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MEASURING MOBILE NETWORK PERFORMANCE:
COVERAGE, QUALITY OF SERVICE AND MAPS

JANUARY 2020

Fratel
Réseau francophone de la régulation des télécommunications

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FOREWORD BY THE COORDINATION COMMITTEE

One of the main features of today's global digital revolution is the importance of having access to information while being mobile. Users want to have access to a network to be able to communicate, stay informed, shop, work and be entertained, regardless of where they are, and especially when on the move.

As a result, the ability to use a mobile network – whose quality is high enough to provide users with access to any service they want, at any given moment – has become a central issue and challenge in every country on the planet. This is why Fratel (the French-speaking network of telecommunications regulation) included the theme of mobile coverage and quality of service (QoS) in its 2019 action plan.

Largely in preparation for the seminar in Douala, Cameroon, which was held on 2 and 3 April 2019, a questionnaire on this topic was sent out to all Fratel members in early 2019. The 25 detailed responses that were received demonstrated how central this issue is for regulators. They expressed the need to discuss and share their experiences on this issue, which includes highly technical aspects and encompasses important regulatory objectives. These include regional digital development, incentivising operators to invest in their networks, and making their country's economy more competitive.

Drawing on an array of mobile quality of service and measurement practices in countries that share French as a common language, this purpose of this document is to deliver an outline of current data collection, use and publication practices. It thereby sets out for authorities the key focal points for ensuring that mobile quality of service and coverage data are published under the best possible conditions.

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SYNOPSIS

Measuring and monitoring coverage and quality of service means being able to assess reality and its representation. Data collection is a vital ingredient in this process. But which data need to be collected? How to go about it? How to process the collected data and ensure their accuracy?

These questions underscore the need to establish a common vocabulary on mobile coverage and quality of service (QoS).

If the practices used to measure, simulate and estimate coverage and QoS may vary, they can nonetheless be summarised by four levels of testing. Namely:

- Utilisation of the data generated by operators' networks, notably those obtained from simulations;
- Measuring technical parameters;
- Use of a network accessibility testing protocol;
- Use of a protocol that reflects actual use.

These measurements can be obtained either within a controlled environment, or an uncontrolled environment via crowdsourcing.

What exactly is being measured? What do the terms coverage and QoS encompass? These two notions are sometimes confused, and need to be defined to be able to properly assess their scope. While coverage is an indicator that is available nationwide, based in particular on theoretical signal propagation simulations (which can then be verified by testing in the field), QoS is both a technical and subjective notion that can be measured by more or less complex tests, whose ultimate purpose is to measure the network's capacity to satisfy the user of a service on that mobile network. When tests make it possible to assess the degree of a user's satisfaction or dissatisfaction, we then refer to quality of experience (QoE).

Measuring coverage means verifying whether a user is able to connect to their mobile network, establish and maintain a call for a set minimum period of time, achieve a specific data transmission speed, and access different services. Several parameters can be used to measure this coverage. If signal strength (signal range and quality) provides an initial indication, measuring service accessibility (ringtone within a certain time, time it takes to download several bytes of data, etc.) makes it possible to obtain a more accurate representation of coverage. By combining these different types of measurement we can eliminate, to some degree, disparities between operators' stated coverage and users' actual experience. Providing only information on signal range can, on the contrary, result in a situation where users are unable to access services despite a location being covered in theory.

As to quality of service, it can be measured using several criteria or indicators set by the regulator. These indicators or criteria make it possible to measure voice call performance (accessibility, integrity, continuity) compared to benchmark thresholds. Indicators for measuring mobile internet quality are more challenging to determine, given the heterogeneousness of data services. Authorities can therefore measure the internet connection success or failure rate, the average time it takes to establish a connection, or the success rate for connecting to a remote server, etc. These criteria can vary from country to country, depending on the ultimate objectives. In any event, regardless of the objectives, it is crucial that these indicators be reliable and reflect QoS as accurately as possible.

In countries where operators are subject to coverage and/or quality of service obligations, QoS and coverage measurements enable regulatory authorities to conduct tests to ensure operators are complying with those obligations.

Monitoring obligations is not the sole aim of these measurements.

Monitoring obligations is not the sole aim of these measurements, however. They can be used by the regulator for information purposes, and to help steer the market and investments. A consumer who is well informed, not only about available products but also, and especially, about network quality and breadth of coverage, can choose the operator that best meets their expectations. Users' choices can create real incentives for an operator wanting to protect its market share. This process of gathering more accurate information from regulated players, and expanding the number of data sources, through crowdsourcing, for instance, of more detailed data processing and centralising data also help amplify the regulator's capacity for action, notably for the purposes of market supervision.

QoS and coverage measurement campaigns can help in establishing and steering the actions of public authorities and of the bodies providing funding regional digital development initiatives. Findings obtained on areas where there is little or no coverage, and where quality of service is poor, can help steer investments and serve to gauge the financing that will be required to remedy the situation.

The audience for these findings can be relatively varied, and each will have their own set of expectations, so the way in which the measurement campaigns' findings are delivered need to be tailored to each. Indeed, one of the most important stages is no doubt the publication of the findings.

Depending on the country and the regulator's practices, this delivery of information to consumers can take various forms, such as rankings, scores by criteria, graphics, audit reports, maps and even raw data, supplied as open data sets, adapted to the different channels (online or print publication, press conference, etc.).

A professional observer, or a partner interested in using these data for publication in the form of their choosing (graphics or maps), will be more interested in data that they can repurpose. On the flipside, the dissemination of QoS and coverage measurements in map form has the advantage of providing a snapshot of QoS and coverage in a given geographical area, and gives consumers a clearer view than information presented in graph form or as raw data.

If the regulator wants to ensure transparency on data, it needs to make clear editorial choices on how to publish them

If the regulator wants to ensure transparency on data, it needs to make clear editorial choices on how to publish them, and pay particular attention to how these data are structured. To this end, it can rely on its own expertise, call on outside experts or form partnerships with them.

INTRODUCTION

Citizens today aspire more and more to be informed, entertained, shop, transfer money and communicate using their mobile phone. Starting a conversation at home and continuing it over their car's speakers, sending out a request while travelling and using that information once they arrive at their destination. Finishing up some work or getting a head-start while on public transport. Getting groceries or shopping online, paying for a taxi or receiving their salary using mobile payment solutions. All actions that are now possible on mobile networks, coming to complement fixed networks.

In reality, however, a distinction must be made between those areas where networks enable access to all of the activities listed above, and those where only some of these activities are possible – not to mention the white areas where the absence of network coverage makes it impossible to use one's device for any form of communication whatsoever.

Talking about coverage and quality of service above all means being able to assess reality through testing, but also knowing how to represent it, through publications adapted to the target audience.

In a great many Fratel member countries, the mobile network was deployed gradually and enables users to take advantage of the services supplied by operators, in most parts of the country. There are a number of issues attached to this deployment, including: the ability to access the network anywhere in the country (coverage) and with a quality that is compatible with the type of use consumers want (quality of service).

Talking about coverage and quality of service above all means being able to assess reality through testing, but also knowing how to represent it, through publications adapted to the target audience.

Because mobile coverage and quality of service are such important issues, the Fratel network held a consultation with its members in early 2019 to assess regulators' different measurement, processing and transparency practices.

The number of responses received (25) testify to how important these issues are to regulators.

These responses helped provide a picture of the range of coverage and quality of service measurement and data processing practices that exist. More importantly, the responses make it possible to assess the underlying objectives of regulators' coverage and QoS data collection and processing initiatives.

A great many governments impose quality of service and/or coverage obligations, and their regulators monitor operators' mandatory compliance with a set of specifications, through a variety of actions. Depending on the regulator and the terms and conditions attached to licences, operators may consider the indicators to be overly numerous and detailed.

For the regulator, measuring QoS and coverage also means obtaining the means to stimulate competition and steer the market in the right direction, by providing users with the information that will enable them to choose the operator that best matches their needs, in an objective fashion. To this end, it is recommended that the results be published in a way that creates informed users, while not overwhelming them with technical details. Collecting data from various sources and centralising that data also creates a new market analysis tool for the regulator.

Verifying the efficiency of investments (for international financial institutions and even operators), steering regional digital development actions, and assessing public policies are all further reasons to conduct QoS and coverage measurement campaigns.

Whatever the motivations, to be able to utilise and analyse the collected data, their format must align with the regulator's goals. Delivering the findings in the form of a map provides a snapshot of nationwide coverage that can be seen at a glance. Quality of service could, for instance, be represented with pictograms or colour coding. For more informed audiences, data could be made available or represented using graphs that can be used to analyse the situation in a given area or country.

The purpose of this document is to lay out the state of the art of mobile quality of service and coverage measurement, based on the experiences of Fratel member countries. If fixed network QoS is an equally significant issue, and the subject of interesting work being done in Fratel member countries, in this document we shall focus solely on mobile quality of service.

Whatever the motivations, to be able to utilise and analyse the collected data, their format must align with the regulator's goals.

The aim of the first part will be to understand the notions and definitions surrounding the measurement of mobile QoS and coverage, before examining the motivations of the stakeholders involved in the second part. The third part will focus on how to represent the collected data, and will draw attention to several key focal points for authorities seeking to ensure transparency on QoS and coverage under the best possible conditions.

CHAPTER 1

WHAT DATA TO COLLECT AND HOW TO OBTAIN IT? COVERAGE AND QUALITY OF SERVICE DATA COLLECTION AND ACCURACY: OVERVIEW OF EXISTING PRACTICES

The exchanges that have taken place within the Fratel network, particularly in response to the questionnaire on mobile coverage and quality of service, led to two conclusions: first, that regulators are employing a wide array of practices for estimating, simulating and measuring mobile coverage and quality of service, depending on their imperatives (aim of the exercise) and their specificities. Despite the disparity of these practices, all share a common goal: to obtain accurate and objective data that enable regulators to qualify the reality of operators' deployments, and the accessibility of the services being provided to users in terms of both coverage and quality. These data can come from a range of sources, starting with operators, from regulators themselves and from third parties such as consumers or data specialists. Next, the regulator must ensure their accuracy.

A host of possibilities and practices are being employed around the world for qualifying mobile networks. We can distinguish four levels of testing that are used to obtain coverage and quality of service data, each of which does not satisfy the same objectives (cf. Chapter II) nor offer the same advantages:

- utilising **data collected directly from operators' networks** (e.g. call failure rate, usage statistics, cell towers, etc.);
- taking a reading of or measuring one or several technical network parameters (e.g. measuring the **strength of the signal** resulting from operators' base station deployments);
- using a protocol that corresponds to a mobile network **accessibility test** (e.g. pinging the network, measuring speed, etc.);
- using a protocol that corresponds to an **actual use case** representing the customer perspective (e.g. downloading a web page, watching a video, running an internet speed test, etc.).

In addition to the existence of these four levels of testing, there are also several ways to collect data, regardless of the level of testing being considered. Including:

- measurements taken in a **"controlled"** environment, by technicians or people performing the same tests, in the same location, at the same time, using the same device;
- measurements obtained through crowdsourcing, both actively by users (dedicated apps) or passively (background tasks that can be incorporated into applications).

Depending on regulators' choices for defining and measuring coverage and QoS and their data sources, these different tests can be employed using both types of data collection. Regardless of the level of testing and how the data are collected, all regulators want to ensure that the data they collect are accurate and high quality.

1.1 Key definitions: coverage, quality of service, licences, etc.

Several key indicators are measured and verified by the different Fratel members, encompassing the notions of coverage, quality of service (QoS) and quality of experience (QoE).

To obtain an accurate measure of mobile coverage, mobile services' coverage maps provide a first level of information. They are produced using digital signal propagation simulations. In addition to network properties (antennae's location, orientation and power, etc.), they take into account the geography of the site's surrounding environment, notably relief and vegetation, whether there are buildings or other obstacles, without necessarily defining them precisely). Produced based on digital simulations, these maps thus provide a simplified rendering of reality. Although theoretical, these maps give a good indication of the mobile signal's *a priori* availability in a given location. They have the added advantage of providing a snapshot of coverage across the entire country. Simplified also means imperfect, however: the maps do not constitute a guarantee of service, but rather reflect a deployment of capacity.

The notion of **quality of service (QoS)** is a technical one that makes it possible to actually test a mobile network using a more or less demanding process. All of the telecom service's properties that could influence its ability to satisfy the mobile service's users are tested. The tested service could be speed (downloading or uploading a file), transfer time (latency or ping[1]), or reliability (packet loss).

As defined by ITU, **quality of experience (QoE)** refers to "the degree of delight or annoyance of the user of an application or service". Measuring QoE thus provides a view of a mobile network from the user's perspective. For instance, watching a video and observing any degradation in quality can be qualified as measuring QoE. To measure the audio quality of voice calls, the benchmark model is the POLQA algorithm defined by the ITU-T P.863 standard. It is a model for measuring degradation obtained from standardised sound samples. This degradation is compared to the behaviour of the human ear to deduce the quality perceived by the end user.

1.2 Information collected by regulators

Fratel member national regulatory authorities (NRA) employ different methods to calculate 2G, 3G and 4G coverage, measure the quality of voice call, SMS and data services, and monitor operators' compliance with their obligations. Each technique has its own set of advantages and disadvantages. The various methods used to measure mobile coverage and QoS can be at-

1) A ping makes it possible to measure the time it takes for a data exchange between the phone and the network.

tributed to the coverage and QoS obligations that are imposed to solve specific problems, or by the different objectives that regulators have set for themselves. This could include expanding coverage across the country, especially to less dense populated areas, helping to reduce the digital divide, incentivise operators to invest in their networks, or to make the country's economy more competitive.

The various coverage and QoS obligations may therefore require specific testing methods to be able to asses operators' compliance with their obligations as accurately as possible. Regulator are also required to collect data to keep users informed about the different mobile networks' performance, and to enable public bodies and governments to obtain a scorecard on the status of digital tech in the country, to map out a digital blueprint and launch network rollout schemes (see Chapter 2 for a more detailed presentation of the objectives attached to coverage and QoS measurements).

1.2.1 Coverage

Generally speaking, a geographical area is considered to be covered if a user, with a compatible device, can connect to their mobile network, establish and maintain a phone call for a set minimum period of time, achieve a specific data transmission speed, or access the different services. NRAs typically measure coverage for voice call, SMS and data services. For practical reasons, they use one or several key parameters to determine whether an area is covered. This could mean, on the one hand, calculating the power of the received signal (signal strength and signal quality) and, on the other, testing the ability to access certain services, which takes greater account of the user experience.

a) Measuring certain technical parameters (signal strength and signal quality)

Because the radio signal's properties will depend on the technology (2G, 3G or 4G), different criteria are used, such as RxLev (received signal level) for GSM, RSCP (received signal code power) for UMTS and RSRP (reference signal receive power) for LTE, to estimate these signal strengths. In principle, this requires setting different tiers. An area is considered covered if the set maximum strength of field is reached.

Specific power thresholds and/or success rates can be set, depending on the type of situation (in a car, stationary, indoors...) or the type of location (large cities, smaller cities, villages and transport corridors).

In addition to signal strength, some regulatory authorities, such as ANRTIC in Comoros and ANCOM in Romania, also include signal quality measurement in mobile operators' obligations (Rxqual for 2G, Ec/no for 3G and SINR for 4G) to define coverage. As a result, when monitoring compliance with these obligations, these regulators consider an area to be covered by mobile communication services if there is compliance with two power criteria combined.

Still in the context of obligations attached to licences, certain authorities may also set minimum speed thresholds, according to the technologies, to ensure good broadband or superfast broadband coverage.

Lastly, in some cases, coverage measurements defined in the specifications of frequency licences, depends on signal power, on the one hand, and on service accessibility, on the other. This is the case in Ivory Coast, Guinea, Qatar and Senegal.

b) Service accessibility

In Senegal, to meet the 4G coverage obligations listed in their licences, coverage is measured, first, by signal strength and, second, by the ability to download a minimum 512 kb file at a speed of at least 2 Mbit/s, in a significant number of locations in the municipality in question, or on the chosen roadway. The download success rate must be equal to or above 90% for a municipality or a road to be declared covered.

If several Fratel member authorities use signal strength to calculate voice call and internet access service coverage, others believe that this method does not reflect the customer experience accurately enough, and instead analyse the services' accessibility to assess whether an area is covered. Indeed, radio signal strength and quality do not guarantee that a mobile user will actually be able to employ the service. As a result, certain authorities assess whether a location is covered using criteria that are tied more to the accessibility of the service being provided in that location, which corresponds more to the user experience. This may simply involve verifying that there is a ring tone within 30 seconds, or the ability to download a file of several bytes of data. The results of the test are binary, so make it possible to qualify an area as being covered or not covered.

Lastly, it should be noted that some authorities impose no coverage obligations. This is true Luxembourg, Mauritius and Madagascar.

While the signal value is the first step in measuring network coverage, it is possible and, depending on the set goals, potentially necessary to go further by analysing the service's accessibility.

1.2.2 Quality of service

Generally speaking, quality of service includes all of the aspects of a service provided from end to end. It therefore depends on the performance of several pieces of equipment (radio equipment or device used), as much at the network core as the access network level. There are several standards and concepts that address quality of service.

Regulatory authorities may define specific parameters to measure a mobile network's coverage and quality. If the most basic criteria may serve to determine whether or not an area is covered (network accessibility, signal quality or power), others are more elaborate and make it possible to measure the various quality of service aspects.

Every authority will be required to set their own performance criteria and indicators according to their regulatory objectives, and these can differ from country to country. The vast majority of Fratel member NRAs does impose QoS obligations on mobile operators to ensure

Radio signal strength and quality do not guarantee that a mobile user will actually be able to employ the service.

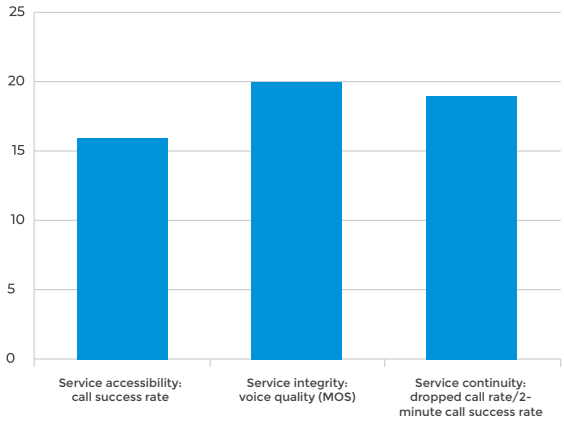
a minimum quality of mobile network for users. For other regulators, the only purpose of this information is to supply end users with clear and accurate information, to enable them to make informed choices, beyond just price, on the operator that best suits their needs – without creating any constraints for operators.

In addition, some regulators may set different QoS obligations for different situations. Requirements for mobile use when travelling (by car, train or metro) are typically less demanding than those imposed on outdoor, static use.

Whether for voice calls or data services, key performance indicators (KPIs) are used to measure the service's accessibility and integrity. For voice calls, however, authorities will also take the service's continuity into account, while generally applying an average speed test for data services.

a) Calling services

The main performance indicators for voice calls



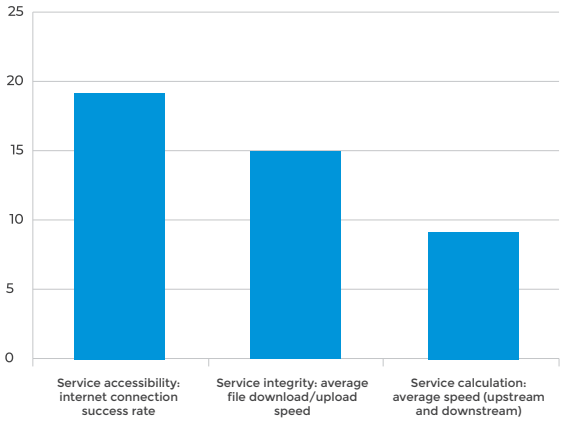
Top three QoS indicators for voice call services, by criteria

Regulatory authorities generally analyse the accessibility, integrity and continuity of voice call services. Several measurements can be defined in each of these different categories. For service accessibility, most authorities measure call success rates. Call failure or call blocking rates are also widely used criteria. For continuity of service, the only criterion used is the ability (or not) to maintain a call for two minutes. Finally, to measure a service's integrity, the quality of the voice and listening quality (MOS score) is the main criterion. The minimum quality threshold does, however, differ from country to country, and different measurements are taken, some of which set relatively high thresholds. If some regulators set a call success rate with a minimum MOS score of 2.1, others have adopted and imposed a success rate for good quality calls, with an MOS score of between 3 and 3.6, or a perfect quality call rate, with an MOS of 3.6 or more. Regulators in a few countries have set several quality levels with which operators must comply.

It is also worth nothing that certain regulators also apply additional criteria, such as handover and signal to interference ratio (SIR).

b) Internet access services

Main key performance indicators for mobile data



Top three QoS indicators for mobile data services, by criteria

As with voice call services, authorities analyse the accessibility and, to a lesser extent, the continuity of data services. Regulators also perform their own calculations of upstream and downstream speeds. However, because data services are more heterogeneous than calling services (including internet access, file downloads, streaming, speed, etc.), regulators typically establish more criteria for measuring quality than they do for voice calls.

For service accessibility, authorities can measure the internet connection success rate or rate of blocking, the average time it takes to establish an internet connection, the rate of successful connection within a set period of time (connection established <x seconds/established connections), the rate of success or failure for connecting to a remote and/or local server (upstream/downstream) or the success rate for video streaming.

On the matter of speeds, regulators can calculate the average or median speed for uploading or downloading a several megabyte file to/from a remote server (located in the country or abroad), but also peak and effective (2/3 of the operator's headline speed) bitrates.

For continuity of service, web browsing speeds will be measured (for 3 or 5 minutes) or the ability to stream a video with perfect or acceptable quality.

As with voice calls, here too additional criteria may be applied: packet loss, acceptable jitter or latency.

c) Other

In addition to KPIs for voice and data services, authorities measure – and in certain cases impose – supplementary quality criteria such as the maximum downtime for a base transceiver station, or administration-related ones such as the accessibility of the operators' call centre, the number of complaints and their resolution rate, frequency of complaints about interference and the time needed to resolve them, billing accuracy, etc.

1.3 Are the same data collected regardless of use (in a train, a car, pedestrian, indoors, etc.)?

Coverage verification protocols are typically relatively simple. They involve calculating signal strength or testing network accessibility under conditions that reflect static use, outdoor use or use when on some form of transport. In some countries, data on indoor use are also collected.

Quality of service measurements, on the other hand, require tests that are adapted to the many potential situations that end users might find themselves in, to be able to reflect the customer experience as fully as possible. This can include indoor and outdoor use, use while stationary or while walking, but also while in a car, a train or the metro. In addition, it is important to spread testing out across densely and more sparsely populated areas, to avoid bias and to compare network performance in these various situations.

1.4 Data sources, their reliability and limitations

The data used to measure coverage and quality of service come from several sources. These can include operators, regulators themselves via surveys, information from user complaints, measurement campaigns from third parties (local authorities, partner enterprises, associations, users through crowdsourcing...). If various data sources are available to regulators, there may also be inherent collection or reliability issues attached to some.

To be able to utilise these data sources, regulators employ different collection and processing methods, to aggregate them and ensure their accuracy, with a view to subsequent analysis.

Viewing data collected from mobile operators - AMRTP (Mali)

1.4.1 Data from operators' networks: data from OMC meters and probes

a) Data from operation and maintenance centre (OMC) meters

To measure performance indicators and monitor quality of service, some regulators gather network data directly from operators. These can be performance files that include a series of KPIs[2] – generally those defined by 3GPP or ITU – or raw data from data collection servers that are connected directly to operators' network equipment.

Operators collect a massive quantity of data for measuring and monitoring their network's performance and quality. Meters record a number of events, notably the different requests that mobile phones send and receive during an exchange with the network[3]. Monitoring platforms then calculate performance criteria based on dedicated protocols and formulas. This also enables operators to configure and adjust the parameters of their network cells. Because these KPI are calculated in real time, operators can intervene immediately when a problem is detected on the network. In addition, thanks to these aggregated data, an operator can analyse its network performance on a daily, weekly, monthly, quarterly or annual basis.

Although abundant and relevant for regulators, the information obtained from operators' networks reflects the operator's viewpoint and network performance, and not necessarily the customer experience and their ability to use the network (end to end view). Moreover, the right to collect data will depend on the legal framework put into place in each country: depending on existing regulations, it may be difficult (if not impossible) to require operators to transmit this information to the regulator, or to install the regulator's data collection servers on their equipment. Added to which, this installation of a data collection server can potentially be a technically complex affair. And, finally, the process of ensuring the data's accuracy requires either that the regulator deploys a platform, or a post-processing and analysis tool for the indicators. Virtually real-time data transmission does, however, give the regulator the ability to monitor the quality of mobile networks in its country on a day-to-day basis, and to obtain a very large quantity of information.

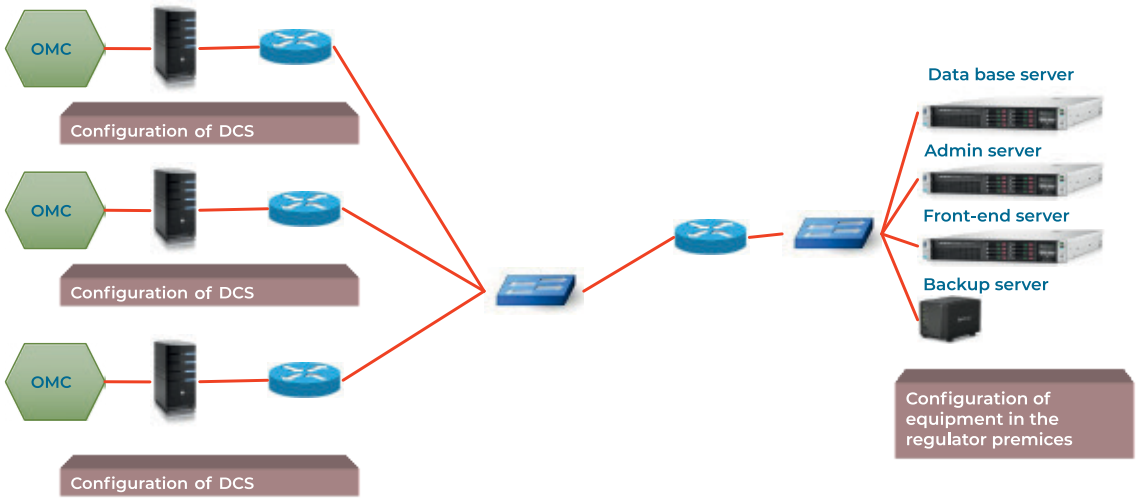
To measure performance indicators and monitor quality of service, some regulators gather network data directly from operators.

b) Performance data files

Authorities can recover these data through performance data files that mobile operators transmit to the regulator at regular intervals, either as raw data (RAW counters) or as PDFs. These files contain a number of KPIs established by operators' OMC meter databases. Each operator uses its own formulas for processing these data and ensuring their accuracy. Operators generally adopt formulas provided by equipment suppliers, which comply with international requirements. Depending on the equipment supplier, the KPIs will not be identical, however, which raises the issue of the comparability of the different operators' data. This information is then verified by the regulator and the data's accuracy ensured by cross-referencing them with field measurements, for instance (see 1.4.3).

2) For instance: regarding network availability, rate of blocking, dropped call rate, call success rate and their progression, intra-cell handover success rate, interference, radio channel traffic congestion...

3) These meters are located at the BTS (2G) and Node B (3G)/e-Node B (4G) level. Raw data files are transmitted to the BSC/RNC which aggregate them and send them to the OMC platforms. The RNC (radio network controller) is an access component in a 3G UMTS mobile telephone network. It is the equivalent of a 2G GSM network's BSC (base station controller). It controls the base stations' (Node B) radio transmissions and interfaces with the mobile operator's core network.



Graphic of data collection of operators' OMC servers

c) Data collection servers in the network

Operators may also install OMC data meters directly on the data collection servers, installed on their networks at the regulator's request These data are then sent to another server located on the regulator's premises, using secure links. These raw data, in CSV or HTML format, are analysed, fed into the database by the authority which, thanks to a reporting system, can issue requests and produce its own indicators, regardless of which equipment supplier operators use. Here, it is the regulator which, based on raw data, must ensure the data's reliability using a post-processing tool. This gives the regulator a more detailed understanding of operators' QoS, and it can compare its own KPI with those calculated by operators.

d) Probes

Probes create the ability to collect all of the streams traveling over a data interface, whether traffic or signalling. Operators use this technology to collect a maximum amount of information (to monitor a particular procedure or a specific mobile phone, for instance). The volume of the data to be collected, stored and processed is substantial. Depending on the existing legal framework in their country, some regulators can require operators to install probes at traffic nodes to log the volume of calls (to verify operators' revenue, whether for international or interconnection traffic) or to collect certain QoS indicators that can be extracted through these probes that regulators use, such as call completion rates. This solution can only serve as a complement to other data sources, to assess an operator's overall quality of service, and is not suitable for monitoring coverage.

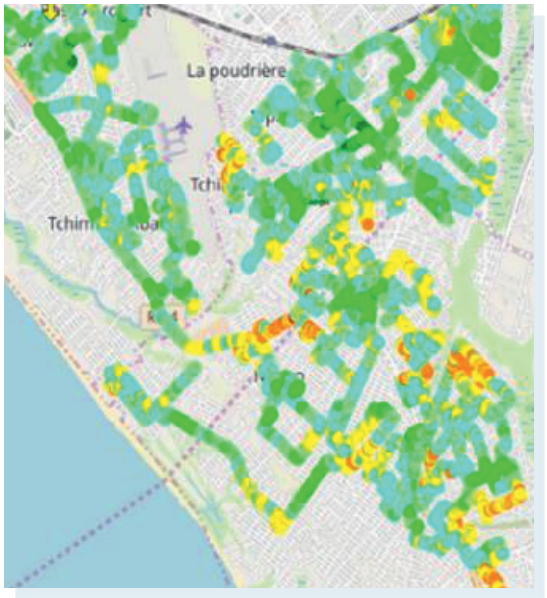
1.4.2 Coverage maps' simulation tools

Regulators can use software to verify, simulate and observe operators' theoretical coverage. In particular, this software makes it possible to calculate theoretical predictions of geographical and population coverage rates, both nationwide and on a regional and local scale.

This therefore enables authorities to produce coverage maps and verify that they are consistent with operators' maps, to verify compliance with coverage obligations and to ascertain the coverage level in an area before scheduling a measurement campaign in the field. That said, the regulator must have the right technical expertise to use coverage maps' simulation tools, which requires it to train its staff.

In any event, this is not necessarily relevant for every authority, notably in those countries where operators do not produce coverage maps.

The feedback obtained from Fratel members revealed that only three authorities (Burkina Faso, France and Morocco) have such a simulation tool.



Results of data collection for 3G voice. Source : ARPCE (Republic of Congo)

The regulator must have the right technical expertise to use coverage maps' simulation tools, which requires it to train its staff.

1.4.3 Field measurement campaigns

For the vast majority of Fratel network members, the main source of data for measuring and monitoring the coverage and quality of service provided to operators' customers is field measurement campaigns.

These campaigns are generally carried out by an independent, outside service provider, overseen by the regulator, and using protocols and criteria agreed upon with operators, to guarantee accuracy. They can either be financed by the regulator or by operators themselves. It should also be noted that some regulators have acquired their own hardware, and conduct these field campaigns themselves.

The scope of the measurement campaigns and the procedure's complexity will vary, depending on the criteria set for defining coverage (only outdoors or in several locations and situations. It should also be noted that these surveys can apply to different networks, notably when some form of network sharing is involved.

Regardless of the country, however, the process of analysing QoS requires a large number of data, as a number of location-related use cases need to be taken into account: indoors, on transportation (car, train, metro, etc.), on specific transport corridors (motorways and main roads, high-speed trains, commuter trains, etc.), in different types of area (urban, suburban, rural) and covering both stationary and mobile use.

There are several limitations and challenges inherent in field campaigns:

- Financially, they are relative costly, which restricts the possible number of measurements that can be taken to verify mobile coverage and measure QoS;
- To ensure the process's accuracy, it is vital that regulatory authorities and operators agree on the measurement protocol. Using an independent outside company to perform these tests may also reduce the risk of disagreements, provided their protocols are robust and mastered or approved by the regulator;
- Compared to simulated coverage maps, field measurement provides only information on a specific location at a given moment in time. And given the time and cost it takes to perform these tests, it is unreasonable to plan on testing every centimetre of the country;
- Data analysis requires several weeks of processing. The information that regulators will potentially publish only reflects the network's status a few weeks before that information is published. Added to which, it is difficult to conduct very frequent campaigns (the rate for most regulators is once a year). The resulting findings that are displayed are therefore several months old in many cases.

It should also be noted that these surveys can apply to different networks, notably when some form of network sharing is involved.

When the aim is, for instance, to verify an operator's deployments, testing will be confined to just that network. But when the purpose is to verify the accuracy of its maps, or customer QoE, measurements will also include situations where the user is roaming.

1.4.4 Consumer satisfaction surveys, complaints and reports

Regulators have traditional tools and technical and economic indicators that contribute to their knowledge of the market. To round out this approach, and create the ability to detect weak signals, they can develop a more detailed understanding of users and the problems they encounter.

The first possible path is a user survey. This solution often makes it possible to better identify the issues that users are encountering in their dealings with the sector.

Beyond that, incident reports, particularly those submitted by users, are an efficient way to develop a more detailed view of difficulties in the sector. By drawing lessons from users' actual experience and their habits, regulators can look at recurring malfunctions that users encounter, and detect peak times to build a body of evidence that will help direct their actions, and devise systemic solutions for improving the way the sector functions. A system for submitting reports can be created by making a freephone number available to consumers, as is the case in Mali, or an online reporting platform, as is the case in France.

Drive-test data collection. Source AMRTP (Mali)

Customer complaints and reports thus make it possible to satisfy two of the regulator's objectives at once: first, to deepen their knowledge of users and the reality in the field and, second, to better inform those users.

Consumer satisfaction surveys, along with collecting consumer complaints and reports are an additional and valuable source of information for regulators. However, setting up an online reporting platform or a dedicated number, or conducting satisfaction surveys can require substantial financial and human resources. The lessons that the regulator can draw from this information requires in-depth analytical processing. These data on their own cannot enable the regulator to analyse network quality of service and coverage.

1.4.5 Crowdsourcing

Quality of service can also be monitored using crowdsourcing solutions. These solutions use a different approach to quality monitoring in a controlled environment: tests are conducted on a user's device, typically using an app. The environment is thus no longer "controlled" and there is no longer a guarantee of comparability for different operators' test results (different devices, testing apps, type of tests, testing conditions, etc.) – unlike the results obtained through a more closely supervised measurement campaign.

The results can also be more or less relevant depending on the testing methods used. They depend to a large extent on users' capacity and desire to perform these tests, and therefore on their devices, their mobile plan's data allowance, their ability to access the network to perform the test and transmit the results, etc.

These measurements can, however, provide a useful complement to those obtained in a controlled environment, creating a larger volume of data, from different parts of the country and on a more regular basis. They can thus help feed the regulator's work and the process of keeping citizens informed, creating a dialogue with the controlled environment's more representative data.

Certain regulators, such as those in Belgium, Burkina Faso, Ivory Coast, Luxembourg, Qatar, Tunisia and Morocco, rely on or plan to rely on their own crowdsourcing apps to collect additional information. One alternative solution could be to establish partnerships with third parties that specialise in crowdsourcing solutions, to share or obtain data that can supplement those obtained through testing in the field.

Consumer satisfaction surveys, along with collecting consumer complaints and reports are an additional and valuable source of information for regulators.

In addition to the technical and financial impediments to developing a crowdsourcing app in-house, there is the issue of representativeness, of analysing and ensuring the reliability of the data collected from different phones, in situations that are not always specified (indoors, in a car, etc.). Added to which the information being sent back will be coming chiefly from areas with sufficiently good coverage, and do not provide a view of white or grey areas. However, based on aggregation and bias reduction criteria, these data can prove a useful complement to those collected directly by regulators.

ARCEP in Burkina Faso: experience with data sources and the accuracy of mobile network coverage and quality of service data

Data sources

There are three sources of mobile network coverage and quality of service data:

The regulator (ARCEP)

We collect data through quarterly campaigns and annual drive testing.

Satisfaction surveys are also an important data source. They make it possible to asses users' perception of the quality of the services being provided.

ARCEP has a radio planning tool for performing national and population coverage simulations, to satisfy white areas' coverage needs.

These different data sources complement one another, and enable ARCEP to reap the benefits of each. We also have a global view of operators' networks' performance, of quality of service and network users' quality of experience, which helps to channel the actions we take to improve QoS.

The choice to tap into crowdsourcing solutions comes from ARCEP's desire to put users at the heart of the quality improvement process. The customer perspective this solution delivers enables us to better steer our actions, and to provide users with reliable information on the quality of the networks where they live.

Operators

Network operators' data gives us an idea of network performance. Operators also have radio planning tools for performing coverage simulations, which they share with ARCEP.

Users

Users provide a treasure trove of valuable information, through the use of crowdsourcing tools to collect QoE data, as well as the complaints that the regulator receives through various channels.

Pros and cons of the different data sources

Collection tools	Pros	Cons
Drive testing	QoS-oriented and simulation of different measurement conditions, objective assessment of voice and service quality	High costs, long time to execute, provides only partial and time-specific view of QoS
Data network	Collecting data on the entire network, low cost and automatic process	KPIs dependent on equipment suppliers, network performance-oriented data, and not QoS/QoE, no data from not-spots, data can be manipulated by operator or equipment supplier
Crowdsourcing	Large quantity of data, information reflects users' quality of experience	Need to have a smartphone, need to implement an efficient communication plan, representativeness of the sample
Radio planning tool/coverage map simulation tool	Global and consolidated view of radio coverage, ability to determine white areas, ability to correct coverage maps via other data sources	Need to calibrate prediction models for greater precision, possible disparities between predicted theoretical data and actual data from the field
User satisfaction survey	Customer viewpoint	Subjectivity of opinions

Ensuring data accuracy

Collection tools	Ensuring data accuracy
Drive testing	‣ Determine a representative sample for each type of service, usage, conditions of use, etc. ‣ Guarantee that measurement tools function correctly ‣ Define a test protocol according to usage, conditions of use, etc.
Data network	‣ Collect raw data from operators' networks ‣ Use standard formulas for calculating KPIs
Crowdsourcing	‣ Involve all players to enable massive data collection
Radio planning tool	‣ Use other data sources (drive testing, crowdsourcing…) to cement coverage maps' accuracy ‣ Use calibrated prediction models
User satisfaction survey	‣ Determine a representative sample

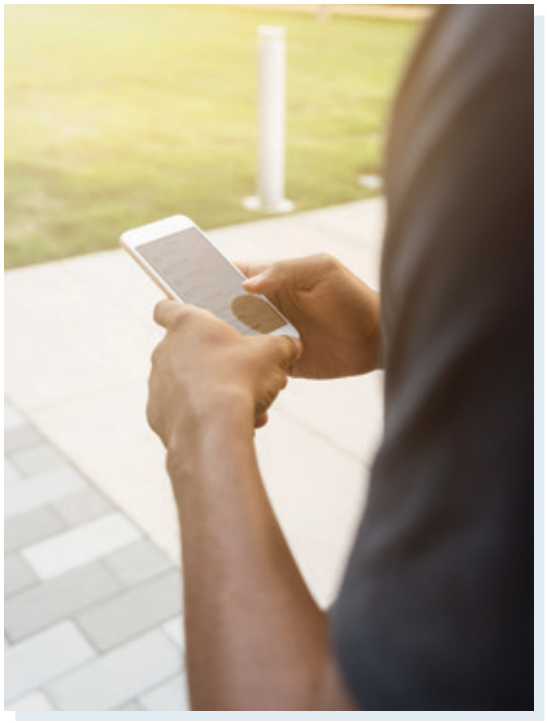
CHAPTER 2

COVERAGE AND QOS DATA, WHAT FOR AND FOR WHOM?

It is essential for regulators to perform coverage and quality of service tests, which fall under the important issues and challenges of connectivity:

- Improving mobile coverage nationwide (to ensure an increasingly large percentage of the population has access to services, including in those locations that operators do not "naturally" cover, such as roads and less dense populated areas);
- Improving quality of service for citizens and businesses alike: this can be achieved through rollout obligations (e.g. written into licences), but also through the information provided to users, enabling them to make informed choices and so steering the market and rewarding operators' investments.

Measuring coverage and QoS can therefore satisfy a variety of objectives: monitoring rollout obligations, transparency, investment choices... These objectives guide or can justify the use of different methods, which is why it is advisable to have a clear idea of those objectives to be able to define exactly what type of testing will make it possible to obtain reliable information on the networks' true status.



2.1 To monitor operators' compliance with their obligations

The first, and most natural, lever to impose on operators – to deploy their services and improve their mobile coverage – is that of obligations attached to frequency licences. Through these obligations, the regulator seeks to ensure that users have access to at least a minimum, satisfactory quality of service.

Of the Fratel members who answered the questionnaire, the vast majority also impose quality of service obligations on operators. This results from the fact that broadband and superfast broadband networks, which are able to deliver a minimum speed and good quality of service for voice and data services, are severely underdeveloped in some countries.

More and more countries are adapting their approach to regulation by adopting **data-driven regulation**. The idea is to be able to leverage the power of information to steer the market in the right direction. In practice, this involves collecting more detailed information from market stakeholders, and diversifying data sources. This in turn amplifies the regulator's capacity to take action, notably when seeking to supervise and monitor obligations, create informed users, better steer the market and reward investments, but also to obtain a more accurate diagnosis of the situation across the country, and to track investments.

Regulators are adapting their collection and use of data depending on their regulatory objectives. This process must not be confused with mere transparency. It is a veritable regulatory tool. Regulators must be involved to define priorities and underscore certain parameters in particular, standardise certain notions and, if appropriate, centralise information.

ARPCE in Congo-Brazzaville: experience with coverage and quality of service indicators

In accordance with Article 5 of Act No. 11-2009 of 25 November 2009 on the creation of a Postal and Electronic Communications Regulatory Agency, ARPCE, has several responsibilities, including to:

- define, establish and monitor quality of service standards in the postal and electronic communications sectors;
- ensure operators' compliance with the clauses written into their licences, authorisations, certifications and specifications.

It is in this context that, after having consulted with mobile operators, ARPCE initiated a test protocol for measuring quality of service on mobile networks. It makes it possible to:

- Assess the quality of the services being supplied by mobile operators that hold 2G(GSM), 3G(UMTS) and/or 4G(LTE) licences, in an efficient manner;
- Ensure that mobile operators are complying with the thresholds set in the specifications attached to their licence;
- Assess the availability, maintainability, mobility, accessibility and integrity of the networks and services being supplied by mobile operators;
- To rank operators by the quality of service provided to customers across the country.

Over the past several years, ARPCE has been acquiring measurement tools capable of reflecting users' quality of experience, including:

- **SWissQual**, tool for measuring and acquiring data in the field, composed of two parts (A and B).

  Each part includes three telephones representing Congo's three established operators.

  Part A is mobile and part B is fixed line. Part B is chosen according to the best radio conditions (ARPCE headquarters in this instance) for every operator.

  Calls between parts A and B are two-way, and each successful call lasts a maximum two minutes.

- **QS tracker**, a tool for processing data collected from probes installed close to mobile operators' networks, making it possible to obtain regular quality of service statistics for each locale/site/cell.

  Congo's main cities were broken down into zones, to be able to obtain a detailed assessment of critical sectors.

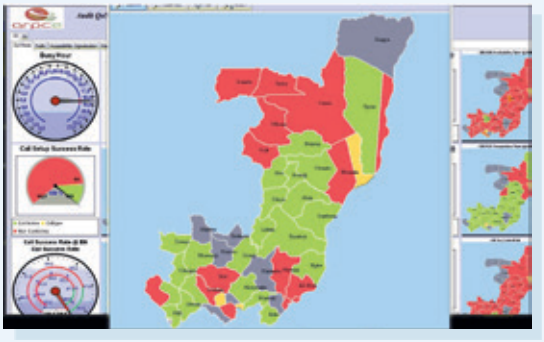
ARPCE also established a scale for the measured indicators, a colour-coded range of the corresponding rates and the number of points that an operator must obtain to satisfy a criterion.

All of the most common services are measured for QoS, namely:

- voice calls
- data
- video streaming.

This testing equipment and method create the ability to obtain the most accurate picture possible of end users' experience on established mobile networks in Congo.

The collected indicators are also relevant from a technical standpoint, and remain a topic of discussion with operators only, during consultations. Failure to comply with thresholds remains the central cause for degraded quality of service on mobile networks.



Control of the quality of service: illustration of results

ARPCE can put operators face to face with the collected indicators, after having conducted testing in the field, especially when the results are critical.

These indicators enable ARPCE to identify the technical problems that are causing the deterioration in network quality. They are not an integral part of the data published for users who are not experts in this area.

Every year, ARPCE performs a minimum of two national measurement campaigns. The results of the tests are presented to operators during a meeting, before their official publication.

Other authorities have chosen to impose only coverage obligations (measured by signal strength or service accessibility tests, see Chapter 1), without regulating quality of service indicators. Such is the case in countries with a widely deployed fixed network.

Obligations can prove an especially powerful form of leverage, as they carry the possibility of non-compliance penalties. Potential sanctions are more or less the same for all regulators: issuing a formal notice to comply, fines, total or partial licence suspension, shortened licence validity and, ultimately, licence withdrawal.

This approach nevertheless has its limitations. It is very difficult to be exhaustive when it comes to network performance indicators. Operators may indeed tend to comply with minimum requirements, and there is no way to oblige them to go above and beyond that and to increase their investments, even if current circumstances demand it. The biggest challenge therefore lies in being able to identify and define the right indicators. The deterioration of an unidentified indicator, defined in the obligations, can have a significant impact on quality of service and, as a result, create customer dissatisfaction without there being a means of forcing the operator to rectify the situation, if it is complying with the imposed indicators. Here then, the regulator must also question the relevance of the criteria and of the imposed obligations.

Some regulators have also observed that quality of service fails to improve, despite the possibility of financial penalties, as operators calculate the trade-off of fines versus investments. Lastly, if the regulator finds itself required to impose penalties, it means that the regulation was not as effective as expected, and can be considered a failure. If authorities have the possibility of withdrawing an operator's licence, or shortening its period of validity, this measure is only very exceptionally employed, as it has the potential to destabilise the market.

2.2 To amplify the regulator's capacity to take action

Monitoring coverage and QoS indicators enables the regulator to develop an approach to supervising the sector in a more or less detailed fashion, depending on the granularity of the information gathered. By fine tuning its tools, the regulator can amplify its capacity to take action, and equip itself to detect weak signals and systemic issues in operators' rollout strategies, and so to accelerate its regulation and make it more efficient.

From a concrete standpoint, utilising these data endows the regulator with deeper knowledge of the market's competition dynamic and the status of deployments, which can be carried over into drafting public policies and streamlining the obligations that will be written into operators' future licences.

2.3 To inform users and stimulate competition based on the relationship between coverage, QoS and prices

When seeking to incentivise mobile operators to invest in improving their coverage and quality of service, several regulators underscore the importance of empowering users to make the most informed choices possible. This process of keeping users informed, which had previously been addressed as a matter of transparency, can in fact go well beyond that by making users veritable conduits for the regulator's actions.

If the regulator publishes information that clearly shows the investments that operators are making to comply with their obligations, consumers will make choices that are no longer based solely on pricing, but also on the quality of operators' networks. As a result, the operators that invest the most in their networks will be rewarded by consumers, which in turn will enable them to earn a return on those investments and will foster increased competition over the networks' quality.

To make these data-driven regulation schemes as effective as possible, regulators must:

- First, be able to disseminate accurate and detailed, in not personalised, information. To be able to make an informed choice, users need to have access to information that most closely aligns with their own experience, and not just to technical indicators that can be hard for users to understand. This information must therefore be local, to allow consumers to assess coverage and QoS, for instance, where they live or work. It must also reflect how they use their devices (calling, texting, watching videos, indoors and outdoors, etc.).

- Second, the regulator must develop a real information strategy rooted in a clear data-driven approach to regulation, whose priorities are defined and in which it plays a crucial role of centralising and editing the data.

"The consumer becomes the main referee," according to Guinean regulator, ARPT

2.4 Producing a digital scorecard for the country and guiding and/or anticipating deployments

In addition to monitoring operators' compliance with obligations and stimulating competition, which are the two main uses of regulators' findings, these measurements can also be used to help bolster regional digital development. They enable a better and objective understanding of operators' actual coverage in the field, and so the ability to establish a diagnosis that will help investors and international financial institutions to better channel their choices, and for public authorities to satisfy coverage needs. For the latter, this means drafting schemes for deploying networks in white areas, and defining priority coverage targets. International financial institutions, meanwhile, will be able to fine tune their projects and better calibrate their investments.

2.5 Assessing public policies and/or investment efficiency

For public authorities or an entity involved in financing public policies, it is crucial to have an objective and, if possible, forward-looking view of mobile rollouts and network performance, to be able to assess the efficiency and effectiveness of the investments made, be they public or private. This in turn will help to substantiate or, if necessary, force a rethink of public policies.

"The main advantage of measurement campaigns is the knowledge they provide on areas that are poorly or not covered, and the problems operators encounter during rollouts." according to ARPCE in Algeria.

The World Bank: mapping high-speed networks to reduce the digital divide

In this hyper connected world of ours, 800 million people still do not have access to a high-speed network. Mobile coverage maps play an important role in identifying poorly served areas. They enable users to leverage competition by comparing networks, while encouraging operators to improve their return on investment by sharing their networks. Public authorities, meanwhile, are able to fulfil their duties by expanding high-speed access to populations that had been left by the wayside up to now.

But mapping high-speed networks is no easy task. The Korean example[4] indeed shows that it is impossible to obtain reliable information without a well established legal framework, combined with an efficient institutional and organisational framework. Operators are thus legally required to publish coverage maps for the services they provide across the country. The accuracy of the maps is assessed by the Ministry of Science and ICT (MSIT) and the National Information Society Agency (NIA). European countries too are in the process of drafting common standards for measuring mobile networks' coverage across EU. In the United States, the Broadband Data Improvement Act seeks to improve the quality and accuracy of the data on high-speed networks collected by the federal government, to be able to better target investments, notably by imposing use of geographic information systems (GIS). The GSMA's Mobile Coverage Maps Platform[5], which is a public-private partnership created in 2017, also seeks to "Gain an accurate and complete picture of the mobile coverage in a given country" while exploring investment possibilities. In Africa, GSMA plans on expanding its eight-country platform to all 54 countries on the continent.

Under the stewardship of the African Union, with the support of the World Bank Group, a new initiative called Digital Economy for Africa seeks to connect all Africans and all of the continent's businesses and government administrations to a high-speed network by 2030. In addition to the considerable resources that will be mobilised to that end, an efficient monitoring mechanism needs to be put into place to track progress, and keep operators' accountable. The success of this initiative depends on a concerted effort from the many stakeholders involved in Africa's digital transformation, to create a reliable mobile services mapping platform that anyone can access.

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Michel Rogy, Practice Manager Digital Development, Africa and the Middle East (mrogy@worldbank.org)

4) Korean example (http://www.smartchoice.or.kr/smc/smartreport/serviceCoverage.do).

5) GSMA mobile coverage map platform (https://www.mobilecoveragemaps.com).

French Development Agency: issues and challenges of data availability for regulators, users and international financial institutions

Although internet access levels around the world are at an all time high (close to 60% of the global population), tremendous disparities persist, as close to 2.5 billion people are still without access. In Sub-Saharan Africa, 47% of the population live in areas outside the reach of networks, due chiefly to a lack of investment by operators in those areas deemed unprofitable, but also because there is little regulator oversight of compliance with obligations, due to a lack of tangible and reliable data.

Extending connectivity and universal access to digital services, for the benefit of poorest and rural users, requires substantial public investment coupled with regulatory incentives, with the support of international financial institutions such as the French Development Agency (Agence Française de Développement – AFD). Over the past several years, AFD has made a commitment alongside several African nations, to connect them to the global internet, and has financed infrastructures such as submarine cables and national backbones. Today, almost every country in Africa is connected to several international optical links. The challenge now is to expand these networks into the remotest areas, and to cover white and grey areas with a high quality signal.

To be efficient, public investments and regulatory incentives need to be based on detailed, up to date, reliable and open data (coverage, quality of service measurements). Regrettably, in a great many countries they do not exist, and the information that is available often comes down to aggregate statistics from regulatory authorities' market observatories, which provide very little geo-referenced information on coverage or quality of service.

Unfortunately, data obtained from coverage analyses and blueprints financed by international financial institutions, as part of cooperation projects, quickly become obsolete, as regulators fail to update their datasets systematically. Although the global data-driven regulation movement is a recent one, it has nonetheless become urgent to support regulators in transforming their operations, and strengthening their capabilities in this area. This is all the more true in light of the heavy public investments involved, and the growing need to coordinate stakeholders.

More transparency, more openness also means empowering the users of the tools to advocate, to challenge operators and so help drive an overall improvement of their services. This is a process that also paves the way to involve civil society more deeply in discussions on reducing digital inequality – a fundamental issue for African governments in the coming years.

The existence of reliable and fresh data would also enable international financial institutions to create more incentivising project financing mechanisms, with payments that would be contingent on tangible and auditable results (results-based financing). Lastly, for a bilateral institution like AFD, it is especially important to use open data in projects to help improve transparency and accountability for development aid.

CHAPTER 3

HOW TO PUBLISH DATA IN A WAY THAT SERVES REGULATORY OBJECTIVES?

In addition to collecting data to monitor and measure coverage and quality of service, there is the matter of publishing the information that regulators receive or collect. Choices will depend heavily on the objectives that authorities have assigned themselves regarding use of these data, their own particular regulatory issues, as well as the legal provisions in force in each country. Publication may, for instance, align with a commitment to transparency, in addition to being a full-fledged regulatory tool, helping to empower users and public authorities, and give them the ability to incentivise operators to invest in increasing the coverage and quality of their services.

3.1 What "editorial choices" to make when publishing data?

3.1.1 How to represent data and whether to self-publish or outsource the task?

Producing raw data is a central ingredient of QoS-related work. It nevertheless requires expertise and skilled staff that regulators do not necessarily have. Thus arises the choice of whether to have data produced by operators or by the regulator.

Most Fratel members rely on data produced by operators: because network operation is their core business, operators have well-developed expertise and the proper tools (e.g. simulation software). This is especially true when it comes to producing coverage maps. The advantage of this approach is that operators are responsible for producing the maps, while the regulator only has the task of verifying their accuracy.

Some regulators, however, have elected to produce their own maps, which enables them to ensure a homogeneous and operator-neutral method is being employed.

3.1.2 What data should be displayed? And in what format?

The data that are published, and in what format, will differ depending on the categories of user the regulator wants to address. Regulators are faced with the following choices, which are not mutually exclusive:

- "Simulated" data (e.g.: theoretical coverage map) or "measured" data (e.g. signal test)?
- Localised data (e.g. a specific coverage area, measuring point…) or aggregated data (e.g. average QoS indicators for the entire country)?
- Raw or processed data?

To inform consumers on network coverage and quality, the regulator can publish graphs that show each operator's performance, rankings for each QoS and (2G, 3G and 4G) coverage criteria, or maps for each operator or superimposed maps to make it easier to compare them, and make the information more clear.

Publication may, for instance, align with a commitment to transparency, in addition to being a full-fledged regulatory tool.

Stakeholders who are interested in using data to publish their own graphs or map, or for analytical purposes, will be more interested in raw data or complete audit reports that provide detailed findings on the field measurements that were performed.

Lastly, public sector players, investors and international financial institutions will be more inclined to want enhanced maps that include more detailed data, to enable them to obtain a diagnosis of the digital development across the country, to plan investments and, subsequently, to assess public policies and ensure successful network rollouts and improved quality of service.

Naturally, these formats will need to be adapted to the chosen information channels. The most classic formats used by regulatory authorities are press releases, articles in the national and regional press, and press conferences. These ensure that the information reaches a large audience and deliver a clear message about the current market situation, and the quality of the different networks. It typically involves presenting the findings of tests and measurements performed by or on behalf of the regulatory authority. This information only remains available for a short period of time, however (one day for a press article or broadcast news report, and several days for a press release), in addition to not always being very detailed or tailored to each situation.

A certain number of regulators publish summary reports of the coverage and QoS measurements on their website, usually as a PDF. These reports are often quite detailed, and enable an analysis of the situation and

a comparison between mobile operators. This type of report may nevertheless seem a little esoteric for the general public, and is not intended to be used to inform consumers.

Several regulatory authorities (see Part 3.3) recently elected to publish operators' coverage maps and quality of service measurements in graph and diagram form. The aim is to deliver a heavy dose of transparency, to orientate the competition between operators so that it is not based solely on price, but also on their networks' performance. Coverage maps also enable consumers to make more informed choices when selecting the network that best aligns with their needs.

The ability to identify areas where coverage is poor or non existent thanks to these maps also helps public authorities establish a diagnosis of the national status quo, and in tailoring their policies to satisfy coverage needs and reduce the digital divide.

3.1.3 Data produced by operators: whether or not to impose a format, and where to make the information available?

Regulators' decisions very often forget to define the format of the data that operators are required to submit, and to specify where these data should be made available – as this type of detail may be deemed to specific, and not appropriate for inclusion in a regulatory act.

But these elements are vital to ensuring that these data are properly integrated and processed efficiently, either by the regulator, or by consumers or third parties in instances where the data are made available directly as open datasets on a portal.

Determining the different information that is expected, file structure (order of the information), its format (most widely compatible), but also the rules for how it will be made available (API, fixed URL...) are an essential part of the regulator's role, to ensure the objectives set out in its decision are fully met.

3.1.4 Making it easy to superimpose/ cross-reference different types of information: coverage maps, test results, other networks (transport, energy, points of interest...)

As the number of sources of information used to monitor and verify operators' coverage and quality of service increases, some regulators are adopting combined approaches, employing several sources with differing features.

Simulated coverage maps are one way to produce a snapshot of coverage across the country, for a reasonable cost. On the other end of the spectrum, because they are more precise, field measurements are more costly to obtain and do not make it possible to have a complete picture of the situation nationwide. Cross-referencing and superimposing these visual data significantly enhances the information produced, by creating a "dialogue" between these different data sources.

Beyond that, as part of an ongoing effort to align coverage and quality of service monitoring with users' actual experience, it is useful to provide the ability to superimpose points that are of interest to users and public policymakers (transport corridors, energy networks, hospitals, schools, tourist attractions, etc.).

3.2 What are the main principles for ensuring a high quality publication?

3.2.1 Transparency on data (how they are obtained, protocols used, collection date...)

It does appear necessary to publish and provide details on the entire test protocols used during a measurement campaign. Transparency on the methodological choices made is vital to third parties' ability to analyse and interpret the findings presented. It is also key to the ability to compare several methods or several measurement campaigns. Details must be given on the test environment, indicating whether the findings are the product of measurements obtained through crowdsourcing, drive testing or from data obtained directly from operators' networks.

Transparency on the methodological choices made is vital to third parties' ability to analyse and interpret the findings presented.

For example, for a publication based on internet speed tests, at the very least details on the parameters and methodology used must be published, as they can have a considerable influence on the final results:

- test volume;
- devices used;
- number and selection of websites tested (list of the sites and method used to select them, e.g. a random page from among the 30 most popular websites in the country in question);
- time out (e.g. 10 seconds);
- web cache status (whether or not it is emptied between each test);
- explanation of the indicators displayed (formulas used to calculate the different indicators).

In addition to these questions, precautions must be taken regarding the data's owners. The use of open data is recommended as they are easier to repurpose (cf. 3.2.4 infra).

3.2.2 Making the information easy for the public to understand

Publishing information aimed at the general public, particularly on the topics of quality of service and coverage, necessarily requires the regulator to analyse whether users will find the information useful and relevant. This relevance is heavily shaped by the form in which the data are presented.

The notion of coverage is very different for a regulator (technical reality of coverage) and for a user (ability to use the services). Experience has shown that publishing regulatory information for the general public can have the opposite of the desired effect, as users see a clear different between the published indicators and their own experience as consumers. Added to which, because they may not have the technical knowledge that would allow them to understand the methodological reasons for this difference, they may well consider the data to be false, which undermines their trust in the regulator.

As a result, the regulator's indicators need to be challenged, to ensure a publication that is both easy for the public to understand and useful to the regulator's supervisory responsibilities. It is, for instance, possible to subdivide coverage information into different levels and so provide users with information which, while imperfect, more closely matches their daily experience.

3.2.3 Relevant, representative and accurate aggregation

In addition to the quality of the indicators proposed, aggregating these indicators is vital to the reliability of operators' publications.

While data aggregated at the national level may be suitable for a report, when producing a map, data need to be aggregated at a more local level.

It is also important to ensure that these indicators are truly representative. To allow any party to judge the accuracy of the presented findings, it is useful to be transparent about the number of measurements underlying the published aggregate results. This applies as well to the test conditions (period, type of device, type of measurement, etc.). It is also necessary to indicate any bias resulting from the testing device that is capable of introducing distortions in representativeness or comparability.

As an adjunct, in instances where the regulator publishes aggregate information by operator for "all technologies (2G, 3G, 4G) combined, " it might be useful to indicate how operators' combination of technologies can affect the results.

These principles apply all the more, and require even more vigilance, when aggregating data in a finely tuned fashion (aggregation at the local, municipal level, producing a map, etc.), as the finer the mesh the more challenging it becomes to ensure the findings are truly representative.

3.2.4 Publish using open data that anyone can reuse (and promote the fact)

Publications help to keep the public informed. Making the data available as "open data" – after having ensured that the regulator has the right to publish these data, and having chosen the right type of publishing licence – will often ensure that they can be properly appropriated by expert users, public policymakers, and indirectly by consumers (by being used by third parties).

Making data open is thus the first step to ensuring that other players can reuse them. During the process, it is important to anticipate and support the potential types of reuse by working carefully on the data's formats and publication structures, and on how they are documented. The ease of reuse, openness and future-proofing of the formats and structures, along with ensuring that they are easy to understand, will be catalysts to their appropriation by users.

Publishing is, however, only the first step in a process that will only bear fruit if the potential re-users of the data are made aware of them, and given proper support. It is therefore especially useful to build a community of re-users, to familiarise them with the published data, enable better appropriation, but also to discuss possible interpretations of the data when they are reprocessed by re-users who are not always telecoms experts.

3.2.5 Regularly refreshed data, while keeping the logs

To give third parties (users, local authorities, the media…) the ability to track the progress of mobile coverage or quality of service results published by regulators, the data being published need to be updated regularly. Mobile networks evolve very rapidly, and the findings for a particular location can vary tremendously when tested only months apart. It therefore seems important that regulators update the data they publish on a regular basis, to take stock of the investments in the networks made by operators, or by the Government through coverage schemes.

Making the data available as "open data" (…) will often ensure that they can be properly appropriated by expert users, public policymakers, and indirectly by consumers.

Lastly, to ensure more detailed tracking, it is advisable to preserve the logs of published data and indicators, to highlight the pace at which coverage and the quality of service are improving in the country.

3.2.6 Enable comparisons between operators – and warn when operators' data are not comparable

If the published data are broken down by operator, it is important that the regulator ensure they can be compared as fully as possible. The results of a quality of service test can vary widely depending on the time or the day it was performed, given variations in traffic (peak hours, holidays, etc.). The device that was used and its compatibility with the latest standards can also have a sizeable impact on results. This is why it is necessary to ensure the findings can truly be compared. There are four criteria in particular that help ensure that findings will be comparable:

- same device used;
- same day, same time;
- same protocols used;
- same position during testing (indoor/outdoor, in a car, etc.).

If the tests are performed while adhering to only some of these criteria, it would seem necessary to warn of the potential bias induced by the test protocol, which is often the case in a crowdsourcing environment. Despite which, measurements that are not comparable can also contain a wealth of information, and provide additional details that may be important to the user. If it assumes its role of educator when publishing these data, the regulator can supply value-added information even if the data's comparability is not guaranteed.

3.3 A selection of case studies (What the experts have to say):

3.3.1 Arcep France's www.monreseaumobile.fr website

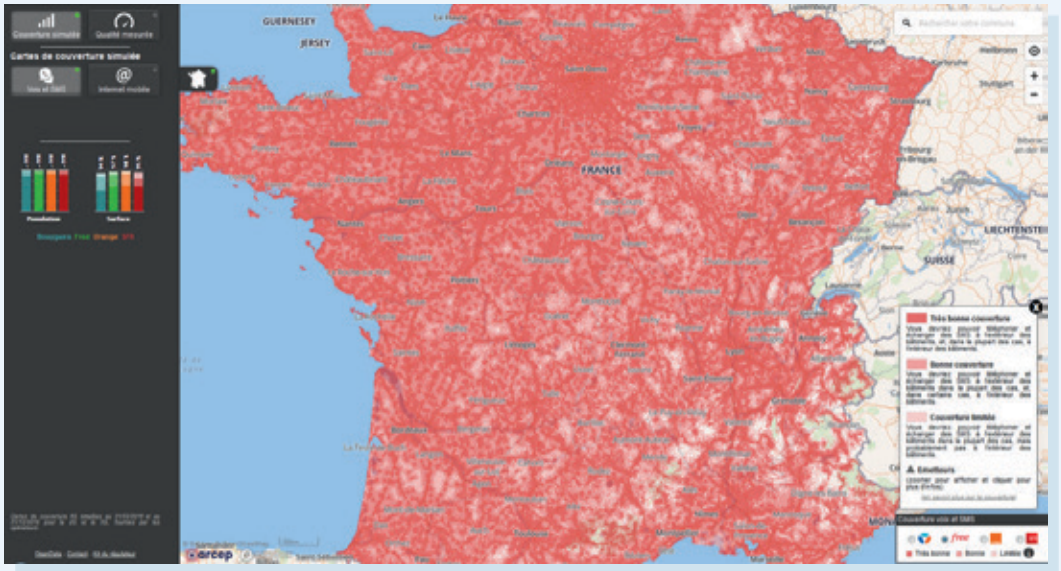
Arcep France: experience with publishing data

The www.monreseaumobile.fr website was launched in a pilot region on 18 September 2017, after a field measurement campaign whose purpose was to verify whether operators had taken the new regulatory framework properly into account. The platform was expanded to the whole of Metropolitan France in March 2018, and to French overseas territories in autumn 2018. Taking the form of a mapping tool, the website allows users to compare operators' coverage and quality of service, and obtain two types of information on mobile networks' performance:

- operators' coverage maps (produced based on digital simulations) with a four-level score and an accuracy of up to 50 m;
- quality of service indicators, obtained from more than a million measurements taken by Arcep in the field, under real-life conditions. Thanks to this information tool that enables consumers to make informed choices, Arcep aims to stimulate operators' investments to bolster mobile coverage further still, and improve the quality of their services.

Providing the public with clear, accurate and detailed information is also crucial to helping users choose their mobile operator. To enable users to make an informed choice of electronic communications provider, operators are required to publish maps depicting the availability of their mobile services.

Arcep adopted Decision 2016-1678, which defines a robust regulatory framework that contributes to better informing the public on the availability of cellular services: for maps of voice call/SMS services, operators are now required to publish maps that distinguish three different levels of coverage.



3.3.2 Publication channels chosen by Ivory Coast regulator, ARTCI

ARTCI: experience in communicating quality of service data

To verify operators' compliance with their quality of service obligations, in accordance with the regulatory provisions in effect, ARTCI performs several forms of monitoring:

- QoS audits of telecommunications networks;
- random checks of fixed and mobile networks' QoS;
- analysis of mobile telephone networks' OMC-R data;
- assessment of telecommunications service users' QoE.

The findings of these different monitoring operations are the subject of regular communications to operators, the media and the public.

The goal of publishing these results is to provide the public (consumers) with reliable and comparable information on the quality of the main services that telephone operators provide. With the development of more and more innovative telecommunications services, QoS has become a criterion in consumer choices, and a lever used by ARTCI to stimulate competition between operators.

The findings are communicated formally to operators during a debriefing session on the results held at ARTCI headquarters. After the working meeting, the audit report is given to operators.

Next, ARTCI holds a press conference, presided by its Director-General, to communicate the main findings of the audit to the media and the public. Members of the print, audiovisual and online media are invited to the press conference.

A section dedicated to quality of service is available on the ARTCI website. This hub brings together information on QoS (audit reports, the main findings, indicator progress, etc.). Reports on the different monitoring activities are published on the hub on a regular basis.

To make the data easy to understand, ARTCI has designed communication materials that summarise results. This summary generally includes findings on the most popular services (voice calls, texting, data) and operator rankings.

Audit results are published on social media (Facebook, YouTube, etc.) and on the main online news platforms (Agence Ecofin, abidjan.net, rti.ci).

Regarding coverage, ARTCI regularly publishes operators' statements and coverage maps on its website.

Lastly, ARTCI plans on implementing a QoS/QoE assessment tool via user devices. To this end, it will run a communication campaign on traditional and social media, to encourage people to download and use the dedicated mobile app. The information collected from subscribers' mobiles through crowdsourcing will be published on a dedicated platform.

3.3.3 Belgian regulator BIPT's mobile atlas

BIPT: experience with publishing data and transparency to support regulation

For 25 years, consumers' needs with respect to quality, performance, price and innovation have been central to BIPT's actions. One of the mandates set by law is to protect users' interests by taking social inclusion, strong protections, clear information and transparency into account.

In its Strategic Plan for 2017 – 2019, BIPT confirms its commitment to providing users with comparable information on quality of service. BIPT also states that it will strive to make this information widely available to the public, so that everyone can make an informed choice about the operator that best suits their needs.

The goal of ensuring transparency on quality is also to push operators to invest in their networks. BIPT especially wants to identify those parts of the country that are suffering from a lack of high-speed connectivity, to implement concrete actions to stimulate investments there.

Above all, the information published on quality of service needs to be accessible. The viewing interface for maps, for instance, must have an attractive design and its features must be easy to use. BIPT has nevertheless pinpointed three main challenges to developing a modern and fluid interface.

First, citizens' expectations are high, and they react strongly when they believe the data do not correspond to the reality they experience. BIPT has thus chosen to collect information on quality of experience. It has also opted to display several quality levels. Lastly, it launched a crowdsourcing app to collect data supplied by users.

Second, the published information is sometimes hard to incorporate. The 16 quality of experience indicators, for instance, are designed more for experts than consumers. They are difficult to summarise for the media and the general public. Work needs to be done on translating them into layperson terms, and discussions are underway over the creation of a composite indicator.

Third, BIPT is having to contend with a loss of reputation outside its regulatory sphere. The public does not yet view BIPT as users' watchdog in the sectors that it regulates. For this information to reach the general public, BIPT began a "re-branding" campaign in late 2018 to improve its image. One of the courses of action has been to create a Facebook page to promote our tools. The ad campaign to promote our crowdsourcing app, for instance, increased user numbers six-fold.

We are deeply committed to continuing to work to increase our impact as much as possible over time.

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