor, In … Indoor only, NI … no information
Source: BEREC

226. The average value of the achievable IP service availability (i.e. the ratio of the time when the IP service is available to the total scheduled IP service time), varies between 99.5% and 99.95% per year and the median is 99.81% per year.

227. A vendor (V2) provided the information that the achievable IP service availability is 99.999% in the case of 4G sites with an aggregated spectrum of 40 MHz up to 100 MHz, 4x4 MIMO, under usual peak-time conditions and based on the use of a certain equipment.

228. Another vendor (V5) informed that the highest IP service availability typically achievable is 99.999% in the case of 4G and an aggregated downlink spectrum of 60 MHz up to 100 MHz, downlink MIMO between 4x4 up to 8x8 and under usual peak-time conditions.

229. This shows that the access network does not necessarily contribute strongly to the values reported by the network operators which refer not only to the access network but instead to the path from the end-user to the point in the network where the end-user traffic is handed over to other public networks (see paragraphs 46 and 195).

230. The determination of the threshold IP service availability of the performance thresholds 2 is based on the median of the values reported by the network operators (see paragraph 178). Therefore, **the threshold IP service availability of the performance thresholds 2 is set to 99.81%.**

Annex 5: Data on further networks

231. This annex provides, for reference purposes only, data for the following further networks based on the corresponding questionnaires (see paragraphs 90):

a. Fixed networks with fibre to the multi-dwelling building and Ethernet on the in-building twisted pair cable of category 5 or higher (section 1 in this annex); and

b. Fixed networks with FTTH (section 2 in this annex).

1. Fixed networks with fibre to the multi-dwelling building and Ethernet on the in-building twisted pair cable of category 5 or higher

232. Fixed networks with fibre to the multi-dwelling building and Ethernet on the in-building twisted pair cable of category 5 or higher have the potential of high typically achievable data rates. Since the performance thresholds 1 have to be based on the achievable data rates (see paragraph 14a) such networks may be relevant for the determination of the performance thresholds 1. Several stakeholders also suggested to consider such networks, in the first phase of the call for initial stakeholder input (see paragraphs 47 and 49).

233. However, in the EU such networks are not very common[45] and, therefore, public electronic communications services based on such networks can only be offered to a small share of end-users and they are not representative from the end-user's perspective.[46]

234. For these reasons, the data collected are used as a reference, but not for the determination of performance thresholds 1. However, this does not mean that such networks do not qualify as a very high capacity network. The opposite is the case, since fibre is rolled-out up to the multi-dwelling building they have to be considered as a very high capacity network (see paragraph 6 criterion 1).

a. Downlink and uplink data rate

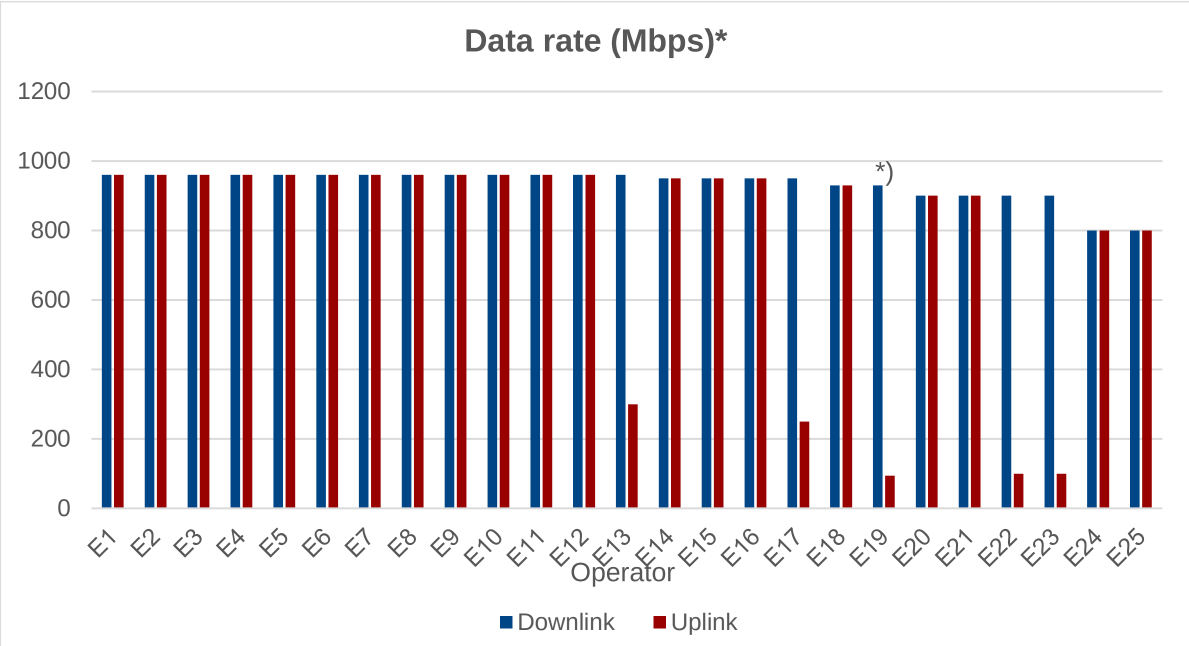
235. Figure 12 and Table 15 show the typically achievable data rates during peak-time in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher under the conditions given in the questionnaire (see paragraph 93 scenario 2) based on the answers received from 25 operators. The data rates shown are data rates at the level of the IP packet payload (see paragraph 38).

[45] Ethernet on twisted pair cable is common in computer networks (e.g. LAN) but not as in-building infrastructure on which public electronic communications services are provided to end-users.

[46] In a few EU countries such networks may be more common, e.g. 51% of the completed questionnaires have been filled in by operators of only three countries (Bulgaria, Latvia and Slovakia, see paragraph 105).

236. These are data rates which an end-user will typically experience in peak-time if his CPE fully supports the Ethernet technology of the network (see paragraph 95).

237. The maximum data rate of Gigabit Ethernet is 1,000 Mbps at the level of the Ethernet protocol (including the Ethernet overhead) and slightly lower (approximately 960 Mbps)[47] at the level of the IP packet payload.[48]



*) Of the IP packet payload (see footnote 48)
Source: BEREC

Figure 12: Typically achievable data rates during peak-time in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

238. The other eight operators who completed the questionnaire (see paragraph 100 and Table 1), use Fast Ethernet on the in-building twisted pair cable which enables solely a maximum data rate of 100 Mbps at the level of the Ethernet protocol (including Ethernet

[47] The data rate of 1,000 Mbps at the level of the Ethernet protocol (incl. overhead) is converted in a data rate of 960 Mbps at the level of the IP packet payload with the following conversion factor. The conversion factor is A divided by B. A is the length of the IP packet payload i.e. the maximum transmission unit (MTU, 1,500 byte) minus IP header (20 byte) and therefore 1,480 bytes. B is the total length of the Ethernet frame (including synchronisation signal and pause time) i.e. the MTU (1,500 bytes) plus the Ethernet overhead (14 byte header + 4 bytes frame check sequence + 8 bytes preamble + 12 bytes Ethernet inter frame space). The conversion factor used is therefore 1,480 bytes / 1,538 bytes = 0.96.

[48] Several operators provided a data rate of 1,000 Mbps and BEREC informed them that a data rate of 1,000 Mbps is not possible at the level of the IP packet payload since Gigabit Ethernet is used on the in-building twisted pair cable. The operators who responded adapted the data rate accordingly, however, not all operators responded. Since a data rate of 1,000 Mbps at the level of the IP packet payload based on Gigabit Ethernet is not possible, the data rates shown in Figure 12 and Table 15 have been adapted to 960 Mbps (see footnote 47).

overhead) and a slightly lower data rate (approximately 96 Mbps) at the level of the IP packet payload.

Table 15: Typically achievable data rates during peak-time in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

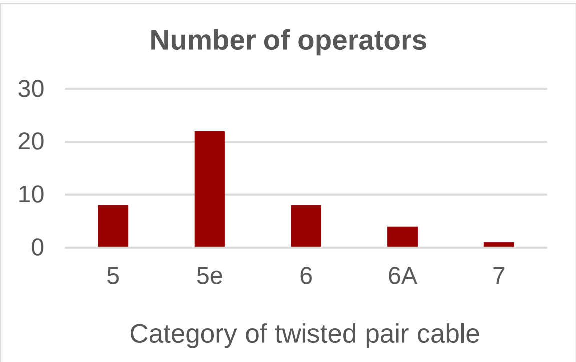
Op.	Data rate (Mbps)		Op.	Data rate (Mbps)		Op.	Data rate (Mbps)	
	Down	Up		Down	Up		Down	Up
E1	960	960	E10	960	960	E19	900-960	90-98
E2	960	960	E11	960	960	E20	900	900
E3	960	960	E12	960	960	E21	900	900
E4	960	960	E13	960	300	E22	900	100
E5	960	960	E14	950	950	E23	900	100
E6	960	960	E15	950	950	E24	800	800
E7	960	960	E16	950	950	E25	800	800
E8	960	960	E17	950	250	*Median*	*960*	*950*
E9	960	960	E18	930	930			

*) Of the IP packet payload (see footnote 48)
Source: BEREC

239. Figure 12 and Table 15 show that the typically achievable downlink data rate during peak-time is in case of 17 (68%) of the 25 operators 960 Mbps (13 operators) or 950 Mbps (4 operators) which corresponds approximately to the maximum data rate of 1,000 Mbps at the level of the Ethernet protocol (including Ethernet overhead). In case of all 25 operators, the downlink data rate is at least 800 Mbps and the median is 960 Mbps.

240. Most of the operators (20, 80%) provide a symmetric data rate, only a few (5, 20%) an asymmetric data rate. The median of the uplink data rate is 950 Mbps.

241. Figure 13 shows that the category of the twisted pair cable used is in most cases (88%) category 5e and in about one third of the cases category 5 and category 6 and rather rarely category 6A (16%) and category 7 (4%).

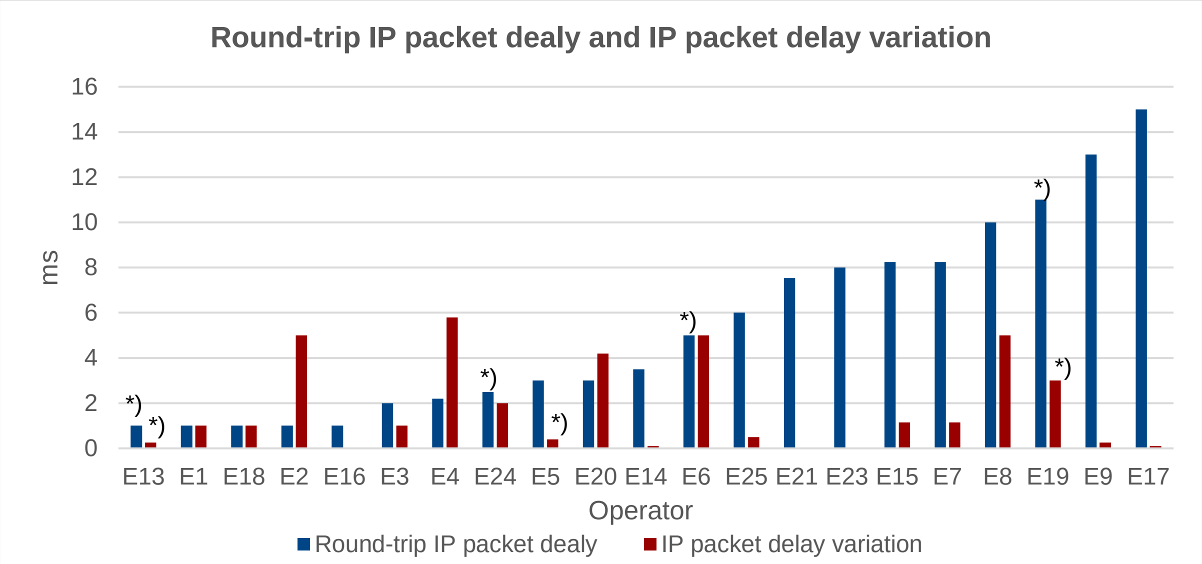


Source: BEREC

Figure 13: Category of twisted pair cable

b. Round-trip IP packet delay and IP packet delay variation

242. Figure 14 and Table 16 show the typically achievable round-trip IP packet delay and IP packet delay variation during peak-time in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher and under the conditions given in the questionnaire (see paragraph 93 scenario 2) based on the answers received from 21 and 19 operators respectively.



*) Range (see Table 16)
Source: BEREC

Figure 14: Typically achievable round-trip IP packet delay and IP packet delay variation in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

243. The round-trip IP packet delay depends on the capacity of the network nodes compared to the processing of the data flow that is necessary and, therefore, on the dimensioning of the network, as well as on the distance the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraphs 46, 154 and 155). For these reasons, some variation in the IP packet delay can be expected and is plausible.

244. The IP packet delay variation is a measure for the variation of the IP packet delay and is mainly caused by the processing of the data flow in the network nodes (node processing and queuing delay, see paragraph 157). Therefore, it depends also on the dimensioning of the network nodes.

245. The typically achievable round-trip IP packet delay varies between 1 ms and 15 ms and the median is 3.5 ms. The typically achievable IP packet delay variation varies between approximately 0 ms and 5.8 ms and the median is 1 ms.

The Table 16: Typically achievable round-trip IP packet delay and IP packet delay variation in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

Operator	Round-trip IP packet delay (RFC 2681) (ms)	IP packet delay variation (RFC 3393) (ms)	Operator	Round-trip IP packet delay (RFC 2681) (ms)	IP packet delay variation (RFC 3393) (ms)
E13	<2	<0.5	E6	< 10	5
E1	1	1	E25	6	0.5
E18	1	1	E21	7.54	0
E2	1	5	E23	8	NI
E16	1	NI	E15	8.25	1.15
E3	2	1	E7	8.25	1.15
E4	2.2	5.8	E8	10	5
E24	<5	2	E19	2-20	1-5
E5	3	<0.8	E9	13	0.26
E20	3	4.2	E17	15	0.1
E14	3.5	0.1	*Median*	*3.5*	*1*

NI … No information
Source: BEREC

c. IP packet error ratio and IP packet loss ratio

246. Table 17 show the typically achievable IP packet error ratio and IP packet loss ratio during peak-time in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher and under the conditions given in the questionnaire (see paragraph 93 scenario 2) based on the answers received from 19 and 20 operators respectively.

247. The IP packet loss ratio depends on the dimensioning of the network nodes and the IP packet error ratio depends on the processing and transmission quality. Therefore, some variation in the IP packet loss ratio and the IP packet error ratio can be expected and is plausible (see paragraphs 163).

248. Both the typically achievable IP packet error ratio and the typically achievable IP packet loss ratio vary between 0%[49] and 1%. The median, however, is solely 0.001 % in case of the IP packet error ratio and 0.01% in case of the IP packet loss ratio.

Table 17: Typically achievable IP packet error ratio and IP packet loss ratio in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

Operator	IP packet error ratio (Y.1540) (%)	IP packet loss ratio (Y.1540) (%)	Operator	IP packet error ratio (Y.1540) (%)	IP packet loss ratio (Y.1540) (%)
E1	0[49]	0[49]	E15	0.001	0.015
E3	0	0	E7	0.001	0.016
E6	0	0	E24	<0.01	<0.01
E9	0	0	E18	0.01	0.01
E25	0	<0.001	E14	0.01	0.01
E4	0	0.05	E5	<0.1	<0.1
E17	0	0.12	E21	0.05	0.05
E13	0	<1	E10	<0.1	<0.1
E2	0.00001	0.001	E11	1	1
E20	0.001	0.001	E8	NI	0.01
Median	*0.001*	*0.01*			

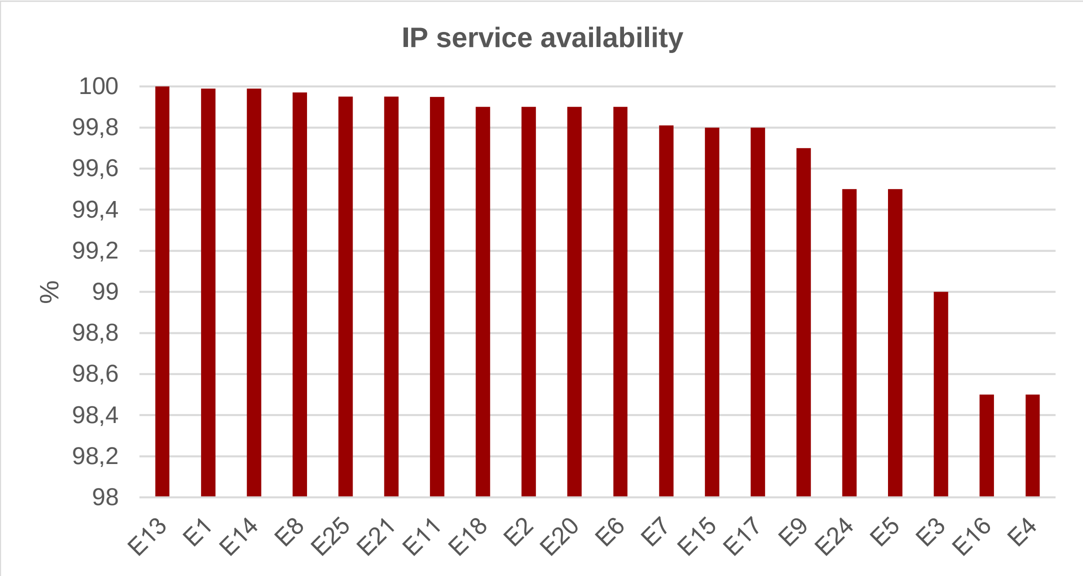
Legend: NI … No information
Source: BEREC

d. IP service availability

249. Figure 15 and Table 18 show the typically achievable IP service availability in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher and under the conditions in the questionnaire (see paragraph 93 scenario 2) based on the answers received 20 operators.

250. The typically achievable IP service availability varies between 98.5% and 100%[50] per year and the median is 99.9% per year.

[49] Estimations of the achievable IP packet error ration and IP packet loss ratio were possible (see paragraph 150) and a value of 0% maybe be an estimation for a value very close to 0%.
[50] Estimations of the achievable IP service availability were possible (see paragraph 150) and a value of 100% maybe be an estimation for a value very close to 100%.



Source: BEREC

Figure 15: Typically achievable IP service availability in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

Table 18: Typically achievable IP service availability in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

Operator	**IP service availability (Y.1540) (% per year)**	**Operator**	**IP service availability (Y.1540) (% per year)**
E13	100[50]	E6	99.9
E1	99.99	E7	99.81
E14	99.99	E15	99.8
E8	99.97	E17	99.8
E25	99.95	E9	99.7
E21	99.95	E24	99.5
E11	99.95	E5	99.5
E18	99.9	E3	99
E2	99.9	E16	98.5
E20	99.9	E4	98.5
Median	*99.9*		

Source: BEREC

e. Comparison with the performance thresholds 1

251. Table 19 shows a comparison of the performance thresholds 1 with the typically achievable end-user QoS in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher. In the

following paragraphs (244 to 248), the latter is only referred to as 'Gigabit Ethernet' in order to increase the readability.

252. The downlink data rate of Gigabit Ethernet is slightly lower than the downlink data rate of performance thresholds 1, since the data rate of Gigabit Ethernet is 1,000 Mbps at the level of the Ethernet protocol but slightly lower at the level of the IP packet payload.

253. The uplink data rate of Gigabit Ethernet is significantly higher. Gigabit Ethernet is a symmetric technology and, therefore, the data rates are typically also symmetric. This is not the case with G.fast and DOCSIS where the available spectrum can be configured as downlink or uplink data rate (G.fast) or different spectrum is used for downlink and uplink (DOCSIS).

254. The round-trip IP packet delay and the IP packet delay variation are lower in case of Gigabit Ethernet compared to performance thresholds 1. The QoS parameters encompass not only the access network but the entire network between end-user and the first point in the network where the traffic of the end-user services is handed over to other public networks (see paragraphs 46). The part of the network between the multi-dwelling building and this handover point is based on fibre in case of both performance thresholds 1 and Gigabit Ethernet. The difference, therefore, may be caused by the different access technologies but also by dimensioning of the nodes in the fibre-based part of the network.

Table 19: Comparison of the performance thresholds 1 with the typically achievable end-user QoS in fixed networks with fibre to the multi-dwelling building and Gigabit Ethernet on the in-building twisted pair cable of category 5 or higher

QoS parameter	Performance thresholds 1	Gigabit Ethernet (median)
Downlink data rate[51]	1,000	960
Uplink data rate[51]	200	950
Round-trip IP packet delay (RFC 2681) (ms)	10	3.5
IP packet delay variation (RFC 3393) (ms)	2	1
IP packet error ratio (Y.1540) (%)	0.05	0.001
IP packet loss ratio (Y.1540) (%)	0.0025	0.01
IP service availability (Y.1540) (% per year)	99.9	99.9

Source: BEREC

255. The IP packet error ratio and the IP packet loss ratio are in case of both performance thresholds 1 and Gigabit Ethernet rather low and close to 0%. The IP packet error ratio is closer to 0% in case of Gigabit Ethernet and the IP packet loss ratio is closer to 0% in case of performance thresholds 1.

[51] IP packet payload data rate

256. The IP service availability of Gigabit Ethernet is the same as of performance thresholds 1.

2. Fixed networks with FTTH

257. The data in this annex are presented for reference purposes only, but not for the determination of performance thresholds 1 (see paragraph 15).

258. Table 20 shows the typically achievable data rates during peak-time in fixed networks with FTTH under the conditions given in the questionnaire (see paragraph 93 scenario 2) for the five operators who deploy the 'best' access technology. The data rates shown are data rates at the level of the IP packet payload (see paragraph 38).

259. These are data rates which an end-user will typically experience in peak-time if his CPE fully supports the access technology of the network (see paragraph 95).

Table 20: Typically achievable data rates during peak-time in fixed networks with FTTH and the 'best' access technology

Op.	Data rate (Mbps)*		Access	
	Down	Up	Topology	Technology
F1	9,600	9,600	P2P	10 Gigabit Ethernet
F2	9,600	9,600	P2P	10 Gigabit Ethernet
F3	5,000	5,000	P2MP	XGS-PON
F4	5,000	5,000	P2MP	XGS-PON
F5	1,000	1,000	P2MP	XGS-PON

*) Of the IP packet payload[52]
Legend: P2P … Point-to-point, P2MP … Point-to-multipoint
Source: BEREC

260. The other 13 operators with a network with FTTH and point-to-point topology use solely 1 Gigabit Ethernet on the subscriber access line which enables symmetric data rates of maximum 960 Mbps.[53] The other 11 operators with a network with FTTH and point-to-multipoint topology use solely G-PON (nine operators) or RFoG[54] (two operators). A G-PON provides in total a data rate to the end-users connected to it that is only one fourth (downstream) and one eighth (upstream) respectively compared to XGS-PON. RFoG provides in upstream direction a significant lower data rate compared to XGS-PON, according to the data of the operators (only 50 Mbps or 100 Mbps).

[52] The data rate is 10 Gbps at the level of the Ethernet protocol (including Ethernet protocol overhead) and slightly lower (approximately 9.6 Gbps) at the level of the IP packet payload (see paragraph 236).
[53] The data rate is 1 Gbps at the level of the Ethernet protocol (including Ethernet protocol overhead) and slightly lower (approximately 960 Mbps) at the level of the IP packet payload (see paragraph 236).
[54] Radio Frequency over Glass

261. Even a better PON technology with regards to the achievable data rate than XGS-PON, the PON technology NG-PON2, is commercially available.[55] The symmetric data rate shared between the end-users connected to the same NG-PON2 is 40 Gbps[56] and, therefore, four times higher compared to XGS-PON.

262. Although the typically achievable data rate of networks with FTTH is very high (see Table 20), still higher data rates are possible. PON technologies with higher data rates are in the process of standardisation[57] and 9,600 Mbps symmetric in case of point-to-point topology is not a technological limit. For example, in core networks 100 Gbps[58] per wavelength are used and WDM[59] enables the use of several wavelengths per fiber. However, currently there does not seem to be a need to exploit this technological potential, since 9,600 Mbps symmetric are more than enough given the current demand of most end-users.

263. Since only two operators in case of point-to-point topology and three operators in case of point-to-multipoint topology deployed the ‘best’ technology and not all provided data for the other QoS parameters, data for the other QoS parameters are not available.

[55] See BEREC Report on the new forms of sharing passive optical networks based on wavelength division multiplexing, BoR (17) 182, p. 28-29

[56] Gross data rate at the level of the Ethernet protocol. Four wavelengths, each with 10 Gbps. Up to eight wavelengths are foreseen in the standard (ITU-T G.989) and, therefore, eight wavelength with a total data rate of 80 Gbps may be available in the future.

[57] See BEREC Report on the new forms of sharing passive optical networks based on wavelength division multiplexing, BoR (17) 182, p. 7

[58] Gross bitrate at the level of the Ethernet protocol.

[59] Wavelength Division Multiplexing

Annex 6: Internet speed test data for 4G

264. This annex provides information on measurements of 4G data rates made with internet speed tests of NRAs.

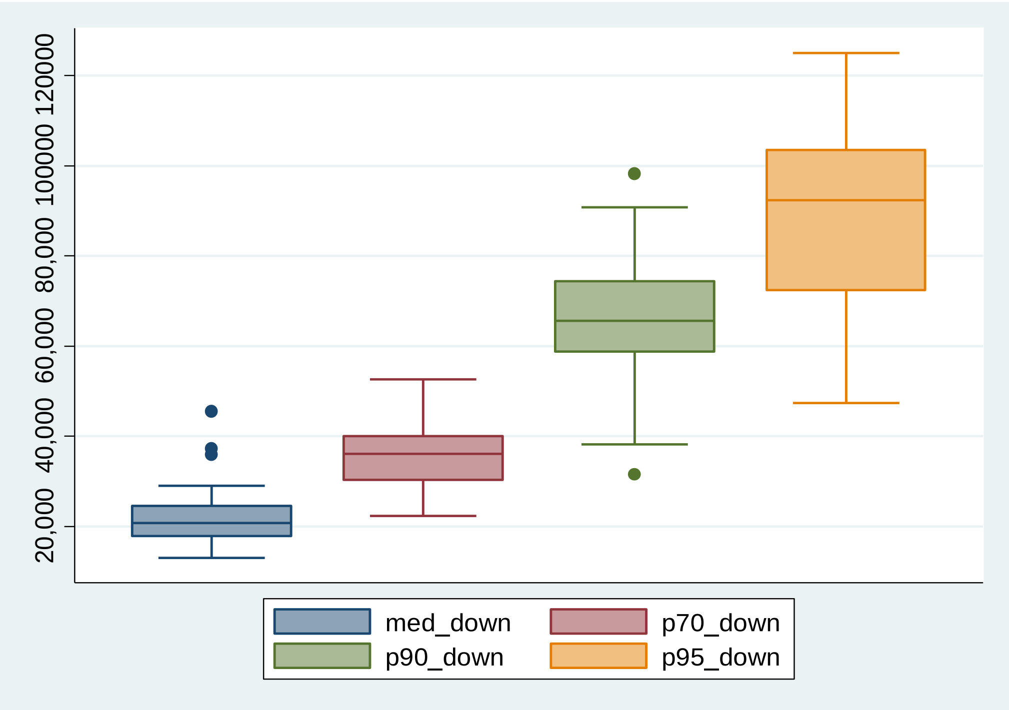
265. Data of the following nine countries are analysed: Austria, Croatia, the Czech Republic, Germany, Hungary, Luxemburg, Serbia, Slovenia and Slovakia. The following data were considered on a quarterly basis and during peak-time (the two evening hours of the quarter with the lowest median downlink data rate):

a. The median and the 70%, 90% and 95% percentiles of the downlink data rate,

b. The median and the 70%, 90% and 95% percentiles of the uplink data rate, and

266. While the median is the value for which exactly 50% of the observations are below and 50% are above the e.g. 95% percentile it the value where 95% of the observations are below and 5% above.

267. The following charts show the distribution of the median and the percentiles of a certain country and a certain quarter taking into account the period Q1/2018-Q2/2019 (whereby not for all countries data are available for the full period).



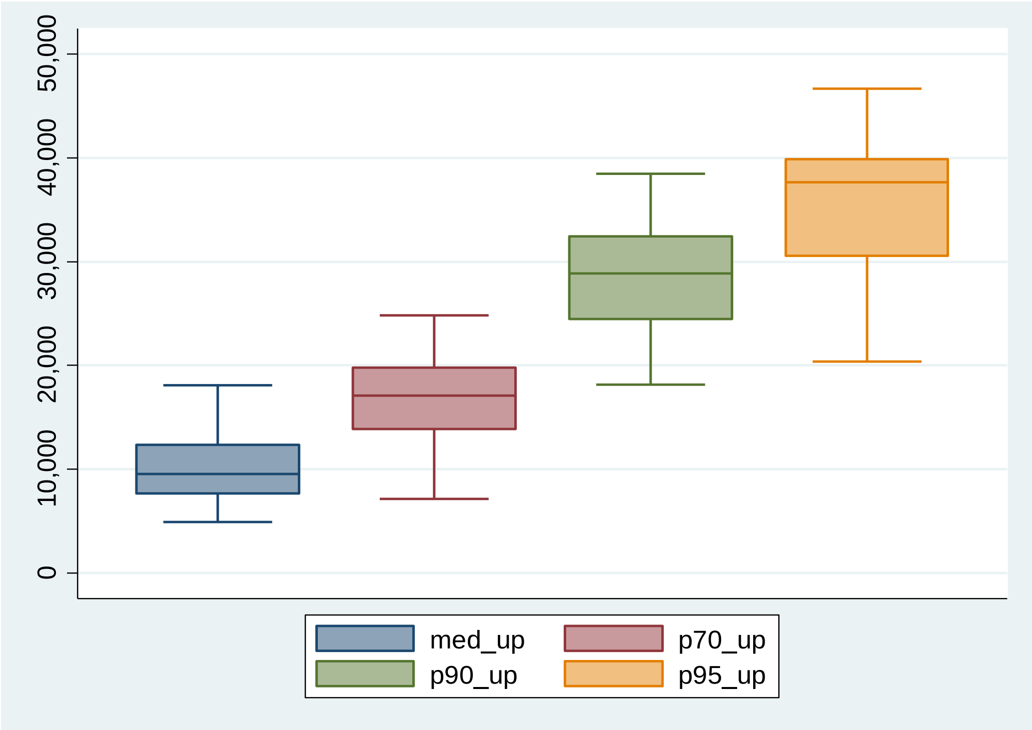
Source: BEREC

Figure 16: Box-Whiskers plot for the median and the 70%, 90% and 95% percentiles of the 4G downlink data rates (in kbit/s) in peak time across countries and quarters Q1/2018-Q2/2019

268. Figure 20 shows the distribution of the median and the 70%, 90% and 95% percentiles of the downlink data rates (in kbit/s). The Box-Whiskers plot has to be read as follows (e.g. with regard to the 95% percentile, p95_down): The values in the box cover 50% of

all observations. Half of the values for p95_down are therefore between 72.3 Mbps and 103.5 Mbps. The so called 'whiskers' show the minimum and the maximum of the distribution, in case of the 95% percentile 47.4 Mbps and 125.0 Mbps. Points beyond the whiskers indicate outliers of the distribution.[60]

269. Figure 21 shows a similar diagram for the uplink data rates.



Source: BEREC

Figure 17: Box-Whiskers plot for the median and the 70%, 90% and 95% percentiles of the 4G uplink data rates (in kbit/s) in peak time across countries and quarters Q1/2018-Q2/2019

[60] These value have a distance to the upper or lower edge of the box which is more than 1.5 times the height of the box.

Annex 7: Abbreviations

BEREC	Body of European Regulators for Electronic Communications
CA	Carrier Aggregation
CMTS	Cable Modem Termination System
CPE	Customer Premises Equipment
DOCSIS	Data Over Cable Service Interface Specification
DPU	Distribution Point Unit
EECC	European Electronic Communications Code
FE	Fast Ethernet
FTTB	Fibre To The Building
FTTH	Fibre To The Home
GE	Gigabit Ethernet
GPON	Gigabit-capable Passive Optical Networks
HFC	Hybrid Fibre Coax
IP	Internet Protocol
IPDV	IP Packet Delay Variation
IPER	IP Packet Error Ratio
IPLR	IP Packet Loss Ratio
LEX	Local EXchange
LTE	Long Term Evolution
LTE-A	LTE Advanced
MDF	Main Distribution Frame
ME	Mobile Equipment
MIMO	Multiple-Input and Multiple-Output
NI	No Information
NRA	National Regulatory Authority
OLT	Optical Line Termination

OTT	Over The Top
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RFoG	Radio Frequency over Glass
RTIPD	Round-Trip IP Packet Delay
SLA	Service Level Agreement
WDM	Wavelength Division Multiplexing
XGS-PON	10-Gigabit-capable Symmetric Passive Optical Network