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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 network' in the EU.

2. BEREC published the first version of these Guidelines in 2020 and determined that any network which fulfils one (or more) of four criteria is a very high capacity network (BoR (20) 165, paragraph 18). However, at that time it was not yet possible to take 5G fully into account, as it had not yet reached mature deployment and significant penetration (see BoR (20) 165, paragraph 25). Therefore, in this new version of the Guidelines, BEREC updates criterion 4 (performance thresholds for wireless network) based on data collected from mobile network operators on 5G, while the other three criteria remain unchanged.

3. Article 3 of the EECC specifies its general objectives, including 'promot[ing] 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'. 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.'

4. 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 network is used also in other initiatives taken by the EU institutions to support this ambition.[4]

[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. The term ‘very high capacity network’ 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)); and
- NRAs may invite undertakings and public authorities to declare their intention to deploy very high capacity networks in designated areas (Art. 22(3)).

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

7. According to Art. 82 of the EECC, BEREC shall update the Guidelines by 31 December 2025, and regularly thereafter. This new version of the Guidelines already updates criterion 4 for the reasons explained in paragraph 2 above. BEREC intends to report on the practical application of these guidelines in accordance with Art. 4(1)(j)(i) of the BEREC regulation.[5] Such a report will provide input to an assessment of the need to revise the guidelines.

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

8. 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]

9. 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

[5] Regulation (EU) 2018/1971 of the European Parliament and of 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, 17 Dec. 2018 (p. 1-35)

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].*

10. 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)).

11. 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 is in line with the principle of technology neutrality based on the equivalence of the achievable performance of the networks.

12. 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'.

13. 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.

14. 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**).

15. 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 11, 14c and 14d) is considered with regard 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 segment 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. Given also that the EECC does not provide a definition of the term 'serving location', a different approach might be arbitrary and even technically impossible to implement. In addition, if it would be considered that the baseline scenario does not include the access network this would mean that a legacy network with fibre rolled-out solely to the local exchange (FTTEx) would have to be considered as a very high capacity network. BEREC considers that this is not the intention of the EECC.

16. 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.

17. 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 that a network has to fulfil in order to be considered a 'very high capacity network'

18. The term 'very high capacity network' is already defined in the EECC (see section 2) and the criteria provided in this section follow this definition. Criteria 1 and 2 below result directly from the first part of the definition, while criteria 3 and 4 below are based on the second part of the definition, using data collected from network operators (see section 4).

19. In accordance with the EECC, 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.

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	≥ 350 Mbps
b.	Uplink data rate	≥ 50 Mbps
c.	IP packet error ratio (Y.1540)	≤ 0.01%
d.	IP packet loss ratio (Y.1540)	≤ 0.01%
e.	Round-trip IP packet delay (RFC 2681)	≤ 18 ms
f.	IP packet delay variation (RFC 3393)	≤ 5 ms

g. IP service availability (Y.1540) ≥ 99.9% per year

20. Notes to criterion 1 and criterion 2

    a. Criterion 1 and criterion 2 result directly from the EECC (see section 2).[6]

    b. A network which qualifies as a very high capacity network according to criterion 1 does not necessarily fulfil criterion 3.

    c. A network which qualifies as a very high capacity network according to criterion 2 does not necessarily fulfil criterion 4.

21. Notes to criterion 3 and criterion 4

    a. For the qualification as a very high capacity network, it is sufficient that a network (without any further investments) 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 a service nor that all services provided by the network have to meet the performance thresholds 1 or performance thresholds 2. However, in order to determine whether a network does have these capabilities an NRA may demand that a test service which meets the performance thresholds 1 or the performance thresholds 2 is implemented in the network.

    b. Criteria 3 and 4 refer to peak-time. This is the time of the day with a typical duration of one hour where the network load usually has its maximum.[7]

    c. The performance thresholds 1 and performance thresholds 2 refer to the path from the end-user[8] 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 54 and 55).

    d. The threshold data rates of performance thresholds 1 are data rates at the level of the IP packet payload and the threshold data rates of performance thresholds 2 are data rates at the level of the transport layer protocol payload.[9]

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[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.

[7] The peak-time may differ across networks and regions. The time period of the peak-time is typically one hour since network dimensioning is usually based on the network load during busy hour and, therefore, on a duration of one hour.

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

[9] The data rates of performance thresholds 2 are data rates at the level of the transport layer protocol payload in accordance with the BEREC Guidelines on the Implementation of the Open Internet Regulation (BoR (22) 81, paragraphs 140 and 166): '*Speeds should be specified on the basis of the transport layer protocol payload, and*

e. 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.

f. 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.[10]

g. The performance thresholds 2 refer to outdoor locations only and to the average value within the coverage area considered (see paragraphs 77 and 78).

h. Events outside the network operator's control (e.g. force majeure) are excluded from the calculation of the IP service availability.

22. 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).

23. A 'wireless very high capacity network' (i.e. a network that meets either criterion 2 or criterion 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'.[11] 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').

24. 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.

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

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not based on a lower layer protocol [e.g. IP packet payload]'. The data rates of performance thresholds 1 are data rates at the level of the IP packet payload, in accordance with the BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules (BoR (16) 127, paragraphs 140 and 166), which were in force 2019 when the data for the determination of performance thresholds 1 were collected (see section 4.6) and which have been superseded by the BEREC Guidelines BoR (22) 81.

[10] The distances refer to orthodromic distances (not to distances from earth to satellite and back to earth).

[11] The 'wireless very high capacity network' has to meet the performance thresholds of criterion 3 at locations where the end-user uses its service indoor similarly as in case of services providing a fixed-line connection. For example, in case of Fixed Wireless Access both would be possible, indoor devices and also devices mounted on the roof or the facade of the building in which the end-user uses the service.

26. 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

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

28. The performance thresholds 1 and 2 need to be determined as defined in paragraph 16, according to the analysis of the relevant legal provisions in the EECC (see section 2, in particular paragraphs 14 and 15).

29. 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

30. The performance thresholds 1 refer to a fixed network with fibre roll out up to the multi-dwelling building (see paragraph 16a). 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.

31. The performance thresholds 2 refer to a wireless network with fibre roll out up to the base station (see paragraph 16b). 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

32. The performance thresholds 1 and 2 refer to the ‘achievable’ end-user QoS (see paragraph 16). Therefore, they are determined based on the ‘best’ technology with regard to the achievable end-user QoS.

33. These Guidelines entered into force for performance thresholds 1 in October 2020 and enter into force for performance thresholds 2 from October 2023 onwards and, therefore, the focus is as much as possible on technologies which will be deployed in networks in this time period.

34. 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.

35. 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.

36. 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).[12] 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.

37. For this reason, the following technologies of the networks mentioned in section 4.1 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, the most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO[13], modulation etc. used in the mobile network of the respective operators.

4.3 'Peak-time conditions'

38. The performance thresholds 1 and 2 have to be determined 'under usual peak-time conditions' (see paragraph 16). Therefore, realistic conditions prevailing in networks which correctly reflect end-user experiences need to be considered. For this reason, the 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.

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[12] At the time when the data were collected (see section 4.6)

[13] Multiple-Input and Multiple-Output

39. Since the performance thresholds 1 and 2 need to be based on the achievable (and not currently achieved) end-user QoS (see paragraph 16), they are determined based on the service with the highest end-user QoS (data rate) possible with the 'best' technology deployed in the network.[14] 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 104.b and 104.f).

4.4 'Typical' end-user QoS

40. 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. average).

41. Since an average QoS is considered, different characteristics of the air (e.g. due to different weather 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).

42. 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

43. 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 12).

General applicability

44. 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 16a and 16b). 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.

[14] At the time of data collection.

45. 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, an exception are the downlink and uplink data rates (see paragraph 47).

Entire communications network

46. 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 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

47. The first two QoS parameters are the downlink and the uplink data rate.[15] Since the QoS parameters should be based on IP (see paragraph 45), the performance thresholds 1 are based on the downlink and uplink data rate of the IP packet payload, in accordance with the BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules (BoR (16) 127), which were in froce 2019, when the data for performance thresholds 1 were collected. The performance thresholds 2 are based on the downlink and uplink data rate of the transport layer protocol payload, in accordance with the BEREC Guidelines on the Implementation of the Open Internet Regulation (BoR (22) 81, paragraphs 140 and 166), which supersede the BEREC Guidelines BoR (16) 127 and do no longer foresee that the data rate is based on the IP packet payload.[16]

Latency and its variation

48. For latency and its variation, it is necessary to consider IP-based QoS parameters (see paragraph 45). 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).[17]

[15] 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).

[16] The QoS parameters and also the downlink and uplink data rate need to be determined under usual peak-time conditions (see criteria 3 and 4, paragraph 19). The speed parameters defined in the BEREC Guidelines on the Implementation of the Open Internet Regulation (BoR (22) 81, p. 42-44) do not refer to ‘under usual peak-time condition’ and, therefore, cannot be applied in these Guidelines.

[17] 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.

Error-related parameters

49. 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 56 and 58), the stakeholders were explicitly asked whether in their view other error-related parameters are more appropriate.

50. 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 46), it was not possible to use these QoS parameters.

51. 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).[18]

Resilience

52. 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).

53. 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 8). 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 56 and 58), 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.

[18] 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 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.

Path of the QoS parameters

54. The EECC demands that an entire network needs to be considered (see paragraph 46). 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.

55. 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

56. 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.

57. BEREC informed the public at the public debriefing on the outcomes of the 38th BEREC ordinary Plenary meeting on 13 March 2019 in Brussels on this call for initial stakeholder input and sent the 'call for initial stakeholder input' documents and the questionnaires to the following stakeholders:[19]

    a. Network operators (sent by NRAs);

    b. Associations of network operators at EU level;[20] and

    c. Major vendors of equipment for fixed access networks based on G.fast[21] and DOCSIS[22] (etc.) and for mobile networks.[23]

58. 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

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

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

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

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

[23] Nokia, Huawei, Ericsson, ZTE

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.

59. For the update of criterion 4 (performance thresholds 2), BEREC asked the mobile network operators to complete the questionnaire for 5G mobile network operators (sent by NRAs) in May 2022.

60. 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

61. The criteria a network has to fulfil in order to be considered a 'very high capacity network' (see paragraph 19) 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

62. According to criterion 1 (see paragraph 19), 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.

63. 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,[24] and therefore, in case of fibre to the building (FTTB) and also in case of fibre to the home (FTTH).

64. 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 19 and 62).

65. 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.

[24] Or offices and industrial buildings

5.2 Application of the criterion 2

66. According to criterion 2 (see paragraph 19), 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.

67. 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.[25]

68. 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 19 and 66).

5.3 Application of the criterion 3

69. 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 19).

70. For the qualification as a very high capacity network, it is sufficient that the network (without any further investments) 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. However, in order to determine whether a network does have these capabilities an NRA may demand that a test service which meets the performance thresholds 1 is implemented in the network (see paragraph 21.a).

71. 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 the performance thresholds 1 are met.[26] If a sub-area meets performance thresholds 1,

[25] 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.

[26] 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.

then the part of the network that covers this sub-area qualifies as a very high capacity network.

72. A sub-area meets performance thresholds 1 if, under usual peak-time conditions, the end-users[27] in this sub-area would 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, in case end-users in this sub-area measure the data rate of the service with an internet speed test in a random point in time 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.

73. 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 is applicable, for example, to networks with an access network based on

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

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

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

74. As mentioned in paragraph 23, a ‘wireless very high capacity network’ (i.e. a network that meets either criterion 2 or criterion 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

75. 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 19).

76. For the qualification as a very high capacity network, it is sufficient that the network (without any further investments) 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. However, in order to determine whether a network does have

[27] The typically achievable data rates reported by the operators could be provided to those end-users which are currently subscribed to the highest data rate currently offered by the operator (see paragraphs 104.f). Therefore, it should also be assumed that only this share of end-users could get this QoS (e.g. data rate) under usual peak-time conditions.

these capabilities an NRA may demand that a test service which meets the performance thresholds 2 is implemented in the network (see paragraph 21.a).

77. 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 stations). For each sub-area, it needs to be determined whether the performance thresholds 2 are met.[28] 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.

78. A sub-area meets performance thresholds 2, if, under usual peak-time conditions, in this sub-area an end-user[29] would experience on average at least the QoS of the performance thresholds 2 at outdoor locations. For example, in case the data rate in this sub-area is measured during peak-time with a drive test, then the average value of the measured data rate would be at least 350 Mbps in downlink and 50 Mbps in uplink (at the level of the transport layer protocol payload) in case the mobile equipment used in the drive test sufficiently supports the technology used in the wireless network.

79. 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).

[28] 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.

[29] The typically achievable data rates reported by the operators could be provided to those end-users which are currently subscribed to the highest data rate currently offered by the operator (see paragraphs 104.f). Therefore, it should also be assumed that only this share of end-users could get this QoS (e.g. data rate) under usual peak-time conditions.

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

80. 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.

<u>Art. 1</u>

81. 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.

<u>Art. 2</u>

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

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

<u>Art. 3</u>

84. 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.

85. 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. […]'.

<u>Art. 22</u>

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

87. 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))

88. 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))

89. 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.'

90. 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>

91. 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>

92. 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>

93. 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>

94. 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 consist of optical fibre elements up to the end-user premises or base station under certain conditions related to co-investment.

95. 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.

Art 105

96. 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

97. 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

98. The determination of the performance thresholds 1 (see paragraph 14c) 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 30 and 37):

    a. G.fast on (usual) twisted pair;[30] and

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

99. The determination of the performance thresholds 2 (see paragraph 14d) is based on mobile networks with fibre roll out up to the base station (see paragraph 31) and the most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO[31], modulation etc. (see paragraph 37c).

100. Therefore, data were collected based on the following questionnaires:[32]

    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 5G mobile network operators.

[30] 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.
[31] Multiple-Input and Multiple-Output
[32] 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 100.b). However, since a sufficient high number of operators filled in the questionnaire referred to in paragraph 100.b, this was not necessary.

101. 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).

102. 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 226 to 228) 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 17).

Main question

103. 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. For a description of the QoS parameters see section 4.5 above in the main body.

104. 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[33] should not be taken into account; and

e. In case of mobile networks also: only consider the part of your 5G mobile network with fibre to the base station and the most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO, modulation, etc.

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

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

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).[34] This service is provided to the end-users which are currently subscribed to the service with the highest data rate from scenario 1.[35]

In case of 5G and scenario 2, condition e is the same, however, since field trials are considered (see f above) it may refer to a different 5G technology, the 5G technology used in the field trial.

105. The network operators were asked to provide estimated values of the achievable end-user QoS[36] 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).

106. Altogether, the main question asked for the typically achievable data rate (and other QoS parameters) under the conditions mentioned above (paragraph 104) 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,[37] if the CPE/ME fully supports the technology in the network (no limitations by CPE/ME).

107. 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

108. In the update of criterion 4 in 2023, the "achievable data rate" was further clarified in the questionnaire as follows, as in 2019 the answers form the mobile network operators received showed that this clarification was necessary.

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[34] In case of the update of criterion 4 in 2023, the wording was slightly adapted as follows to make the difference of scenario 2 compared to scenario 1 clearer: "For a mobile service based on the most advanced 5G technology deployed in a pilot project or a field trial in your network."

[35] 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.

[36] In case of 5G mobile networks outdoor.

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

a. The “achievable data rate” is the data rate which an end-user would measure with an internet speed test. Please provide the average value of this data rate outdoor during peak-time and over the coverage area of scenario 1 / scenario 2. Therefore, this area includes not only locations near the base stations but also those locations further away, but which are still covered by the most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO, modulation, etc. However, this area should not be limited to only one (or a few) small area(s) covered by mmWave spectrum, because a mobile coverage area typically does not consist only of such small areas. In addition, the conditions of paragraph 104.a to 104.e apply.

b. For example, if measurements from drive tests are available for scenario 1, the answer to question 2 would be an average of all measured speeds during peak time in the area with the most advanced 5G technology (however, not limited to only one (or a few) small area(s) covered by mmWave spectrum, see paragraph 108a above). In addition, the measurements should be representative for this coverage area. The achievable data rate is not 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) and it is also not the average data rate of the real traffic in the network during peak-time, which depends on how end-users use their service.

109. Since at the time of data collection (May to June 2022, see paragraph 59) the mobile network operators were still rolling out 5G, their new 5G networks may not yet have been fully used. In the following two years, the number of end-users who use 5G services and consequently also the 5G network load may increase and, therefore, the “achievable data rate” may decrease. This could be (partly) compensated by a more advanced 5G technology (e.g. more spectrum, more parallel MIMO data streams) which the mobile network operators may then deploy. Therefore, the 5G mobile network operators were asked if they expect the "achievable data rate" they reported to decrease in the next two years, and if so, approximately to what extent (5% / 10% / 15% / 20% / 30% / other).

Additional questions

110. 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.

111. 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 and the population coverage of these base stations (in case of mobile networks).

2. Number of completed questionnaires

112. 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 5G mobile network operators was completed by 44 operators and 19 (43%) 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
5G mobile network	44/34[38]	19
Total	194/184	105

Source: BEREC

113. 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 trial, nor pilot deployment nor regular operation;

c. In case of both scenarios, the main question was not answered with regard to the achievable data rate or the achievable data rate is obviously implausible[39]

d. The answers inform that they do not fulfil the conditions of question 2 (see paragraph 104);

[38] Ten mobile network operators completed the questionnaire but did not provide data on the QoS parameters (see paragraph 114).

[39] 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.

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

f. The answers are unclear.

114. 25 questionnaires for 5G mobile network operators were not taken into account for the following reasons:

a. The operator does not (yet) deploy a 5G mobile network (6 operators);

b. The operator informed that it is not possible to answer the main question (see paragraphs 103 to 108) as it does not have these data (4 operators);

c. The answers inform that they do not fulfil the conditions of question 2 (see paragraph 104) (8 operators) or the operator did not confirm this (7 operators).

115. 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

116. Bulgaria, Latvia and Slovakia are represented rather strongly. However, this is limited to only one questionnaire, namely 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.

117. Table 3 provides an overview of the number of completed questionnaires for 5G mobile network operators received per country.

118. The 5G mobile network questionnaire has been filled in by 44 operators of 20 European countries and the questionnaires of 19 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)

Country	Questionnaire	Country	Questionnaire	Country	Questionnaire
Austria		Finland	3/3	Netherlands	
Belgium	1/3	Greece	1/2	Poland	
Bulgaria	1/2	Hungary	0/2	Portugal	1/2
Croatia	1/5	Ireland		Romania	1/1
Cyprus	0/1	Italy	3/4	Spain	2/2
Czech Republic	1/1	Latvia	1/3	Sweden	
Germany	0/1	Lithuania	0/1	Slovenia	2/4
Denmark	0/3	Luxembourg		Slovakia	
Estonia	0/1	Macedonia	0/1		
France		Malta	1/2		

Source: BEREC

3. Questionnaires for vendors

119. Vendors do not operate networks and do not offer electronic communications services, therefore, it is not possible to ask vendors the same main question the network operators were asked (see paragraphs 103 to 108). 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.

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

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

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

121. 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.

122. 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.

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

123. This annex determines the performance thresholds 1 (see paragraph 16a) based on the data collected from fixed network operators (see annex 2).

124. 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 30) and the use of the following access technologies are considered (see paragraphs 37a and 37b).

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

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

125. 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).

126. 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 16a). Therefore, the determination of the performance thresholds 1 focuses on scenario 2 (not scenario 1) of the main question in the questionnaires (see paragraphs 104 and 107).

127. 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.

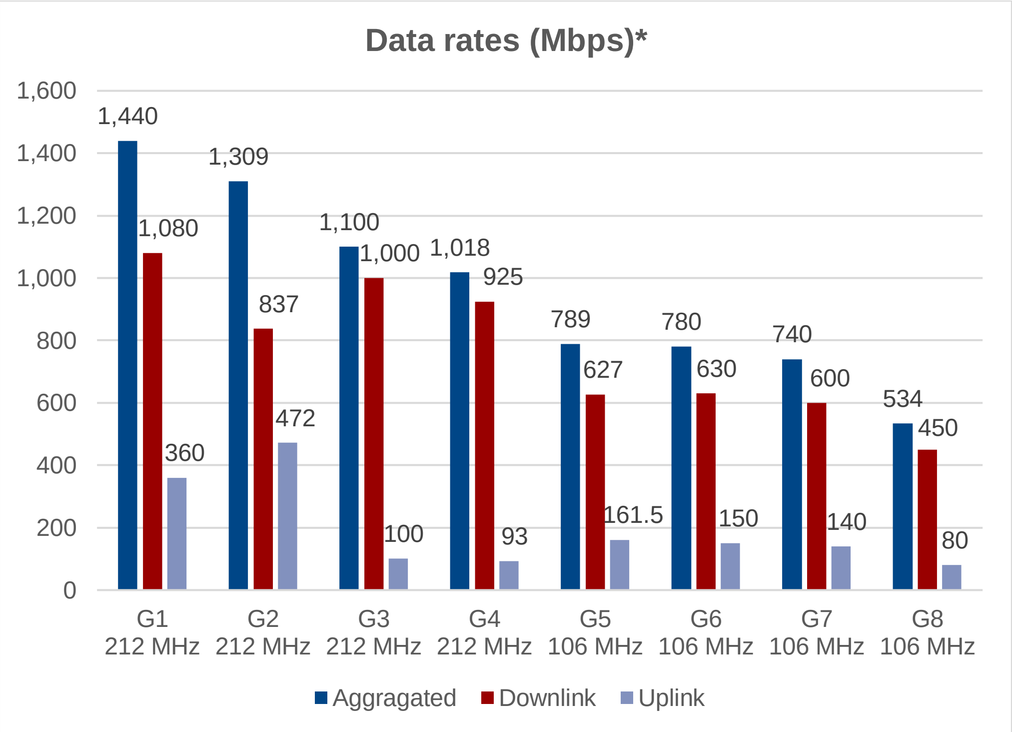
1. Downlink and uplink data rate

128. 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 124).

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

129. 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 104 scenario 2 and paragraph 126), according to 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 47).

130. 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 106). Four of these eight operators use the frequency spectrum up to 212 MHz, the other four use it 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) and all data are based on one twisted pair.
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

131. 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.

132. 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.

133. Since the performance thresholds 1 have to be based on the 'best' technology with regard to the achievable data rate (see paragraph 32), only the data rates provided for G.fast with 212 MHz are relevant for the determination of the performance thresholds 1.

134. 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 its experiences with this technology in a lab environment (it has not yet implemented it in field trial).

135. 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.

136. 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[40] 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).[41]

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.[42]

137. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 127) 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 131) and therefore e.g. 1,000 Mbps in downlink and 200 Mbps in uplink.

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[40] Star quad cable, diameter 0.5 mm, length 100 m, 3 dB margin

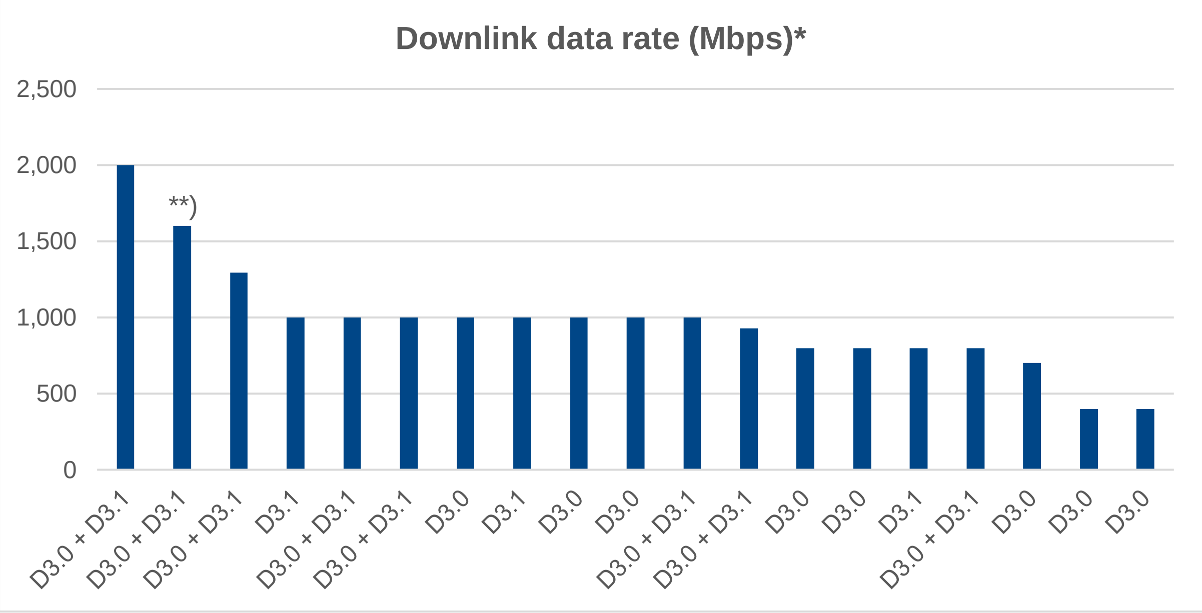
[41] No further information was provided on these target values and the common network requirements.

[42] 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

138. 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 104 scenario 2 and paragraph 126) 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 47).



*) 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

139. 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 106). In downstream direction, 11 operators use DOCSIS 3.1, eight of them together[43] with DOCSIS 3.0, and the other eight operators use only DOSICS 3.0.

140. 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 paragraph

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

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

141. 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 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.

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

143. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 127) and the median of the typically achievable downlink data rate of the 11 operators who use 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

144. 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.

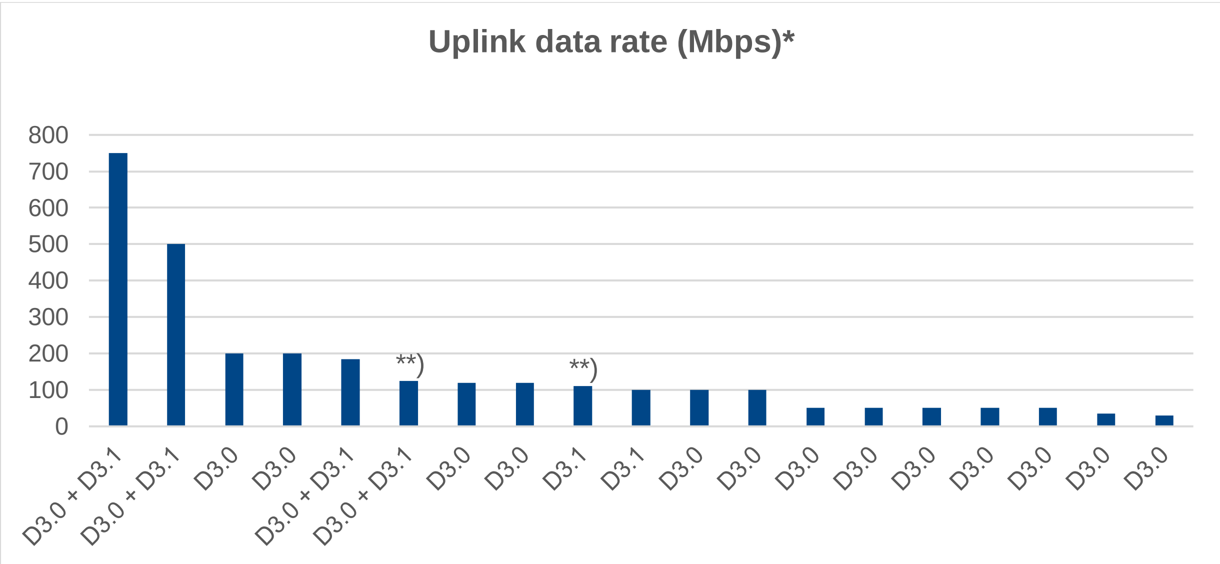
Table 5: Total downlink capacity of a coax network based on DOCSIS 3.0 and DOCSIS 3.1

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

145. 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 104 scenario 2 and paragraph 126) 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 47).



*) 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

146. 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 106). In upstream direction, six operators use DOCSIS 3.1, four of them together[44] with DOCSIS 3.0, and 13 operators use only DOSICS 3.0.

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

147. For the determination of the performance thresholds 1, only the data rates provided for DOCSIS 3.1 are relevant (see paragraph 140) and some variation in the data rates can be expected and is plausible (see paragraph 141).

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

149. The performance thresholds 1 are based on the median of the values reported by the network operators (see paragraph 127) and the median of the typically achievable uplink data rate is 160[45] Mbps.

150. 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 144). 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

151. 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 32 and 33).

152. 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 132); and

b. DOCSIS 3.1 on in-building coax network (see paragraph 140).

[45] Rounded value

153. 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 137). 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 143 and 149), i.e. an aggregated data rate of 1,160 Mbps.

154. The aggregated data rate of performance thresholds 1 need to be based on the achievable aggregated data rate (see paragraph 16a) 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.

155. 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 131). 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**.

156. The threshold data rates are data rates at the level of the IP packet payload (see paragraphs 43 to 47) and at the point where the fixed subscriber access line (e.g. twisted pair, coax cable) ends in the end-user’s living space.

157. 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 19) and do not need to meet the threshold data rates of performance thresholds 1.

2. Other QoS parameters

158. This section determines the thresholds of the other QoS parameters of the performance thresholds 1 (see paragraphs 125.c to 125.g).

159. The threshold aggregated data rate of performance thresholds 1 (1,200 Mbps) is defined based on G.fast 212 MHz (see paragraph 154). Only very few G.fast 212 MHz operators, if any, provided data for the other QoS parameters.

160. 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 153). 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.

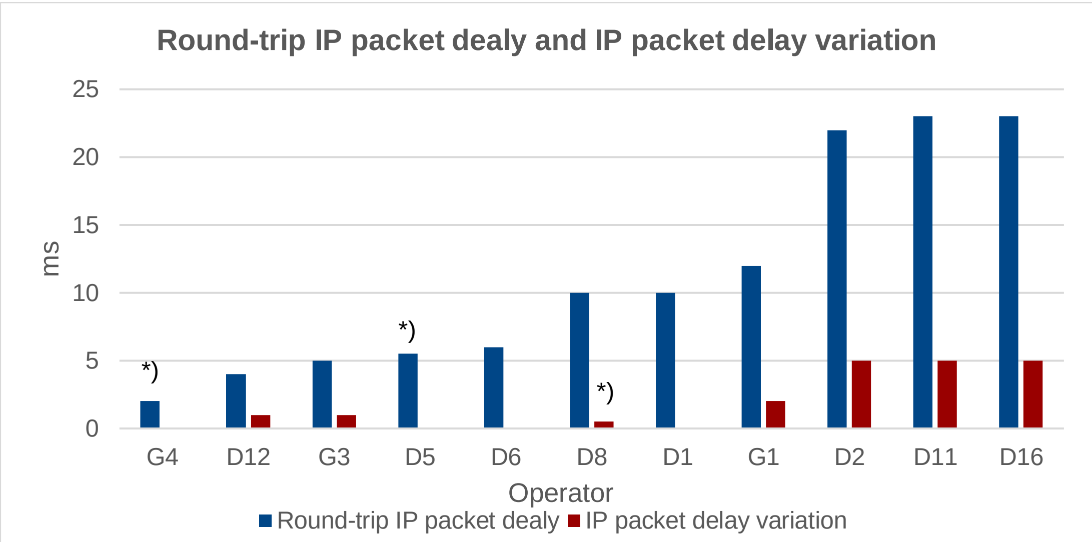
161. Not all network operators who provided data for the data rates were able to provide also data for the other QoS parameters. In response to the first phase of the call for initial stakeholder input (see paragraphs 56 and 58), network operators informed that they provide services to end-users without 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 8). 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.

162. 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 55).

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

163. 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 104 scenario 2 and paragraph 126) based on the answers received from 11 operators.



*) 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

164. 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).[46] 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.

165. Therefore, the round-trip IP packet delay depends on the dimensioning of the network nodes and on the distance over which the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraph 162). For these reasons, some variation in the IP packet delay can be expected and is plausible.

166. 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.[47]

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

167. 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.

168. 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.

[46] 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.

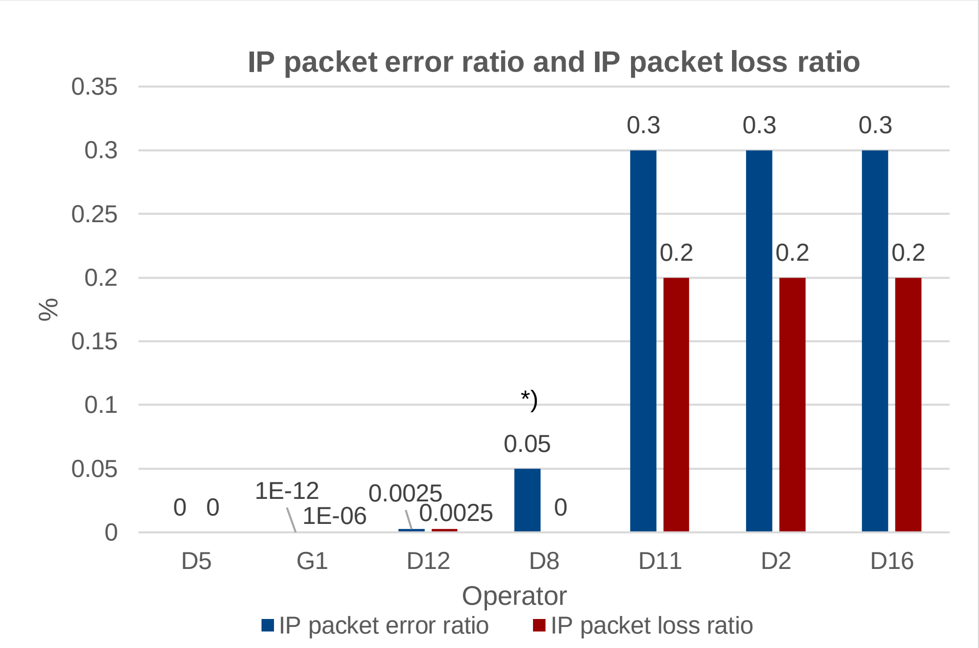
[47] See http://www.m2optics.com/blog/bid/70587/Calculating-Optical-Fiber-Latency

169. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 127). 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**.

170. 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 166).

b. IP packet error ratio and IP packet loss ratio

171. 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 104 scenario 2 and paragraph 126) according to 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

172. IP packets may get lost in the queuing and the processing of the data flow in the network nodes. This processing and, in addition, the transmission of IP packets may also result in IP packet errors. Therefore, the IP packet loss ratio, i.e. the ratio of the lost IP packets to the transmitted IP packets, depends on the dimensioning of the network nodes while on the other hand, the IP packet error ratio, i.e. the ratio of the errored IP packets to the sum of error-free and errored IP packets, depends on the processing and transmission quality.

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

174. The typically achievable IP packet error ratio varies between 0%[48] and 0.3% and the median is 0.05%. The typically achievable IP packet loss ratio varies between 0%[48] 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[48]	0[48]
G1	10E-12	10E-6
D12	0.0025	0.0025
D8	<0.1	0[48]
D11	0.3	0.2
D2	0.3	0.2
D16	0.3	0.2
Median	0.05	0.0025

Source: BEREC

175. 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).

176. 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.[49] According to these measurements, the IP packet error ratio and the IP packet loss ratio during peak-time are 10E-5 %.

177. 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

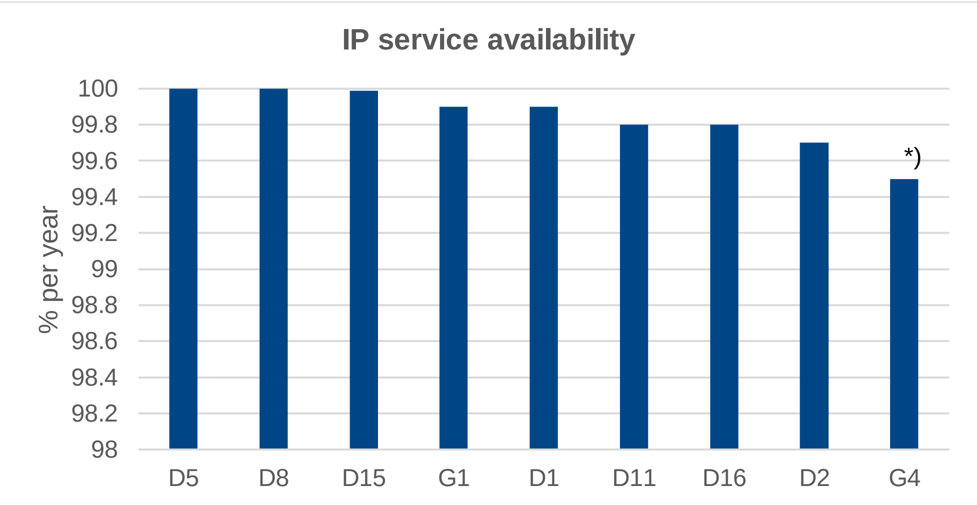
[48] Estimations of the achievable IP packet error ratio and IP packet loss ratio were possible (see paragraph 161) and a value of 0% maybe be an estimation for a value very close to 0%.
[49] 200 pairs cable, diameter 0.5 mm, length 100 m

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 55 and 162).

178. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 127, 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

179. 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 104 scenario 2 and paragraph 126) 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

180. 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%50 per year and the median is 99.9% per year.

181. 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 55 and 162).

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[50]
D8	100[50]
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

182. The determination of the performance thresholds 1 is based on the median of the values reported by the network operators (see paragraph 127, Table 9). Therefore, **the threshold IP service availability of the performance thresholds 1 is set to 99.9% per year**.

[50] Estimations of the achievable IP service availability were possible (see paragraph 161) 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)

183. This annex determines the performance thresholds 2 (see paragraph 16b) based on the data collected from mobile network operators (see annex 2).

184. The determination of the performance thresholds 2 is based on mobile networks with fibre roll out up to the base station (see paragraph 31) and the use of the most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO, modulation etc. (see paragraph 37c).

185. 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).

186. 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 16b). Therefore, the determination of the performance thresholds 2 should in principle focus on scenario 2 of the main question in the questionnaires (see paragraphs 104 and 107). However, 5G mobile network operators began rolling out 5G technology in their networks around 2020 and, therefore, the most advanced 5G technology of scenario 1 at the time of data collection (May to June 2022, see paragraph 59) was a very new 5G technology. Therefore, only a few of the 19 5G mobile network operators, whose completed questionnaire have been taken into account (see paragraphs 112 and 118), reported data for scenario 2, and most of them reported data only for scenario 1, as at that time they may not had a need for further field trials. For these reasons, the analysis is mostly based on scenario 1.

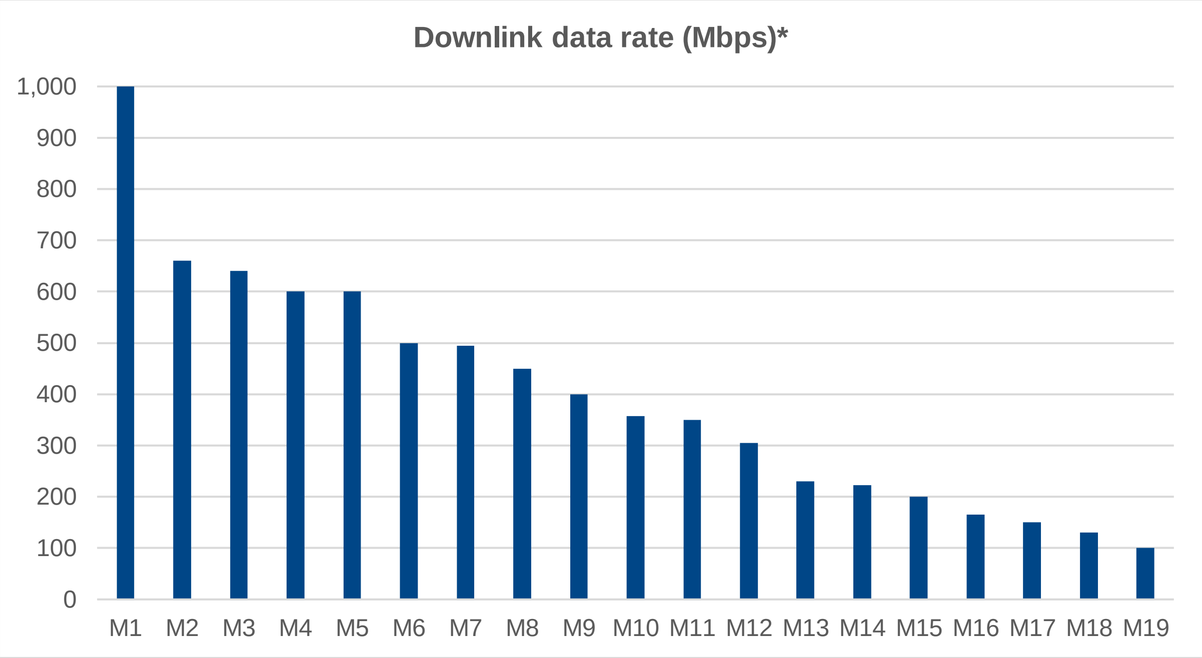
187. BEREC received answers to the relevant questionnaires from several operators and therefore a range of values for each of the QoS parameters a.-g. mentioned above. Since the performance thresholds should reflect parameters which are typically achievable, the median of these values is used as a basis to determine the performance thresholds 2. 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

188. 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 most advanced 5G technology in terms of aggregated radio channel bandwidth, MIMO, modulation etc. (see paragraph 184).

Downlink data rate

189. Figure 7 and Table 10 show the average value of the achievable downlink data rates outdoor in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network under the conditions given in the questionnaire (see paragraph 104) based on the answers received from 19 operators.



*) Of the transport layer protocol payload
Source: BEREC

Figure 7: Average value of the achievable downlink data rate outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

The achievable downlink data rate outdoor 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 most advanced 5G technology (in terms of aggregated spectrum, MIMO order, modulation etc., see paragraphs 99 and 108). The downlink data rates shown are data rates at the level of the transport layer protocol payload (see paragraph 47).

Table 10: Average value of the achievable downlink data rate outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

Operator	**Average data rate (Mbps)***		**Aggregated radio channel bandwidth downlink (MHz)**			**MIMO downlink**	
	Downlink	Uplink	**5G** Low band	**5G** Mid band	**5G+4G** Total	**5G** Low band	**5G** Mid band
M1	1.000	150	20	100	220	2x4	64x64
M2	660	60	10	100	175	2x2	4x4
M3	640	75		100	150		64x64
M4	600	100-120		65	130		4x4, 32x32
M5	600	50		100	160		4x4
M6	500	50	10	100	110	2x2	4x4
M7	494	50		100	110		4x4
M8	450	80	5	90	160	2x4	4x4
M9	400	20		100	185		8x8
M10	357	17		100	140		64x64
M11	350	30		100	100		4x4
M12	305	32		100	160		32x32
M13	230	64		100	150		64x64
M14	223	42		50	100		4x4
M15	200	15		20	50		4x4
M16	165	NI***)		80	130		2x2, 4x4
M17	150	50		80	5G+4G**)		Up to 64x64
M18	130	40		40	90		4x4
M19	100	50	10	90****)	NI***)	2x2	mMIMO*****)

*) Of the transport layer protocol payload, **) Aggregated radio channel bandwidth is based on aggregation of 5G and 4G, data on 4G aggregated radio channel bandwidth is not available, ***) No information, ****) In addition, 200 MHz in mmWave bands (24 GHz and higher), *****) Massive MIMO

Low band means < 1 GHz and mid band 1-6 GHz

The total aggregated radio channel bandwidth is based on an aggregation of 5G and 4G if it is higher than the 5G aggregated radio channel bandwidth (low plus mid band), otherwise it is based on 5G only.

The Modulation is 256 QAM in downlink (low and mid band) with the following exceptions. In case of M12, M15 and M16 it is maximum 256 QAM and in case of M14 64 QAM.

Source: BEREC

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

a. The 5G technology used (aggregated radio channel bandwidth, MIMO order, modulation, transmit power, geometrical parameters of the antenna, etc.);

b. The total aggregated radio channel bandwidth, whether it is based on an aggregation of 5G and 4G or on 5G only;

c. The number of the end-users who share the same 5G 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;

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

5G is also a new technology currently rolled out by the mobile network operators. Overall, it follows that considerable variation in the data rates can be expected and is plausible.

191. The average value of the achievable downlink data rate outdoor during peak-time varies between 100 Mbps and 1000 Mbps and the median is 357 Mbps.

192. In the next two years[51], the number of end-users who use 5G services and consequently also the 5G network load may increase and, therefore, the average value of the achievable data rate may decrease. This could be (partly) compensated by a more advanced 5G technology (e.g. more spectrum, more parallel MIMO data streams) which the mobile network operators may then deploy. The higher the average value of the achievable data rate the mobile network operator reported, the more advanced 5G technology (e.g. 5G spectrum, MIMO) may already be used and therefore, in principle, the lower the possibilities to deploy a further advanced 5G technology.

193. Table 11 shows the reported expected decrease (in three cases even an increase) in the next two years[51] of the average value of the achievable downlink data rates listed in Table 10, based on the answers received from 12 out of 19 operators (see paragraph 109).[52]

194. Seven of these 12 operators reported average values of the achievable downlink data rate below the median (M11, M12, M14, M15, M17, M18, M19), one operator (M12) expected a slight decrease (5%) and the two operators (M18, M19) which reported the lowest values of this data rate, even expected an increase, however, not to a level above the median.[53] Therefore, expected changes on achieveable downlink data rates reported by these seven operators do not have an impact on the median in the two year horizon.

195. Four of the 12 operators reported average values of the achievable downlink data rate above the median (M3, M4, M7, M8), three expected a decrease, M7 at a maximum 10%, M3 of 10% and M4 at a maximum 20%, however, values from all three operators remain above the median. Therefore, expected decreases reported by these three operators do not have an impact on the median level of achieveable downlink data rates in the two year horizon.[54] Similarly, the value reported by the fourth operator (M3) does not change the median, as it reported an expected increase.

196. The operator (M10) which reported an average value of the achievable downlink data rate at the level of the median (357 Mbps) expected a decrease of 10% (321 Mbps) and

[51] From the time of data collection in June 2022.

[52] The seven other oprators (M1, M2, M5, M6, M9, M13, M16) did not provide any values.

[53] Operator M19 expects an increase of the average value of the achievable downlink data rate it reported, but it was not possible for it to quantify this increase. However, it is assumed that in the next two years this data rate will not triple and, therefore, not increase above the median.

[54] Operator M9 reported an average value of the achievable downlink data rate of 400 Mbps (see Table 10) and informed that it is not possible for it to answer the question whether and, if it is the case, to what extent this data rate will decrease in the next two years. However, if it would decrease by 10 % as in case of operator M10, this would not have an impact on the median.

therefore falls below operator M11 (350 Mbps). This results in a reordering of the list of average values of the achieveable downlink data rates in Table 10 and M11 and M10 swap places. Consequently, the median changes and the new value is 350 Mbps (the value changes from 357 Mbps to 350 Mbps) reflecting the expected outlook over a two year horizon as reported by the operators.

197. In summary, the threshold downlink data rate of the performance thresholds 2 needs to be based on the median of the values reported by the network operators (see paragraph 187), taking into account the slight decrease of the median in the next two years due to the increase of 5G users (see paragraphs 192 to 196). Therefore, **the threshold downlink data rate of the performance thresholds 2 is set to 350 Mbps** and it refers to the data rate at the level of the transport layer protocol payload (see paragraphs 47) and to outdoor locations only.

Table 11: Expected decrease in the next two years of the average value of the achievable downlink data rate

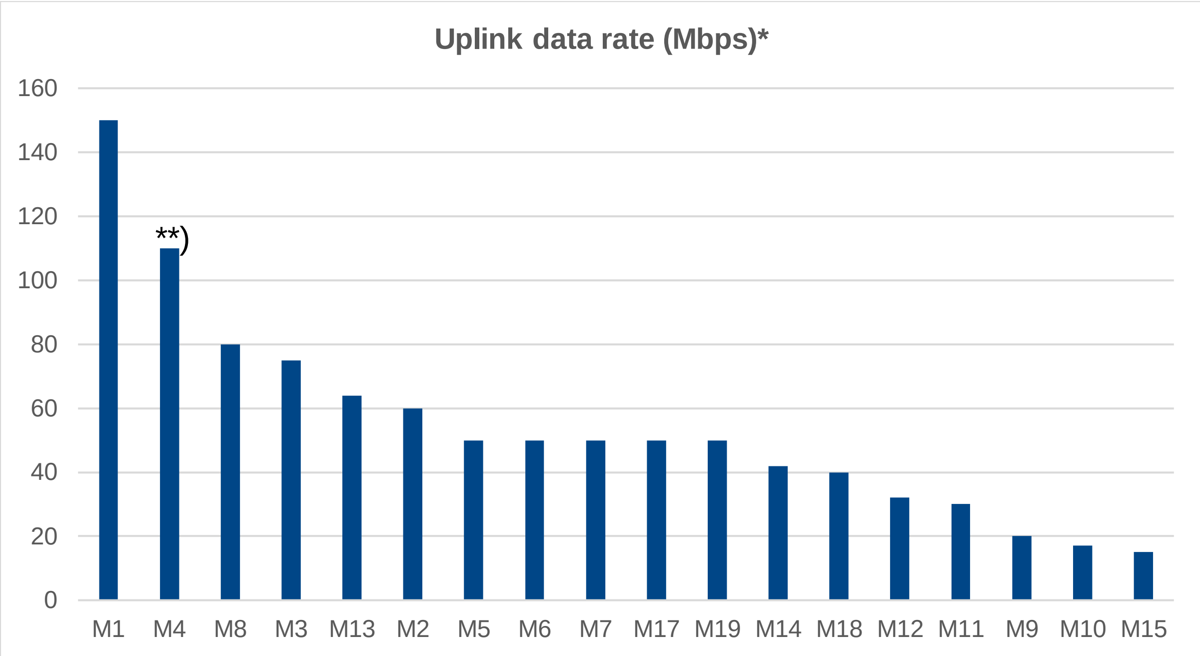
Operator	**Average value of the achievable downlink data rate (Mbps)***		
	Reported)**	**Expected decrease in the next two years***)**	**In two years***)**
M3	640	10% increase	704
M4	600	Max. 20% decrease	≥ 480
M7	494	Max. 10% decrease	≥ 445
M8	450	20% decrease	360
M10	357	10% decrease	321
M11	350	No decrease	350
M12	305	5% decrease	290
M14	223	No decrease	223
M15	200	No decrease	200
M17	150	No decrease	150
M18	130	Increase of max. 50%	≤ 195
M19	100	Increase	> 100

*) Of the transport layer protocol payload, **) See Table 10, ***) From the time of data collection in June 2022
Source: BEREC

Uplink data rate

198. Figure 8 and Table 10 show the average value of the achievable uplink data rates outdoor in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network under the conditions given in the questionnaire (see paragraph 104) based on the answers received from 18 operators. The uplink data rates shown are also data rates at the level of the transport layer protocol payload (see paragraph 47).

199. The average value of the achievable uplink data rate outdoor during peak-time varies between 15 Mbps and 150 Mbps and the median is 50 Mbps.



*) Of the transport layer protocol payload, **) Range 100-120 Mbps (see Table 10)
Source: BEREC

Figure 8: Average value of the achievable uplink data rate outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

200. Table 12 shows the reported expected decrease (in three cases even an increase) in the next two years[55] of the average value of the achievable uplink data rates listed in Table 10, based on the answers received from the same 12 operators (see paragraphs 192 to 196).

201. Three (M8, M10, M12) of these 12 operators expected the average value of the achievable uplink data rate to decrease. Two of them (M10, M12) reported values below the median and the other (M9) a value above the median, but it does not fall below the median. Therefore, the expected decrease of these three operators does not have an impact on the median.

202. Three other operators (M3, M18, M19) expected the average value of the achievable uplink data rate even to increase. One of them (M19) moves from the median (50 Mbps) above the median (>50 Mbps) and one other operators (M18) may also move from below the median (40 Mbps) to above the median (up to 60 Mbps). However, this does not have an impact on the median, as four operators (M5, M6, M7, M17) reported the value of the median (50 Mbps). The third operator (M3) is above the median and, therefore, also does not change the median.

[55] From the time of data collection in June 2022.

203. The threshold uplink data rate of the performance thresholds 2 needs to be based on the median of the values reported by the network operators (see paragraph 187), taking into account that the median is not expected to decrease in the next two years due to the increase of 5G users (see paragraphs 200 to 202201). 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 transport layer protocol payload and to outdoor locations only.

Table 12: Expected decrease in the next two years of the average value of the achievable uplink data rate

Operator	**Average value of the achievable uplink data rate (Mbps)***		
	Reported)**	**Expected decrease in the next two years***)**	**In two years***)**
M4	100-120	No decrease	100-120
M8	80	20% decrease	64
M3	75	5% increase	79
M19	50	Increase	> 50
M17	50	No decrease	50
M7	50	No decrease	50
M14	42	No decrease	42
M18	40	Increase of max. 50%	≤ 60
M12	32	10% decrease	29
M11	30	No decrease	30
M10	17	10% decrease	15
M15	15	No decrease	15

*) Of the transport layer protocol payload, **) See Table 10, ***) From the time of data collection in June 2022
Source: BEREC

2. Other QoS parameters

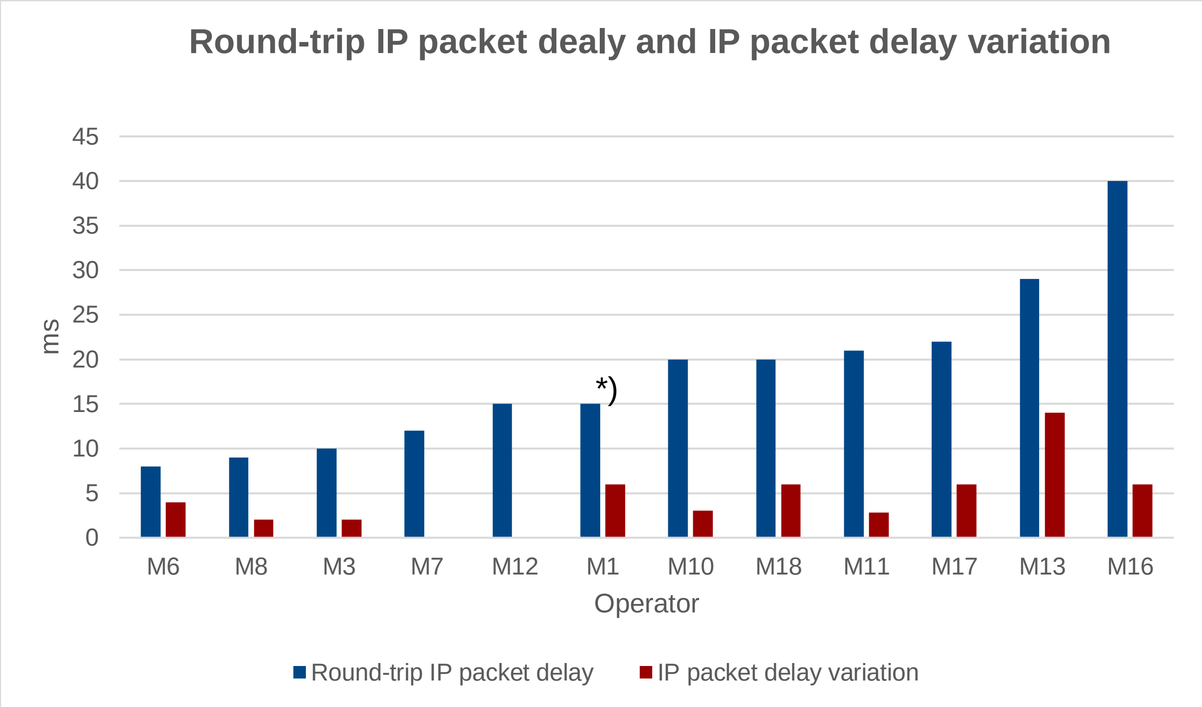
204. This section determines the thresholds of the other QoS parameters of the performance thresholds 2 (see paragraphs 185.c to 185.g)..

205. 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 56 and 58), 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 8). In order to enable as much operators as possible to provide data for the other QoS parameters, the questionnaire foresees also the possibility to provide estimated values of the QoS parameters.

206. 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 55).

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

207. Figure 9 and Table 13 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 most advanced 5G technology used in this network and under the conditions given in the questionnaire (see paragraphs 104 and 186) based on the answers received from 12 and ten operators respectively. The average value considers measurements outdoor during peak-time and over the whole coverage area of the most advanced 5G technology (in terms of aggregated radio channel bandwidth, MIMO order, modulation etc., see paragraphs 99 and 108).



*) Range 10-20 ms (see Table 13)
Source: BEREC

Figure 9: Average value of the achievable round-trip IP packet delay and IP packet delay variation outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

208. 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 164 and 166). The node processing is e.g. access network specific in case of the access node (5G base station) and the common data flow forwarding in case of e.g. Ethernet switches and IP routers.

209. 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 over which the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraph 206). For these reasons, some variation in the IP packet delay can be expected and is plausible.

210. 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 13: Average value of the achievable round-trip IP packet delay and IP packet delay variation outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

Operator	Round-trip IP packet delay (RFC 2681) (ms)	IP packet delay variation (RFC 3393) (ms)
M6	8	4
M8	9	2
M3	≤ 10	≤ 2
M7	12	No information
M12	15	No information
M1	10-20	< 6
M10	20	3
M18	20	6
M11	21	2.8
M17	22	6
M13	29	14
M16	≤ 40	≤ 6
Median	*18*	*5*

Source: BEREC

211. The average value of the achievable round-trip IP packet delay varies between 8 ms and 40 ms and the median is 18 ms. The average value of the achievable IP packet delay variation varies between 2 ms and 14 ms and the median is 5 ms (see Table 13).

212. 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 187). Therefore, **the threshold round-trip IP packet delay of the performance thresholds 2 is set to 18 ms and the threshold IP packet delay variation of the performance thresholds 2 to 5 ms**.

213. 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 166 and 208).

b. IP packet loss ratio

214. Table 14 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 most advanced 5G technology used in this network and under the conditions given in the questionnaire (see paragraphs 104 and 186) based on the answers received from nine operators. The average value considers measurements outdoor during peak-time and over the whole coverage area of the most advanced 5G technology (in terms of aggregated radio channel bandwidth, MIMO order, modulation etc., see paragraphs 99 and 108).

215. 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.

216. The average value of the achievable IP packet loss ratio varies between 10-6% and 3.7% and the median is 0.01%.

Table 14: Average value of the achievable IP packet loss ratio outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

Operator	IP packet loss ratio (Y.1540) (%)
M2	10^{-6}
M6	< 0.001
M3	≤ 0.005
M1	0.0015-0.015
M8	0.01
M18	0.05
M11	0.057
M16	≤ 0.1
M13	3.7
Median	*0.01*

Source: BEREC

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 187). Therefore, **the threshold IP packet loss ratio of the performance thresholds 2 is set to 0.01%.**

c. IP packet error ratio

218. Table 15 shows 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 most advanced 5G technology used in this network and under the conditions given in the questionnaire (see paragraphs 104 and 186) based on the answers received from six operators. The average value considers measurements outdoor during peak-time and over the whole coverage area of the most advanced 5G technology (in terms of aggregated radio channel bandwidth, MIMO order, modulation etc., see paragraphs 99 and 108).

219. 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.

Table 15: Average value of the achievable IP packet error ratio outdoor during peak-time in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

Operator	IP packet error ratio (Y.1540) (%)
M2	10^{-6}
M18	0.005
M3	≤ 0.01
M8	0.01
M13	0.01
M11	0.08
Median	*0.01*

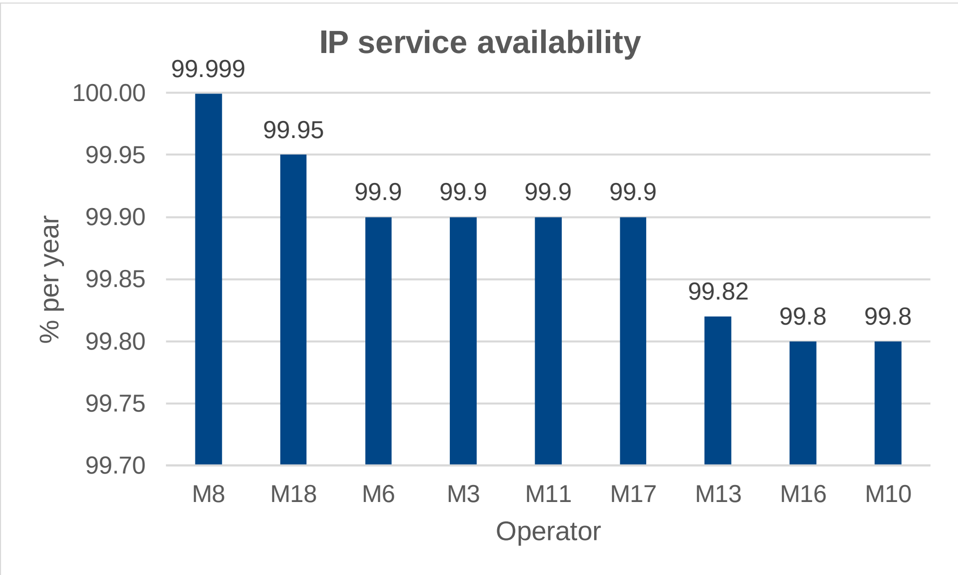
Source: BEREC

220. The average value of the achievable IP packet error ratio varies between 10-6% and 0.08% and the median is 0.01%.

221. 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 187). Therefore, **the threshold IP packet error ratio of the performance thresholds 2 is set to 0.01%.**

d. IP service availability

222. Figure 10 and Table 16 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 most advanced 5G technology used in this network and under the conditions given in the questionnaire (see paragraphs 104 and 186) based on the answers received from nine operators. The aver-



Source: BEREC

Figure 10: Average value of the achievable IP service availability outdoor in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

age value considers measurements outdoor and over the whole coverage area of the most advanced 5G technology (in terms of aggregated radio channel bandwidth, MIMO order, modulation etc., see paragraphs 99 and 108).

Table 16: Average value of the achievable IP service availability outdoor in a mobile network with fibre roll-out up to the base station and the most advanced 5G technology used in this network

Operator	**IP service availability (Y.1540) (% per year)**
M8	99.999
M18	99.95
M6	> 99.9
M3	≥ 99.9
M11	99.9
M17	99.9
M13	99.82
M16	≥ 99.8
M10	99.8
Median	99.9

Source: BEREC

223. 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 99.8% and 99.999% per year and the median is 99.9% per year.

224. 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 187). Therefore, **the threshold IP service availability of the performance thresholds 2 is set to 99.9% per year.**

Annex 5: Data on further networks

225. This annex provides, for reference purposes only, data for the following further networks based on the corresponding questionnaires (see paragraphs 101):

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

226. 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 16a) such networks may be relevant for the determination of the performance thresholds 1. Several stakeholders made in the first phase of the call for initial stakeholder input (see paragraphs 56 and 58) the suggestion that such networks should also be considered.

227. However, in the EU such networks are not very common[56] and, therefore, public electronic communications services based on such networks can only be offered to a small share of end-users and are not representative from the end-user's perspective.[57]

228. 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 19 criterion 1).

a. Downlink and uplink data rate

229. Figure 11 and Table 17 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

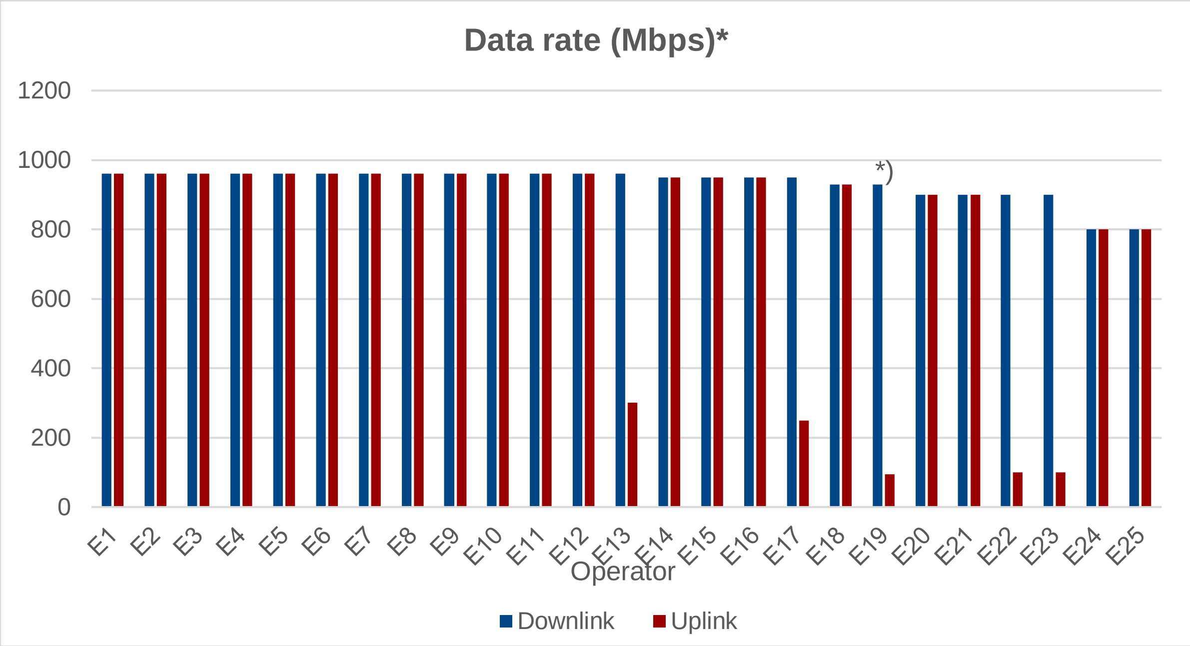
[56] Ethernet on twisted pair cable is common in computer networks (e.g. LAN) but not as in-building infrastructure on which public electronic communications services are provided to end-users.

[57] 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 116).

(see paragraph 104 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 47).

230. 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 106).

231. 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)[58] at the level of the IP packet payload.[59]



*) Of the IP packet payload (see footnote 59)
Source: BEREC

Figure 11: 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

232. The other eight operators who completed the questionnaire (see paragraph 112 and Table 1), use Fast Ethernet on the in-building twisted pair cable which enables solely a

[58] 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.

[59] 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 11 and Table 17 have been adapted to 960 Mbps (see footnote 58).

maximum data rate of 100 Mbps at the level of the Ethernet protocol (including Ethernet overhead) and a slightly lower data rate (approximately 96 Mbps) at the level of the IP packet payload.

Table 17: 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

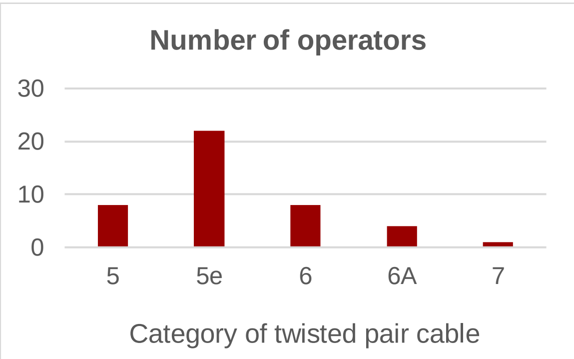
Op.	**Data rate (Mbps)***		**Op.**	**Data rate (Mbps)***		**Op.**	**Data rate (Mbps)***	
	Down	**Up**		**Down**	**Up**		**Down**	**Up**
E1	960	960	E10	960	960	E19	900-960	90-98
E2	960	960	E11	960	960	E20	900	900
E3	960	960	E12	960	960	E21	900	900
E4	960	960	E13	960	300	E22	900	100
E5	960	960	E14	950	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 59)
Source: BEREC

233. Figure 11 and Table 17 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.

234. 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.

235. Figure 12 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%).

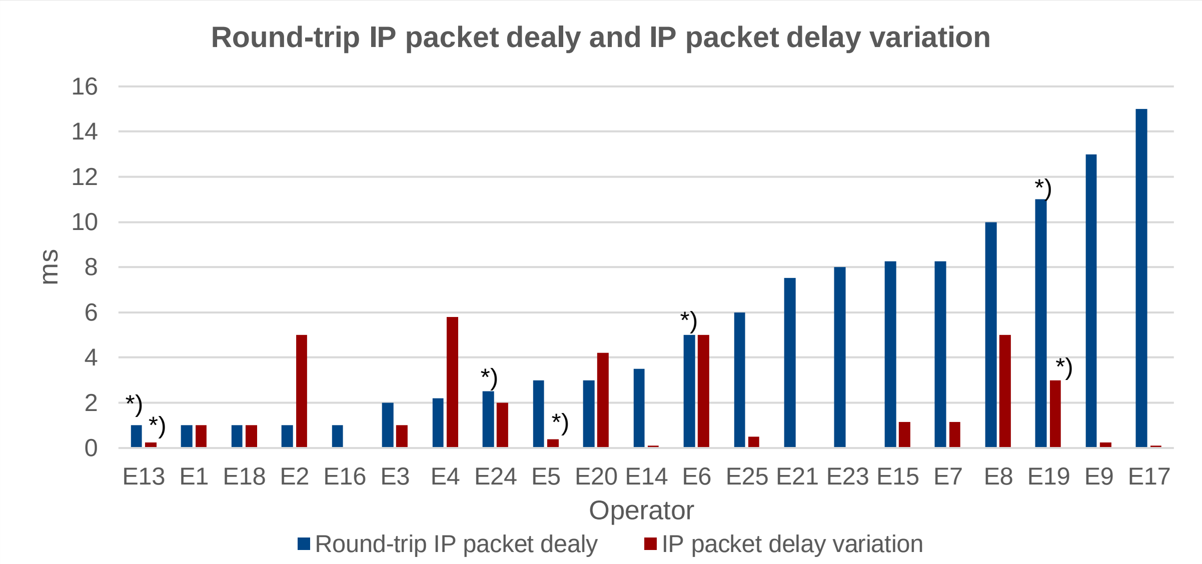


Source: BEREC

Figure 12: Category of twisted pair cable

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

236. Figure 13 and Table 18 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 104 scenario 2) based on the answers received from 21 and 19 operators respectively.



*) Range (see Table 18)
Source: BEREC

Figure 13: 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

237. 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 over which the signal has to be transmitted (from the end-user to the point of handover and back to the end-user, see paragraphs 55, 164 and 165). For these reasons, some variation in the IP packet delay can be expected and is plausible.

238. 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 167). Therefore, it depends also on the dimensioning of the network nodes.

239. 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 18: 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

240. Table 19 shows 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

Table 19: 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[60]	0[60]	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

[60] Estimations of the achievable IP packet error ration and IP packet loss ratio were possible (see paragraph 105) and a value of 0% maybe be an estimation for a value very close to 0%.

Ethernet on the in-building twisted pair cable of category 5 or higher and under the conditions given in the questionnaire (see paragraph 104 scenario 2) based on the answers received from 19 and 20 operators respectively.

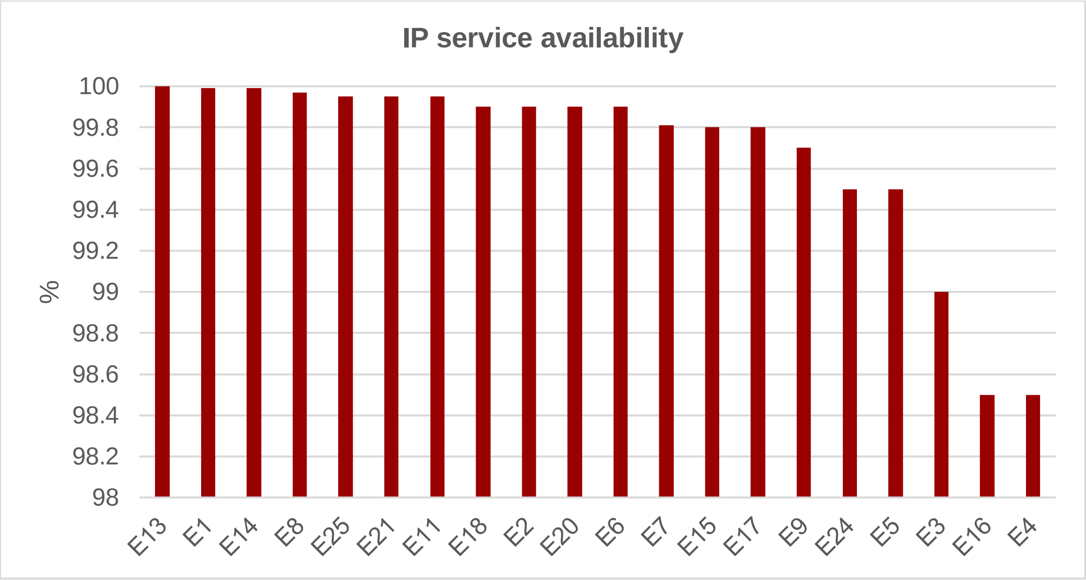
241. The IP packet loss ratio depends on the dimensioning of the network nodes and the IP packet error ratio depends on the processing and transmission quality. Therefore, some variation in the IP packet loss ratio and the IP packet error ratio can be expected and is plausible (see paragraph 173).

242. Both the typically achievable IP packet error ratio and the typically achievable IP packet loss ratio vary between 0%[60] 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.

d. IP service availability

243. Figure 14 and Table 20 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 104 scenario 2) based on the answers received 20 operators.

244. The typically achievable IP service availability varies between 98.5% and 100%[61] per year and the median is 99.9% per year.



Source: BEREC

Figure 14: 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

[61] Estimations of the achievable IP service availability were possible (see paragraph 105) and a value of 100% maybe be an estimation for a value very close to 100%.

Table 20: 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[61]	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

245. Table 21 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 (246 to 250), the latter is only referred to as ‘Gigabit Ethernet’ in order to increase the readability.

Table 21: 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[62]	1,000	960
Uplink data rate[62]	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

246. 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.

[62] IP packet payload data rate

247. 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).

248. 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 55). 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.

249. 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.

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

2. Fixed networks with FTTH

251. The data in this annex are presented for reference purposes only, but not for the determination of performance thresholds 1 (see paragraph 17).

252. Table 22 shows the typically achievable data rates during peak-time in fixed networks with FTTH under the conditions given in the questionnaire (see paragraph 104 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 47).

253. 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 106).

254. The other 13 operators with a network with FTTH and point-to-point topology use 1 Gigabit Ethernet on the subscriber access line which enables symmetric data rates of maximum 960 Mbps.[63] The other 11 operators with a network with FTTH and point-to-multipoint topology use G-PON (nine operators) or RFoG[64] (two operators). A G-PON

[63] 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 231).
[64] Radio Frequency over Glass

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).

Table 22: 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[65]
Legend: P2P … Point-to-point, P2MP … Point-to-multipoint
Source: BEREC

255. Even a better PON technology with regards to the achievable data rate than XGS-PON, the PON technology NG-PON2, is commercially available.[66] The symmetric data rate shared between the end-users connected to the same NG-PON2 is 40 Gbps[67] and, therefore, four times higher compared to XGS-PON.

256. Although the typically achievable data rate of networks with FTTH is very high (see Table 22), still higher data rates are possible. PON technologies with higher data rates are in the process of standardisation[68] and 9,600 Mbps symmetric in case of point-to-point topology is not a technological limit. For example, in core networks 100 Gbps[69] per wavelength are used and WDM[70] enables the use of several wavelengths per fibre. 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.

257. Since only two responding operators in case of point-to-point topology and three operators in case of point-to-multipoint topology deployed the 'best' technology and not

[65] 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 231).
[66] See BEREC Report on the new forms of sharing passive optical networks based on wavelength division multiplexing, BoR (17) 182, p. 28-29
[67] 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.
[68] See BEREC Report on the new forms of sharing passive optical networks based on wavelength division multiplexing, BoR (17) 182, p. 7
[69] Gross bitrate at the level of the Ethernet protocol.
[70] Wavelength Division Multiplexing

all provided data for the other QoS parameters, data for the other QoS parameters are not available.

Annex 6: List of 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

Annex 7: List of Figures

Annex 8: List of Tables