Body of European Regulators for Electronic Communications

BEREC

BoR (18) 115

Draft

Common Position on monitoring mobile coverage

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Contents

1. Introduction and objective

In fulfilling their duties, National Regulatory Authorities (NRAs) and competent authorities (CAs) monitor mobile coverage of licensed spectrum in bands identified for International Mobile Telecommunications (IMT). Each NRA uses different means to provide information on national mobile coverage, which may constitute an obstacle to a consistent approach in presenting mobile coverage both for public policy and for consumer information. In the latter case, there is a greater emphasis on accessibility of mobile coverage information via different means (e.g. a map, apps, etc.). There are benefits to achieve a common understanding on how mobile coverage can be defined and measured for monitoring purposes, see section 1.1.

The principles of mobile coverage obligations specifications and the specification process are outside the scope of this document.

In 2017[1], BEREC conducted a public consultation on a preliminary report in view of a Common Position (CP) on monitoring mobile coverage. This report aimed at facilitating a common understanding through better defining key concepts, baselines and accessibility of information; and fostering a consistent approach on how mobile coverage information can be made available and understandable among NRAs and to the public throughout Europe.

Following on from last year's work and taking into account the comments received from the public consultation, BEREC continued its initial work of 2017[2] with the aim of establishing a set of future-looking CPs that achieve a common understanding on how to provide information on mobile coverage, and how it can be defined, measured and reported for monitoring purposes.

In 2018 and to meet this aim, BEREC gathered expertise from European NRAs through a survey entitled "Practices in Europe Regarding Monitoring Mobile Coverage". BEREC received the contribution of 33 NRAs which constitutes a solid basis that depicts a clear picture of the current state of methods to monitor mobile coverage in Europe.

In this document, BEREC provides the outcome from studying the range of current NRA practices, the outcome from last year's consultation and four common positions on monitoring mobile coverage:

- CP1 – Technical specifications for monitoring mobile coverage in Europe;
- CP2 – The use of signal predictions for mobile coverage;
- CP3 – Ensuring the reliability of coverage information;
- CP4 – Availability and presentation of mobile coverage information.

[1] http://berec.europa.eu/eng/document_register/subject_matter/berec/public_consultations/7300-draft-berec-preliminary-report-in-view-of-a-common-position-on-monitoring-mobile-coverage

[2] BEREC launched a consultation on its draft Preliminary report on monitoring of mobile network coverage on 11 October, 2017, in which it sought input from stakeholders, particularly, on the list of characteristics for mobile coverage and on the key features of maps identified in the draft Preliminary report.

These CPs have been developed for outdoor coverage of mobile services only. They are underpinned by the initial BEREC work of 2017.

1.1. Context for monitoring mobile coverage

As the BEREC preliminary report (BoR (17) 186)[3] already stated there are a number of reasons why mobile coverage monitoring would be necessary:

- to provide highly-accessible independent and reliable information on the state of mobile coverage in their respective countries. Such information is often made available by the NRAs to consumers; respective policy makers and/or national governments; the European Commission; industry and wider public;

- to assist in ensuring mobile network operators (MNOs) meet their coverage obligations. Some NRAs monitor the level of mobile coverage provided by operators to assess if they comply with any relevant coverage conditions and obligations set out in their licences. This can help ensure that mobile spectrum is used to deliver greater geographic and population coverage in particular in rural areas, which can have a positive impact on the reduction of the digital divide.

In this context, two different aspects of monitoring mobile coverage can be considered:

a) Estimating and predicting mobile coverage: this is normally based on theoretical calculations and the results are displayed in a specific map format (e.g. resolution, colour coding, etc.) taking into account predetermined assumptions (e.g. technology, propagation modelling, user specific parameters)

b) Measuring mobile coverage through the field signal and/or the service availability in specific location and time taking into account equipment used to perform such measurement. This can be done for example by using calibrated equipment. The results of the measurements can also be represented in a specific map format.

Publication of mobile coverage information at regular intervals by the NRAs gives an overview of the development of the different electronic communication services provided over mobile networks. This greater transparency on the coverage provided by different operators can help promote more competition between operators with regard to delivering better coverage and possibly future investments in network coverage. Such publications are often in the form of numerical data usually contained in report published by the NRAs on a regular basis (e.g. annually).

From consumer perspective, publishing easy-to-access, accurate, reliable and comparable information increases transparency and helps consumers to know if they receive the service they bought or to be empowered to make informed decisions before subscribing to a MNO –

[3] https://berec.europa.eu/eng/document_register/subject_matter/berec/public_consultations/7300-draft-berec-preliminary-report-in-view-of-a-common-position-on-monitoring-mobile-coverage

these have an overall effect of promoting competition. To date, the use of coverage maps has, for some NRA, been the preferred method of providing mobile coverage information.

1.2. Key elements of mobile coverage information from consumer perspective

The following set of elements is of relevance to consumers from mobile coverage information point of view.

1. The services:
    a) Data services, which are split into two subcategories, namely
        - o Basic quality service sufficient to carry out web browsing, email, satnav, Internet banking, audio download and social networks (excl. videos).
        - o Good quality service sufficient to carry out most data functions, video content in social networks, video streaming and high-quality audio streaming.
    b) Voice service (noting that voice is provided over data in some technologies)
2. The location where services are consumed:
    a) Outdoor
    b) Indoor[4] (home/office/shopping malls/etc.; within sight of a window or deep indoor).
    c) Along transportation routes (car/train/underground/tram/ferries/etc.)
3. The device[5]:
    a) Feature phone
    b) Smartphone
    c) Tablet
    d) Mobile broadband device (e.g. 4G router)

However, in order to provide a data set which is easy to understand by consumers, coverage information presented to consumers should be based on a limited number of combinations of these elements that are deemed relevant to consumers.

[4] BEREC recognises that indoor coverage depends on the type of building material used and that other connectivity solutions may be available to consumers indoors (e.g. native Wi-Fi calling or mobile repeaters, or both).

[5] BEREC recognises that along with the large number of consumer devices used for accessing mobile services, different factors may affect consumer's quality of experience such as handset sensitivity and performance by radio frequency band. For example, one NRA published a technical report on the transmit performance of 71 handsets in its market, which also showed differences in performance between left-hand and right-hand usage scenarios (ComReg Document 18/05, June 2017)

2. Technical specifications for monitoring mobile coverage in Europe

2.1. The Common Position (CP1)

From the perspective of giving information about mobile coverage, NRAs should choose either of the following criteria:

1. Specifications based on the strength of the signal received: a given area is declared in-coverage if the average received signal power in that area is greater than a pre-specified minimum, which is chosen by the NRA to achieve a high probability of successful service reception, or

2. Specifications based on the minimum probability of successful service (e.g. voice or data) reception: a given area is declared in-coverage if the service in that area is available with a pre-specified minimum rate of success.

Considering the first case above, although other factors may affect the service quality, the available received mobile signal power is an indicative measure towards the definition of the level of coverage. Such a metric will also facilitate the display of mobile coverage on a map. The metrics for measuring signal power are dependent on the mobile technology. NRAs should use the following metrics for different mobile technologies:

- RxLev (Received Signal Level) for GSM (also referred as 2G),

- RSCP (Received Signal Code Power) for UMTS (also referred as 3G), and

- RSRP (Reference Signal Received Power) for LTE (also referred as 4G).

NRAs should consider applying an appropriate threshold to the available mobile signal power in a given area.

Two approaches to such thresholding may be:

- Binary thresholding: here, coverage in a given area should be declared present if the average level of mobile signal power in that area is greater than a prespecified threshold. NRAs should note that different mobile technologies will have different thresholds. The thresholds should be chosen by the NRAs to ensure a high probability of successful service reception.

- Multi-level thresholding: here, coverage in a given area should be defined with respect to a set of probability values of successful service reception that would be specified by a corresponding set of thresholds. Again, a relevant consideration for NRAs would be that different mobile technologies will have different set of thresholds for different probability of successful service reception. The thresholds should be chosen by the NRAs to ensure a range of probability of successful service reception that is meaningful to consumers.

2.2. Further elaboration

Parameters that NRAs measure in the field may depend on the national licence obligations, but also aim to objectively depict the quality of service that mobile networks offer to the end users. Technology dependent radio signal levels are the most commonly used criteria to define whether a specific location is covered or not. It is used by 20 out of 33 NRAs surveyed. The received mobile signal power that underpins mobile coverage of 2G/3G/4G networks is often based on RxLev, RSCP and RSRP for GSM, UMTS and LTE respectively.

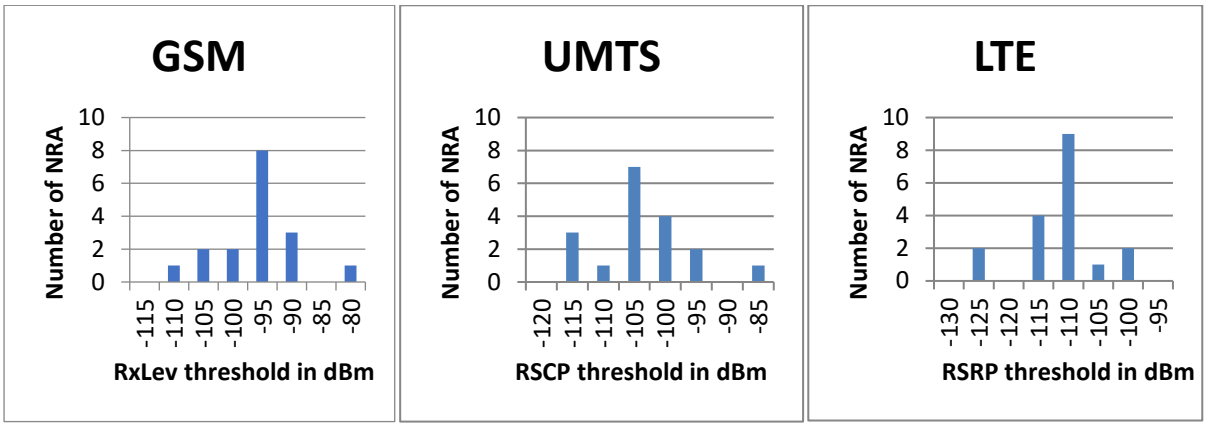
The outcome of the survey shows that 22 out of 33 NRAs define thresholds for the classification of different levels of mobile coverage. It also shows that the reasons for defining thresholds differ – the main reason concerns the definition and the verification of coverage obligations, the other reason being the publication of a mobile coverage map by an NRA at a later stage.

Out of the 22 NRAs defining thresholds, 18 NRAs define thresholds for RSRP, 18 for RSCP and 17 for RxLev. Among those defining thresholds for RSRP are some that also define thresholds for RSCP but not for RxLev. On the other hand, there are some NRAs that only define thresholds for RxLev or which take into account other parameters, such as the level of interference (Ec/Io).

This different practice may be explained by the fact that Member States have imposed different coverage obligations to resolve the specific coverage issues they deal with, or due to the requirements they have specified to do measurements in the field. Different coverage obligations may require different measurement metrics and measurement methods to best assess MNO's compliance with those obligations (BoR (17) 186).

Figure 1 gives the range of thresholds reported by the NRAs.

Figure 1: Number of NRA using given thresholds for GSM, UMTS and LTE



From a consumer perspective, the signal power received may be of less relevance that the probability of successfully connect to the service. Therefore, some NRAs are considering that a given area is covered when the probability of connecting to the service (e.g. the call success rate for voice service) is higher than a given threshold.

Further, 7 out of 33 NRAs use multi-level thresholds to define coverage. BEREC estimates that this practice gives more accurate information to the public. Considering this, BEREC recommends NRAs to choose a multi-level thresholding approach.

In order to improve the information on mobile coverage given to the public, there would seem to be merit in NRAs consider specifying at least three levels of mobile coverage (for example: basic / good / excellent). With regards to the publication of coverage maps this may enable end-users to come to well-founded decisions when choosing their MNO. It may also help identify areas where mobile coverage is available, but could still be improved, which would be of interest for MNOs as well as for the governments.

3. The use of signal predictions for mobile coverage estimation

3.1. The Common Position (CP2)

BEREC recognizes that mobile signal prediction enables the estimation of mobile coverage over the whole of the geographic surface of a given country. The NRAs should note that signal predictions are a statistical representation of the coverage achieved in practice.

NRAs should base coverage estimation (numerical data or maps) on coverage calculations/predictions, whenever it is not economically or technically possible to carry out field measurements of the whole country. Such predictions may be generated from modelling a number of relevant input parameters[6] to predict the level of available mobile signal power or service accessible in any given area.

An NRA may elect to:

1. generate coverage predictions and publish information themselves (maps and/or metrics about mobile coverage);
2. obtain the results of predictions from the operators and publish information themselves (maps and/or metrics about mobile coverage); or
3. use a third party to generate the coverage predictions and publish information (maps and/or metrics about mobile coverage).

In all cases, the NRA should be confident of the accuracy of the mobile signal predictions they use – see CP3.

[6] Such as models of signal propagation for different bands, terrain information, network topology, geographic topology, etc.

3.2. Further Elaboration

The answers to the survey showed that 10 out of 33 NRAs use their own mobile signal prediction software which they combine with network data that is mainly provided by the mobile operators (e.g. base station locations, antenna parameters, frequencies). The software predicts mobile coverage, whose output can be referred to as theoretical mobile coverage, or mobile signal predictions.

These are mainly used to verify whether coverage obligations are being fulfilled by the operator. More generally, this approach allows the verification of national population or geographic area being covered by a pre-defined service parameter.

23 out of 33 NRAs surveyed do not perform calculations of mobile coverage by themselves. Here, the mobile operators provide the coverage mainly based on estimation/simulation tool. This theoretical mobile coverage which is sent to the NRA, can then be used in a similar way as above.

It is clear that in the majority of countries each operator or NRA has its own way of calculating mobile coverage. Whether the NRA performs the calculation itself or obtain the coverage information from the operators, it should ensure the accuracy of the information. This would help ensure comparability between the operators. See CP3.

It is worth noting that theoretical/predication-based mobile coverage information is the only known methodology that enables NRAs to derive an estimate of mobile coverage over 100% of their country land mass. Thus, theoretical/predication-based mobile coverage information should be used unless field measurements are feasible over 100% of the geography.

The constraints referred above concerning theoretical mobile coverage are related to the following:

- the digital terrain model which can have different resolutions and sources,
- the digital terrain clutter which can have different classes and sources,
- the software tool that can be from different providers,
- the propagation model (e.g. ITU.R P.1812, Okumura-hata, Crosswave model, ray tracing) than can be different and configured in different ways (e.g. the diffraction model + sub-path attenuation),
- the radiation pattern of the antennas,
- the sensitivity (received signal power) per service and respective link budget, and
- other planning parameters (e.g. penetration losses, body loss, height gain, coverage reliability, fading margins, etc.).

All these requirements have varying impact on theoretical mobile coverage information and may benefit from a more harmonised approach in the future.

A theoretical mobile coverage, by itself, should be understood as an estimation. To obtain the theoretical mobile coverage there is a need to specify the mobile coverage in terms of a particular target, which may be received signal power, percentage successful voice service or data service of certain downlink data rate. Variations exist amongst the NRAs whether coverage is estimated on a QoS or QoE basis.

4. Ensuring the accuracy of coverage information provided to the public

4.1. The Common Position (CP3)

NRAs should verify the reliability of mobile coverage information using, where appropriate, field measurements, noting that for technical and resourcing reasons it may not be possible to make widespread measurements[7]. Measurements by drive-testing offer an effective method of testing the accuracy of mobile signal predictions. NRAs should ensure statistical robustness of the measurement methodology and of the measurement processing and analysis.

4.2. Further Elaboration

The outcome of the survey[8] shows that NRAs can have similar reasons for using field measurements. Indeed, the NRAs carry out measurements[9] to:

- verify that MNOs comply with their license obligations on mobile coverage,
- safeguard the end users' rights to have transparent information on mobile networks' coverage and performance. In several countries, NRAs measure mobile coverage as part of resolving consumer complaints with respect to the mobile networks performance, and
- verify the reliability of the mobile coverage maps provided or/and published by the MNOs by collecting in-field measurements through drive testing across a representative sample of a given country where appropriate. This kind of measurements can act as incentive and strengthen the competition between operators because informing consumers helps them choosing the right service on their living area. Thus, publishing maps displaying mobile coverage of each of the MNOs in a market pushes them to constantly improve their networks.

The radio signal level and its quality do not guarantee that a mobile user can effectively access and use mobile services. Therefore, approximately half of the NRAs determine whether a location is covered, by measuring parameters that are more related to the QoS/QoE provided

[7] For example, it may not appropriate to carry out field measurements at indoor locations for reasons of accessibility.
[8] BEREC Survey: Practices in Europe regarding monitoring mobile coverage, February 2018; 33 NRAs responded (26 from EU countries and 7 from non-EU countries);

[9] 29 out of 33 NRAs stated that they perform field measurements of the mobile coverage;

at that location. In few countries, NRAs aligned with MNOs on the exact set of parameters to be measured in the field, nonetheless these parameters differ across European states.

Drive testing is a standard method that should be used to monitor mobile coverage in the field – it may inform the level of mobile coverage (end/or service availability) along routes or at specific locations and may provide an opportunity to reflect the end users' perception and experience of the mobile networks. Drive testing refers to the outdoor measurements, performed as static or in-move measurements. They typically include vehicle(s) equipped with at least a RF scanning equipment. Besides, this method ensures that all MNNOs are measured at the same time in a same location and, thus, gives a comparable picture of MNOs.

One NRA reported using crowdsourcing for providing some form of testing of coverage maps.

5. Availability and presentation of mobile coverage information

5.1. The Common Position (CP4)

To realize the benefit of dissemination of mobile coverage information, NRAs should strive to provide easy-to-access accurate mobile coverage information to the widest possible range of consumers. The information published would be in particular useful for end-users to be able to compare the coverage provided by the operators and therefore to compare their services.

NRAs should consider a range of methods of access such as via their own and third-party website and apps, with the aim of maximization of coverage information accessibility by the widest range of consumers possible. Providing the information on mobile coverage in open data would be in particular beneficial as it can easily be widely reused by external parties. Third-party publication of NRAs' coverage information should reference the source and whether the information has been tested for accuracy.

When NRAs publish coverage maps, they should consider the following:

1. Provide for consumer confidence in the maps by:

- stating if the data used to create the maps were provided by the MNOs or by the NRA itself.
- stating if the data used for the creation of the maps were tested for accuracy.
- describing the method used to test the data for accuracy (theoretical calculation and/or drive tests etc.), as well as the extent to which the data were tested for accuracy.

2. Increase the effectiveness of information conveyed by the maps by:

- providing consumers with the choice to select/unselect the available services and/or technology.

- displaying layers for different levels of coverage by exploiting the notion of multi-thresholding.

- providing a coverage map resolution of 100m or lower.

NRAs mobile coverage maps are also meant to complement and feed the *EU Mapping Platform* which collects data about mapping broadband coverage and quality of service (for fixed and mobile services). The platform is carried out in close cooperation with relevant Member State administrations (ministries) and with BEREC.

5.2. Further Elaboration

With regard to the publication of information on the state of mobile coverage, BEREC considers that publishing coverage maps is beneficial for consumers and very easy way to portray mobile coverage. BEREC notices that – for the time being – less than half[10] of the NRAs publish their own coverage maps based on data they collected themselves or data they received from MNOs (which were tested for accuracy by the NRA). The reasons for this situation range from copyright issues to competence issues up to budgetary matters.

Nonetheless, NRAs which do not publish their own coverage maps may also have data on mobile coverage available]. Some NRAs might not be free to publish this data for legal reasons. For example, when – according to national law – MNOs can only be obliged to relay data for the purpose of verification of coverage obligations and when doing so explicitly limit the usage of this data to this purpose. Even aggregating data from published coverage maps of the MNOs might be confronted with legal restrictions. Thus, the degree of data that each NRA is free to publish differs between Member States.

This calls for a measured approach encouraging NRAs to publish on their website any information on mobile coverage that they have available and are free to share. This may include coverage maps compiled by NRAs, links to coverage maps of MNOs or other government agencies. Further to this, it may be useful to include information explaining (a) who is responsible nationally for the monitoring of mobile coverage and (b) if there is an organization they can turn to for more information or if they encounter coverage issues, thus enabling consumers to inform themselves accordingly.

Concerning the distinction between levels of mobile coverage, several NRAs (BIPT, Arcep, EETT, RRT, NKOM, ANACOM, OFCOM, CRC, CTO, AEC, ANCOM, PTS, RATEL, and NMHH) define more than two levels of mobile coverage (covered/not covered) for the purpose of mobile coverage maps publication.

[10] 14 out of 33 NRAs declared they publish own coverage maps based on data they collected themselves or data they received from

ComReg does not currently publish maps, but its proposal "[…] is to make available a composite national coverage map on its consumer website from comprehensive network architecture data provided by MNOs"[11].

In some countries, one or several MNOs decided to publish maps showing several layers. For example:

- in Finland, one MNO publishes maps with 4 levels of coverage: no coverage / basic coverage / Good coverage / very good coverage,
- in Iceland, one MNO shows 3 levels,
- in Montenegro, one MNO distinguishes indoor/outdoor/no coverage, and
- in Malta, some MNOs have published several layers maps: excellent/variable (+limited for one of the MNOs).

These layers usually derive from combinations of elements of section 1.2 describing consumers' situations in accessing a mobile network that are deemed relevant to consumers by the NRA. Such combinations include but are not limited to outdoor coverage using mobile handset for voice services and outdoor coverage using mobile handset for data services.

[11] ComReg's answer to the BEREC Survey: Practices in Europe regarding monitoring mobile coverage, February 2018; 33 NRAs responded (26 from EU countries and 7 from non-EU countries).

Appendices

Appendix 1. Summary of responses

This table summarises answers provided by NRAs and it provides information about monitoring practices in place.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-	Comments
AT Austria (RTR)	Only for the purpose of verifying coverage obligations	NO	NO	NO	YES (1)	YES (2)	(1) RTR uses a mobile app to measure a sample of statistically significant locations in order to predict the coverage of mobile networks to verify the coverage obligations. (2) The RTR-NetTest informs users about the current service quality (including upload, download, ping, signal strength) of their Internet connection. In addition, a map view and statistics of previous tests can be accessed. (Source: https://www.netztest.at/en/) The NetTest data is not used to check the coverage obligations. Although, it is a good source to check the plausibility of the results.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
BE Belgium (BIPT)	Inform consumers and public authorities Verify coverage obligations compliance	NO	YES (1)	NO	Not yet	Not yet (2)	(1) Currently, only outdoor signal strength is measured (scanner). – drive testing project (QoS2) : Quality of the calls : – Coverage – Network availability – Dropped call rate – Blocked rate – Transmission quality – Call setup time Quality of data services : – Coverage – Success rate “transfer d’un fichier” (en upload et download) – Débit de données (UL/DL) – Streaming quality – Time to transfer a file (UL/DL) – Network unavailability – Occupancy rate in spectrum allocation Success rate to download a webpage in 10 sec. (2) Expected in Q3 2018 Project: measure signal strength, delay, DL/ UL speeds Indoor + outdoor

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
BG Bulgaria (CRC)	Verify the reliability of coverage maps (only in case of complaints)	YES (1)	YES (2)	NO	NO	NO	(1) Calculation of the coverage from network data (e.g. base station locations, antenna parameters, frequencies). The data is provided by the undertakings. No verification But no verification of calculation. (2) In case of complaints, measurements are made at fixed point for comparison between declared mobile coverage on the web-site of the MNO and the real mobile coverage. – drive tests with a UE terminal, with which call attempts are made to auto-answering stationary phone line of the measured mobile operator. – RxLev for GSM networks, RSCP for UMTS networks and RSRP for LTE networks. The other mobile benchmarking parameter is call statistics of successful calls - with more than 90% of the total number of call attempts for GSM, and more than 95% of calls made - for UMTS.
CH Switzerland (BAKOM)	NO	NO	NO	NO	NO	NO	
CY Cyprus (OECPR)	NO. Competency of Department of Electronic Communications of the Ministry of Transport, Communications and Works.	NO	NO	NO	NO	(1)	(1) Consumers can use OCECPR's tool called NET2MAP that was developed to view mobile networks coverage Field measurement of mobile coverage. (http://geomatic.com.cy/geomaps/?map=geriet)

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
CZ Czech Republic (CTU)	Verify coverage obligations compliance	YES (1)	YES (2)	NO	NO (Not available)	YES	(1) CTU uses coverage calculation software To find out whether the coverage obligations are executed. To provide coverage maps (2) CTU measures the parameters related to signal (e.g. RSRP, SINR) and those representing QoS (download, upload). cars with special equipment (ROMES, QualiPoc, TSMW)
DE Germany (BNetzA)	BNetzA measures coverage in order to verify maps provided by MNOs. MNOs are obliged to provide coverage maps in context with coverage obligations following the tender of spectrum. the Federal Ministry of Transport and Digital Infrastructure (MoT) is responsible for the maps	NO	YES (1)	NO	NO	NO	(1) The BNetzA does not check the services. The coverage is checked according to the parameters RxLEV at GSM, RSCP at UMTS and RSRP at LTE. A sample gets defined and BNetzA's radio monitoring and inspection service (Prüf- und Messdienst, PMD) drives along the roads in the sample area and measures the coverage. The parameters are recorded outside with a scanner. The measuring vehicle is a van with a roof height of 3 m.
DK Denmark (DBA)	provide information to the public	NO (1)	NO	NO	NO	NO	(1) The mobile operators provide information on the mobile coverage. They have agreed on a common model for how coverage calculations should be done, so the results are comparable between the operators.
EE Estonia (ETRA)	Verify coverage obligations compliance	NO	YES (1)	NO	NO	NO	(1) - drive testing method prevails Signal strength (2G=RxLev/3G=RSCP/4G=RSRP) measurements are carried out by drive test method on driving lanes (outdoors). And we have used ordinary customer equipments (dongles, smartphones), which were equipped with measuring software.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
FI Finland (FICORA)	verify the reliability of the coverage maps provided by the operators Investigate complaints from the consumers.	NO	YES (1)	NO	NO	NO	(1) Rhode&Schwarz TSMW network scanner and 3 x Samsung Galaxy Note 4 measurement phones with Nemo Handy software. Measurement is handled by Nemo Outdoor software and analysed with Nemo Analyze software. Field strength (GSM: Rxlev (threshold - 90 dBm); UMTS: RSCP (threshold -100 dBm); LTE: RSRP (threshold -110 dBm). With the measurement phones FICORA measures only Ping-values to verify that the connection is working properly.
FR FRANCE (Arcep)	To verify coverage obligation compliance To inform consumers	NO (1)	YES (2)	NO (3)	NO	NO (4)	(1) However Arcep uses coverage calculation software in order to extract metrics from the mobile coverage maps provided by the MNOs. (2) Drive testing are conducted – each time there is a deadline date for coverage obligation – every year to check the reliability of coverage maps (through tests of the availability of service : outdoor, phone calls / downloading files, user oriented) Every year to evaluate QoS/QoE (UL/DL, Streaming, web surfing, quality of voice,…) (3) However Arcep uses walk testing to assess mobile quality of service (4) Not yet but we intend to use crowdsourcing in the near future, essentially as a complement to our drive testing measures.
FYROM Macedonia (AEC)	To verify coverage obligations compliance To verify the reliability of a coverage map provide by operator on its website To inform consumers and push the operators to constantly improve their networks	No	YES (1)	No	No	No	(1) Same measuring equipment and measuring terminals are used for all operators. Service quality measuring voice and data = methods are user oriented

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
GR Greece (EETT)	To inform the end users objectively regarding the existing mobile coverage and service quality To verify mobile coverage of an operator is according to obligations to investigate consumers' complains (indirectly) this kind of measurements can strengthen the competition between operators	NO	YES (1)	NO	NO	NO	(1) During 2016 and 2017, EETT conducted drive test campaigns. The measured parameters were divided in two categories: – Category 1: Radio network availability (RxLev at GSM /RSCP at UMTS /RSRP at LTE) Category 2: Quality of Services (voice / data)
HR Croatia (HAKOM)	to verify coverage obligations compliance. To inform consumers	NO MORE (1)	YES (2)	NO	NO	YES (3)	(1) It was used to verify licence coverage obligation (2) HAKOM measures mobile coverage (signal strength) in the field in order to verify coverage data submitted by operators. Measurements are performed as drive tests with Rohde & Schwarz ROMES platform (3) To inform consumers

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
HU Hungary (NMHH)	to verify the coverage maps of the MNOs to give reliable and independent information about technology and service availability to help inform customers choosing the right service on their living area	NO	YES (1)	NO	NO	NO	(1) To check coverage based on contract between Authority and Operators NMHH uses calibrated receivers (scanners). These are Rohde&Schwarz TSMW and TSME scanners. To give information about data transfer, NMHH uses SwissQual Diversity Benchmarker system with mobile phones followed the technology upgrade on mobile network (at this moment, phones are HTC10)
IE Ireland (ComReg)	to assess the mobile network operators' compliance with the obligations	YES (1)	YES (2)	YES	NO	Eventually	(1) Radio network planning tool from Forsk called Atoll is currently being used to predict mobile coverage. Propagation model tuned with all the network architecture data including, base station locations, antenna details, powers etc. + coverage calculation software uses data collected from field measurements (to tune the propagation models) (2) Bi-annual Drive Tests in winter and summer are carried out by an independent contractor to validate ComReg's predicted coverage maps/licence obligations. (MNOs' maps are not verified) These drive tests cover all primary and secondary national routes in full. Outdoor mobile signal strength, quality and download and upload speeds are measured.
IS Iceland (PFS)	To verify coverage obligation compliance To look into were coverage is not good.	YES (1)	YES (2)	No	No	No	(1) In order to publish coverage maps. Coverage calculation (predication) is compared to field measurements on short roads. (2) Measurements on the field (signal strength) are done with a scanner from Rohde and Schwarz (TSMW) and Romes Software in order to verify the maps (calculated with a software)

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
IT Italy (AGCOM)	To ensure an efficient use of spectrum resources To guarantee a minimum coverage beyond the coverage level that is the result of market forces (e.g. in rural areas) To ensure that users derive maximum benefits in terms of choice, price and quality.	YES (1)	YES (2)	NO	NO	YES (3)	(1) Coverage data provided by MNOs are verified (sample checks) by Agcom (supported by FUB) using a software simulator (implementing the same models used by MNOs). (2) With the support of Fondazione Ugo Bordoni (FUB) measurement campaigns on the field based on drive tests (both static and dynamic) Outdoor measurements (drive tests) are carried out by means of a vehicle equipped with SwissQual Diversity Benchmarker. The following service level KPI are measured (reflecting the user's perception and experience): – service accessibility rate; – throughput (both DL and UL); – delay (Round Trip Time); – jitter; – packet loss; data transmission failure rate. (3) Users of BB map can report errors (there is a dedicated section on www.agcom.it/broadbandmap), so the app-based results (crowdsourcing) are also used as additional checking.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-	Comments
LT Lithuania (RRT)	For fine-tuning of the theoretical coverage calculation models; To verify reliability of coverage in problematic areas To verify if the base stations registration information, provided by operators to our institution is correct or if these stations are working at all.	YES (1)	YES (2)	NO	NO	NO	(1) Mobile operators are obliged to register base stations before putting them into operation. For this reason they provide all technical data to regulator. (2) Drive tests/stationary measurements; outdoors; A car with roof mounted omni-directional antennas; universal radio network analyser (Rohde & Schwarz ROMES) measurements (drive tests) for tuning of a propagation method which is used for coverage calculations.
LV Latvia (SPRK)	NO	NO	NO	NO	NO	NO	

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
ME Montenegro (EKIP)	To verify coverage obligations compliance To inform customers	YES (1)	YES (2)	NO	NO	NO	(1) For internal studies: EKIP uses Calculation software for calculation of mobile coverage, verification of fulfilment operator obligation from license etc. Calculation software uses data from tech documentation of base station (location, eirp, azimuths, elevation angle, antenna model etc.) + EKIP uses data from field measurements for tuning of propagation model and terrain clutter. (2) Every two years approximately EKIP conducts measurements of QoS and benchmark test of three mobile networks. Outdoor drive test measurement (cities and roads) with a Rohde & Schwarz equipment (+Samsung Galaxy S3 mobile phones) Services independent: Radio Network Unavailability, Attach Failure Ratio, PDP Context Activation Failure Ratio, PDP Context Cut-off Ratio, Default EPS Bearer Context Activation Failure Ratio, Dedicated EPS Bearer Context Activation Failure Ratio Voice: Telephony Service Non-Accessibility; Telephony Setup Time, Telephony Speech Quality on Call Basis, Telephony Cut-off Call Ratio, Technology used Data: FTP {DL/UL} IP-Service Access Failure Ratio; FTP {DL/UL} Mean Data Rate, FTP {UL/UL} Data Transfer Cut-off Ratio, HTTP IP-Service Access Failure Ratio, HTTP Mean Data Rate, HTTP Data Transfer Cut-off Ratio
MT Malta (MCA)	To ensure that the stipulated licence conditions are met. 2018: To provide better visibility to consumers with regards to coverage and quality.	NO (1)	YES (2)	NO	NO	NO	(1) MCA makes use of spectrum planning software which is primarily used to carryout interference related analysis (example LTE - DVB-T interference) but not for mobile coverage assessments. (2) Field measurements are carried out to verify the MNOs' compliance with their licence conditions concerning coverage. Test of the service availability: a connectivity check is performed at every test point, using terminals that are available on the market (that reflects user experience) 2G -> Voice / 3G (HSDPA) -> Voice / Data Access / 4G -> Data Access.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-	Comments
NL Netherlands (ACM / Radiocom-munications Agency)	To check probability of a successful connection with the 112 emergency number To check coverage to solve problems in municipalities where people experience no or a low coverage Monitor licencing conditions of putting into service obligations with a certain geographical coverage within certain timeframes	NO	YES (1)	NO	NO	NO (2)	(1) Measures from a user perspective. This means that the parameter that we use is the percentage of succeeded and failed connections to the network. (active connections outdoor with average consumer smartphones) For network scanning/logging, the Radiocommunications Agency uses equipment of Rohde & Schwarz ROMES. Maps are not assessed, but At the moment The Netherlands is testing with drive tests (projects for dialogue in local municipalities). (2) An app-based tool owned by the Radiocommunications Agency is in early development

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
NO Norway (NKOM)	To verify mobile coverage obligations To monitor objectively the development of cellular coverage over time To check the coverage level made available to the public.	YES (1)	YES (2)	NO	NO	YES (3)	(1) To verify coverage stated by mobile operators. Digital terrain model + clutter (2) NKOM uses measurements of signal strength (coverage, and downlink capacities) for validating coverage, obligations in the 800 MHz band licenses and for validating theoretical simulations. Outdoor drive measurements using the 3 most commonly sold terminals (cellphones) on each mobile network to measure download speeds, but also signal power and signal quality. Measurements is also performed with a dedicated spectrum analyser and antenna for reference measurements of signal power and signal quality. NO verification process for coverage maps. (3) Nettfart app provides a speedtest for DL/UL capacity and latency (ping), several QoS-tests, which combined informs the user about the available quality of their Internet connection. The tests include reachability of well-known TCP- and UDP-ports, a VoIP/jitter emulation test, tests for intermediate proxies and DNS tests. The Nettfart mobile app provides a map view of all test results with filter options for test parameters, statistics, operator, and time.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
PL Poland (UKE)	To investigate and solve users' problems To verify operators' coverage obligations. In the past UKE monitored mobile coverage to provide information to consumers but doesn't continue to do so.	NO	YES (1)	NO	NO	NO	(1) Drive tests, outdoor, with a scanner Rohde&Schwarz ROMES.
PT Portugal (ANACOM)	To verify if the mobile operators are fulfilling their coverage obligations. To provide users information on QoS from a user's perspective	YES (1)	YES (2)	NO	NO	YES (3)	(1) ANACOM implemented a methodology to assess if the mobile operators are fulfilling their mobile coverage obligations. The theoretical studies are performed with a mobile planning tool called XG-PLANNER (please consult http://www.lstelcom.com/en/). Based in the information provided by the MNOs ANACOM defines thresholds (sensitivity level per service) to define the level above which there is coverage by service – in UMTS networks the load factor is also considered. Additionally, the limits defined for field measurements can also be used as thresholds, to define coverage based in quality criteria. (2) ANACOM conducts periodical drive-tests on GSM/UMTS/LTE mobile communication systems, based on which it publishes reports with the outcome of the evaluation of the quality of mobile voice and data services and of the network coverage. Reports available at https://www.anacom.pt/render.jsp?categoryId=293535&languageId=1 (3) Net.mede, available at https://www.netmede.pt/ for users checking some Internet QoS parameters. It does not include signal strength.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
RO Romania (ANCOM)	To verify coverage obligations compliance with the licenses.	YES (1)	YES (2)	NO	NO	NO	(1) To calculate mobile coverage (2) ANCOM measures mobile coverage in the field in order to calculate the mobile coverage and verify coverage obligations compliance. – Verification of the radio parameters: outdoor drive tests => Rohde&Schwarz Romes software controls a TSMW scanner and four Qualcomm terminals. indoor measurements a portable ensemble it is used. It has a R&S TSMW scanner, two quad band antennas, GPS antenna and a power supply system based on batteries. – Verification of the quality of voice and data services
SE Sweden (PTS)	To ensure that the MNO's coverage maps on their webpages correspond to the end user experience	NO	NO	YES (1)	NO	NO	(1) Once a year, PTS verifies the speech coverage that the MNO states and the parameters that are related to coverage. For 4G the downlink speed is verified on some fixed locations since one of the MNO working in the 800MHz have obligations to deliver at least 1mbit/s. To imitate the end user the best way PTS measures in dedicated mode at a low speed ~ 5km/h. (E.g. by walking along a poor covered road with the phones (Swissqual)) and maps the samples against the coverage map provided by the operators.
RS Serbia (RATEL)	To verify the maps delivered by mobile operators (//to check the coverage made available to the public.)	NO	YES (1)	YES (2)	NO	YES (3)	(1) To verify the maps: outdoor drive test measurements (measuring large cities, small cities and roads). The equipment used is Rohde & Schwarz (scanner, chassis, Samsung Galaxy S4/Note4 mobile phones). (2) Walk testing is used to check QoS parameters, not to verify coverage maps. (3) Crowdsourcing app RATEL NetTest is used to check internet QoS parameters, but not to verify coverage maps.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
SK Slovakia (RU)	To verify the reliability of a coverage calculation.	YES (1)	(2)	NO	NO	NO	(1) The distribution of populations units can be obtained from the Statistical Office of the Slovak Republic. Technical parameters of base stations are provided by mobile operators for each BTS. (2) – Field strength measurements – Outdoor Scanner (“analyzator of spectrum”)
SI Slovenia (AKOS)	To verify the fulfilment of obligation from issued licenses To verify the actual situation on the field and compering with the calculated coverage. To calculate and monitor 700MHz & 800 MHz coverage obligations	YES (1)	YES (2)	YES (3)	NO	YES (4)	(1) AKOS calculates the prediction of mobile coverage according to the network data submitted by MNOs and compares them with coverage submitted by operators and with actual field measurements. (2) Field measurements results are only used as additional checking of the calculated prediction of mobile coverage. AKOS uses calibrated receivers (scanners) from Rohde & Schwarz (TSMW). The measurement antenna is installed on the roof of the vehicle at a height of about 2 meters. For end-to-end measurements, which cannot be conducted with a scanner, commercial mobile phones (with unmodified hardware and modified firmware) are used. – For radio coverage: Signal Levels in 2G, 3G, 4G frequency bands. Coverage is checked according to RxLEV at GSM, RSCP at UMTS and RSRP at LTE. For data connections: downlink data rates, uplink data rates, network latency – ping, jitter and packet loss (3) In some special circumstances (4) Crowdsourcing results are only used as additional checking of the calculated prediction of mobile coverage.

Country (NRA or competent Authority)	Reasons to monitor or/and measure mobile coverage of maps and metrics	Theoretical calculation	Drive Testing	Walk Testing	App-based (Panel)	App-based (Crowd-sourcing)	Comments
TR Turkey (ICTA)	To verify the reliability of operators' coverage information	NO	YES (1)	NO	NO	NO	(1) ICTA measures the signal strength by drive test method with related benchmark equipment for outdoor and transport locations. – planned or unplanned inspections – For 2G and 3G technologies the signal strength parameter is measured. 4.5G obligations have not been determined yet.
UK United Kingdom (OFCOM)	To verify coverage obligations and provide consumer information	NO	YES	YES	NO	NO	Ofcom uses MNO supplied coverage predictions in order to monitor coverage in the UK. Ofcom also bases its published coverage maps on the same set of MNO supplied converge predictions. Ofcom uses drive testing to establish confidence in the MNO supplied coverage predictions.

Appendix 2. Thresholds used in European countries to qualify if there is outdoor coverage or not (covered / not covered)

No	Country	GSM	UMTS	LTE
1	BE Belgium (BIPT)		Satisfying -105 dBm (Good -95 dBm / Very good -85 dBm)	Satisfying -115 dBm (Good -105 dBm / Very good -95 dBm)
2	BG Bulgaria (CRC)	RxLev ≥ - 100 dBm	RSCP ≥ -105 dBm	RSRP ≥ -110 dBm
3	HR Croatia (HAKOM)	RxLev > -95 dBm	CPICH RSCP > -114 dBm	RSRP > -115 dBm
4	CZ Czech Republic (CTU)	Depends on the frequency band : 900 MHz: RxLev > -93 dBm 1800 MHz: RxLev > -91 dBm	Depends on the frequency band : 2100 MHz: RSCP > -86 dBm	Depends on the frequency band : 800-900 MHz: RSRP > -109 dBm 1800 MHz: RSRP > -107 dBm 2100 MHz: RSRP > -106 dBm 2600 MHz: RSRP > -105 dBm
5	FI Finland (FICORA)	Rxlev ≥ -90 dBm	RSCP ≥ -100 dBm	RSRP ≥ -110 dBm
6	DE Germany (BNetzA)			According to a BNetzA ruling chamber decision of 2015 a minimum data rate of 50 Mbit/s in the antenna sector was defined: RSRP ≥ -104 dBm for LTE@10 MHz, RSRP ≥ -109 dBm for LTE@15 MHz, RSRP ≥ -114 dBm for LTE@20 MHz
7	ET Greece (EETT)	RxLev > -110 dBm	RSCP > -115 dBm	RSRP > -125 dBm
8	HU Hungary (NMHH)	RxLev > -93 dBm	RSCP > -96 dBm	RSRP > -110 dBm
9	IS Iceland (PTA)	RxLev -75 dBm in towns in 95% measurement -95 dBm in rural area in 95% measurement	UMTS (RSCP) -85 dBm in towns -100 dBm in rural area	LTE (RSRP) -85 dBm in towns -100 dBm in rural area
10	LT Lithuania (RRT)	RxLev > -95 dBm	RSCP > -105 dBm	RSRP > -115 dBm

No	Country	GSM	UMTS	LTE
11	FYROM Macedonia (AEC)	RxLev> -95 dBm	RSCP>-105 dBm	RSRP > -110 dBm
12	NO Norway (NKOM)	RxLev >- 90 dBm,	RSCP > -100 dBm	RSRP > -110 dBm
13	PT Portugal (ANACOM)	RxLev > -105 dBm	RSCP > -115 dBm	RSRP > -125 dBm
14	RO Romania (ANCOM)	RxLev > -92 dBm	RSCP > -107 dBm	RSRP > -112 dBm
15	RS Serbia (RATEL)	RxLev > -95 dBm	RSCP > -105 dBm	RSRP > -110 dBm* *will be added in 2018
16	SI Slovenia (AKOS)	RxLev > -93 dBm	RSCP > -96 dBm	RSRP > -108 dBm
17	SE Sweden (PTS)	RxLev > -99 dBm	RSCP > -104 dBm	RSRP > -111 dBm
18	TR Turkey (ICTA)	RxLev > -104 dBm	RSCP > -110 dBm	
19	UK United Kingdom (OFCOM)	RxLev > -81 dBm	RSCP > -100 dBm	RSRP > -105 dBm
	Range	(-75 dBm) -81 dBm > RxLev > -110 dBm	(-85 dBm) -86 dBm > RSCP > -115 dBm	(-85 dBm) -100 dBm > RSRP > -125 dBm

Appendix 3. Abbreviations

Acronym	Definition
ACM	Authority for Consumers and Markets
AEC	Agency for Electronic Communications
AGCOM	Autorità per le Garanzie nelle Comunicazioni
AKOS	Agency for Communication Networks and Services of the Republic of Slovenia
ANACOM	Autoridade Nacional de Comunicações
ANCOM	National Authority for Management and Regulation in Communications of Romania
Arcep	Autorité de régulation des communications électroniques et des postes
BAKOM	Federal Office of Communications
BEREC	Body of European Regulators for Electronic Communications
BIPT	Institut Belge des Postes et Télécommunications
BTS	Base transceiver station
ComReg	Commission for Communications Regulation
CPICH	Common Pilot Channel
CRC	National Markets and Competition Commission
CTU	Czech Telecommunication Office
DBA	Danish Business Authority
DNS	Domain Name System
DVB	Digital Video Broadcasting
EETT	National Telecommunications and Post Commission of Greece
EKIP	Agency for Electronic Communications and Postal Services
EPS	Evolved Packet System
ETRA	Estonian Technical Regulatory Authority
EWG	Expert Working Group
FICORA	Finnish Communications Regulatory Authority
FTP	File Transfer Protocol
FUB	Fondazione Ugo Bordoni
GPS	Global Positioning System
GSM	Global System for Mobile communications
HAKOM	Croatian Regulatory Authority for Network Industries
HSDPA	High Speed Downlink Packet Access
HTTP	Hypertext Transfer Protocol
ICTA	Information and Communication Technologies Authority
ITU	International Telecommunications Union
KPI	Key Performance Indicators
LTE	Long Term Evaluation
MCA	Malta Communications Authority
MNO	Mobile Network Operator
NKOM	Norwegian Communications Authority
NMHH	Nemzeti Média és Hírközlési Hatóság
NRA	National regulatory authority
OECPR	Office of the Commissioner of Electronic Telecommunications and Postal Regulation
OFCOM	Office of Communications
PDP	Packet Data Protocol
PMD	Prüf- und Messdienst
PTA	Post and Telecom Administration
PTS	Swedish Post & Telecommunications Agency
RATEL	Republic Agency for Electronic Communications and Postal Services (Serbia)
RRT	Communications Regulatory Authority
RSCP	Received Signal Code Power
RSRP	Reference Signal Received Power
RxLev	Received Signal Level

Acronym	Definition
RTR	Regulatory Authority for Broadcasting and Telecommunications (Austria)
SINR	Signal to interference plus noise ratio
SPRK	Public Utilities Commission (Electronic Communications and Post Dpt)
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UKE	Office of Electronic Telecommunications
UMTS	Universal Mobile Telecommunications System