OECDpublishing

Please cite this paper as:

OECD (2014-06-13), “Access Network Speed Tests”, *OECD Digital Economy Papers*, No. 237, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5jz2m5mr66f5-en

OECD Digital Economy Papers No. 237

# Access Network Speed Tests

OECD

OECD

## FOREWORD

This report was presented to the Working Party on Communication, Infrastructures and Services Policy (CISP) in December 2013 and the CISP agreed to recommend it for declassification to the Committee on Digital Economy Policy (CDEP). The CDEP Committee approved the report in April 2014.

The document was prepared by Hajime Oiso of the OECD's Directorate for Science, Technology and Industry.

*Note to Delegations:*
*This document is also available on OLIS under reference code*
*DSTI/ICCP/CISP(2013)10/FINAL*

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

# TABLE OF CONTENTS

# ACCESS NETWORK SPEED TESTS

## Main points

This report examines the approaches being taken in OECD countries to measure broadband performance. The actual performance of Internet connections, particularly their speed, is critical to meeting various objectives set out by a range of stakeholders including consumers, policy makers and regulators. It is a fundamental metric for consumers to make informed choices as it reflects the quality of their experience and enables them to assess any differences between advertised speeds and actual speeds. For policy makers and regulators, being able to assess broadband performance is essential in ensuring accessibility to services (e.g. education, health and so forth) and whether services are meeting their goals for overall market development (e.g. competitiveness, coverage and so forth).

OECD governments have been aware of the importance of actual performance measurement for many years though the choices and capabilities of technologies have rapidly evolved and greater attention given to this area in recent years. In 2011, as a general policy direction, the OECD Council Recommendation on Principles for Internet Policy Making set out the need to develop capacities to bring publicly available, reliable data into the policy-making process. Accordingly, the OECD organised two workshops on broadband metrics, held in Washington in 2011 and in London in 2012 respectively, which considered measurement of advertised and actual performance. Participants noted the emergence of several tools for measuring the performance of broadband, as well as the existence of significant barriers to the creation of a unified methodology, arising from the high number of technical choices required.

As a result of the discussions two approaches were agreed on actual performance measurement as summarised below:

- Adopt the best currently available datasets, such as the ones provided by private entities, in the short-term, which enable robust like-for-like comparisons between countries and over time.

- Work towards the longer-term goal of achieving a dataset based on common methodologies of measuring actual broadband speeds, with the first step to agree principles of good practices in data collection.

This report mainly focuses on the second – longer-term – goal, by reviewing information on official speed tests to date as well as their strengths and drawbacks in methodologies, emerging good practices and the challenges in undertaking a harmonised approach across OECD countries. As a number of factors can influence results and only users can control some of them, measurement projects face greater potential hurdles than for traditional telecommunication networks. At the same time, new opportunities are emerging in terms of "crowd-sourced" data that have the potential to empower consumers by making unprecedented information available to them. These tests may, however, not always provide the information needed to inform specific policy and regulatory goals.

It is commendable that authorities in a growing number of OECD countries are developing tools to fit their policy needs as well as providing greater information to all stakeholders. It is documented here that 19 OECD countries have commenced official projects as of January 2014. Tables listing those official measurement projects collected by the Secretariat and complimented by information provided by the OECD Working Party on Communication Infrastructures and Services Policy (WPCISP) delegates are made available in the Annexes of this document.

Different approaches can be taken for official projects depending on policy objectives relevant to the measurements undertaken and other constraints such as resources, with due consideration to the advantages and disadvantages of those approaches. This report categorises the types of clients that initiate each performance test at the end-user side and examines their characteristics. They are End-user Application Measurement (EAM), End-user Device Measurement (EDM), Project Self Measurement (PSM) and PSM by Internet Service Provider (PSM-ISP). Their strengths and drawbacks are summarised in a table in the final section of this document. In short, for fixed network measurements, EDM can be a better choice if the project aims at undertaking comparisons between ISPs with respect to differences between advertised and actual speeds. A carefully implemented EAM, which takes additional measures on-board, can be appropriate for the purpose of comparing between ISPs with data from other sources. For mobile network measurements, EAM and PSM both have their advantages and if possible, adoption of both approaches would be very desirable, provided that they are well designed to take into account mobile specific issues.

As there is no clear standard yet in measuring actual broadband quality, official measurements are encouraged to provide as rich online information as possible on the metrics and methodologies adopted. In addition, provision of more detailed datasets is also encouraged, as it will benefit others who may wish to reuse data collected.

With a view to achieving the longer-term goal of a dataset based on a common methodology, this document offers a classification to facilitate the discussion. It notes that fixed network projects are more advanced and that it may take longer to make progress in mobile networks. In the short term, private sources can continue to be reviewed noting the differences in methodologies and ensuring multiple sources. As for using official measurement sources, multi-country aggregation and comparison will become possible if they converge on a certain range of methodologies, provided that they aim at achieving common policy goals.

As with "OECD Broadband Maps"[1] provided on the OECD Broadband Portal[2], links from the Portal will be provided to the collected current official measurement projects to assist in making these practices available for convenient international reference, with periodical updates[3]. Similar measurements in key partner countries could also be collected and linked to as available and reviewed periodically.

## Introduction

This report examines developments in the measurement of broadband performance on fixed access networks, particularly in the actual Internet speeds experienced by end users. In addition, measuring mobile broadband performance is also discussed both in terms of existing practices and future possibilities.

The actual performance of Internet connections, particularly their speed, is critical to meeting the objective set out by a range of stakeholders including consumers, policy makers and regulators. It is a fundamental metric for consumers to make informed choices as speeds influence the quality of their experience and to a significant extent can determine the availability of certain kinds of services – for example, good quality video streaming requires sufficient download speeds and low levels of packet loss, while VoIP telephony requires sufficiently low latency. For policy makers and regulators, being able to assess broadband performance is essential in ensuring accessibility to services (e.g. education, health and so forth) and whether services are meeting their goals for overall market development (e.g. competitiveness, coverage and so forth).

It is, of course, not unusual for there to be large variations in the actual broadband speeds experienced by users even within the same network and service option. In other words, it is possible for consumers to have significant differences between the "advertised" or "headline" speeds and the speeds actually delivered due to factors such as distance, shared usage (i.e. contention ratios), type of technology and so forth.

Although it is relatively easy to be aware of the existence of factors that influence the actual experience of users, significant challenges arise in measuring and comparing performance by taking these factors into account. These may include, for example, equipment at an end user's premises and the exchange of traffic between different networks that provide access and the source of content. Nonetheless, there are a growing number of tools and services provided by public and private sources, which attempt to provide greater knowledge to all stakeholders on network performance.

OECD governments have been aware of the importance of actual performance measurement for many years though the choices and capabilities of technologies have rapidly evolved and greater attention given to this area in recent years. In 2011, as a general policy direction, the OECD Council Recommendation on Principles for Internet Policy Making set out the need to develop capacities to bring publicly available, reliable data into the policy-making process. Accordingly, the OECD organised two workshops on broadband metrics, held in Washington in 2011 and in London in 2012 respectively, which considered measurement of advertised and actual performance. Participants noted the emergence of several tools for measuring the performance of broadband, as well as the existence of significant barriers to the creation of a unified methodology, arising from the high number of technical choices required.

The outcomes of the workshops were compiled at: "Summary of the Recommendations from Rapporteur Group's 1, 2, 4 and 5 from the London Workshop on Broadband Metrics" in an internal working document (OECD, 2012). These results were discussed at the 48th Working Party on Communication Infrastructure and Services Policy (WP-CISP) in December 2012.

As a result of the discussions in the workshops and the WP-CISP, two approaches for methodologies were agreed on actual performance measurement as summarised below, as "Broadband Metrics Check List":

- Adopt the best currently available datasets, such as the ones provided by private entities, in the short-term, which enable robust like-for-like comparisons between countries and over time.

- Work towards the longer-term goal of achieving a dataset based on common methodologies of measuring actual broadband speeds, with the first step to agree principles of good practices in data collection.

The OECD *Communications Outlook 2013* (OECD, 2013) included a section on existing datasets of actual broadband speeds that were measured by private sources. It compared three kinds of speed indicators developed by Akamai, Measurement Lab (M-Lab) and Ookla respectively for each OECD country in the first quarter of 2012. It was, therefore, the first implementation of the recommendations described above. It pointed out that although the results from these three sources strongly correlate with each other, one of those indicators (Ookla) systematically delivered higher speeds than the other two indicators reflecting different methodologies. It was also found that for the two sources that relied on voluntary speed tests by users (M-Lab and Ookla), there were large differences in the amount of tests among the countries covered, which implied users' preferences to the speed tests varied significantly.

In addition, for the shorter-term goal, another dataset derived from these three sources of speed indicators has been included in the annex of this report. Data are provided from the first quarter of 2012 to the second quarter 2013. The better performing countries are generally consistent between different indicators as shown in Annex 2.2. However, the similarities that the different indicators measure may be small (a statistical test shows nearly zero probability of that a common population is measured, although each indicator moderately or strongly correlates with each other - Annex 2.5). The trend for actual speed changes is sometimes measured differently - as shown in Annex 2.4.

In the following sections, this document aims to follow and expand the past discussions by providing case studies of various measurement projects that have already been established in the OECD area as a contribution to work on the implementation of improved broadband metrics, and also by presenting future possibilities for speed tests, particularly to measure the actual quality of mobile broadband services.

Several tables listing the measurement projects as of January 2014 that were collected by the Secretariat and complimented by information provided by WP-CISP delegates are made available in the Annex of this document. It is also proposed to provide links[3] from the OECD Broadband Portal to the collected official projects, which are currently measuring performance to assist in making these practices available for convenient international reference.

To ensure harmonisation and comparability in the information gathered, some guidelines on the scope of measurement projects included in this report are as follows:

- Internet speed: Aggregated statistics, which at least includes an actual Internet speed indicator, other than individual results, are provided by the project to everyone online. For mobile statistics actual signal levels can be measured instead of speed.

- Access network: Access network (e.g. DSL, Cable, FTTH, 3G, and LTE) is included in the scope of measurement.

- Multiple ISP coverage: Multiple ISPs are covered unless the country has only a single ISP or the measurement is for a national broadband programme.

- National-level project: The project provides a nation-wide performance indicator or an indicator for international comparison.

- Additional future projects: Any future planned project that has been announced but has not started is included if endorsed by a Ministry or Regulator (i.e. Official).

- Official and unofficial projects: A project is regarded as official if it is led, funded or participated in, by the government, at least with its input, on metrics and methodology, even if the actual measurement is done by a private entity.

With regard to measurement projects referred to in this report, a "client" (also designated as a measurement point) means terminal equipment and a person associated with the measure of the performance. A client is connected to an access network of an ISP, associated with a project, and tests that network by communicating with a server that is dedicated to performance measurement. The "client type" of each measurement project is also identified in the list, which indicates how the client is equipped with a testing software or device to undertake measurement with the server. There are four categories of client type as follows:

- End-user Application Measurement (EAM): this means the daily use of an end-user's computer or mobile phone is employed for measurement with an application or browser under the user's control.

- End-user Device Measurement (EDM): this means that tests are done by specific devices which are installed by end users for measurement, but they are separated from the daily use of computers and mobile phones thus controlled remotely by the project.

- Project Self Measurement (PSM): this means the project itself installs or allocates and controls a device or computer to do tests. Unless otherwise noted, measurements are done by some entity different from the measured ISPs, but if it is done by the ISPs themselves with controlled methodology then this report calls it PSM-ISP for distinction.

In the following sections, these client types are referred to discuss the strengths and drawbacks of each methodology.

As of January 2014, there are 19 OECD countries that have already launched some official measuring project, which meets the guidelines above. Some 13 of them provide or plan to provide publicly available statistics on mobile broadband. It is also noted that six countries are planning to launch other projects and three of them explicitly states their target will include mobile broadband statistics. Looking at the client type of current projects, there are 12 EAMs, three EDMs, four PSMs and four PSM-ISPs.[4]

This report conducts a brief survey of these measurement projects from the perspective of good practices for ISP comparisons and to reflect on user experience as well as the possibilities for international comparisons. First, the purpose of the official measurement projects is described, particularly from the perspective of what role they can play, followed by a section that refers to how to identify Internet access clients such as in respect to mobile or fixed broadband. Second, clarification is undertaken on which part of a network can be measured (measurement origination) in this section. Two sections further examine how measurement can be undertaken, in particular focusing on possible differences in the measured download speeds, which should be a basic indicator included and how sampling is made according to client characteristics. Third, mobile measurement and its future possibility are discussed. Finally, a proposition on future OECD work is made and a table of the advantages and disadvantages of each client type is provided in a summary section. To simplify the information included in each section, fixed broadband is targeted in the second part that discusses measurement origination and how performance is measured. A dedicated section focuses on mobile measurement after discussion on the measurement of fixed broadband.

**Purpose of official measurements**

It is a readily understandable desire for Internet users to wish to gauge, by objective means, the speed they are actually receiving. This is particularly the case when they experience poor performance or are interested in achieving the best speed possible for their location or in their selection of an Internet access service. Such tests can help inform users of the likely performance of certain services they may wish to utilise. Different applications require a variety of performance levels to enjoy a high quality of service. For example online video streaming with HD quality needs more than 5-10 Mbit/s, and VoIP usually requires latency of less than 400 milliseconds if a user wishes to have a quality equivalent to traditional fixed telephone services. There are several speed test services that enable users to measure the performance of their Internet connection (i.e. delivery of traffic over the public Internet to their client). These include speedtest.ne by Ookla and Measurement Lab (M-Lab). These services further enable data to be shared by their users (i.e. crowd sourced data). Country-specific websites for speed tests are easy to find too and many ISPs also offer such online tools for their customers. This raises the question of what services carried out by or for government agencies can add, which assists in carrying out their mandates and in providing further information to all stakeholders.

The primary role for official engagement in speed tests is to be better able to inform policymaking and effective regulation. Most OECD countries have specific national broadband plans or have this area as a high priority in their general communication policies. A key issue in both these areas is the geographical coverage of broadband and the adequacy of services to meet economic and social development. Private sources may not provide sufficient information about all regions in terms of geographic coverage and client participation. In addition, tests undertaken by the users on a propriety test associated with a specific network (i.e. their ISP) will not be aggregated in a way that can provide a national perspective and may use a different methodology across different ISPs.

From a regulatory perspective it is essential to ensure sufficient competition and official speed tests have a role to play. Due to the relatively high cost of providing broadband networks some areas may only have a limited number of service providers. If this amount is further reduced by some of these operators not being able to deliver competitive services this is an essential piece of information that regulators need to have readily available. The information may also be used to inform issues that could arise in respect to traffic prioritisation for specific services or websites (e.g. video, VoIP) or related network neutrality issues. Any tool that can increase transparency and consumer empowerment is to be commended as well as the role this plays in spurring competitive responses from all market participants in rolling out further infrastructure. From these perspectives, it can be noted that the Body of European Regulators for Electronic Communications (BEREC) has also been discussing how regulators can monitor quality of Internet access services in the context of net neutrality, which includes measurement of the actual speeds of Internet connections. Its draft report was issued in March 2014 for public consultation[5].

Information asymmetry between suppliers and consumers is a characteristic of many aspects of ICT markets and broadband is no exception. Many consumers may have limited time and knowledge to compare different offers in advance of selecting an ISP. The role of official information may be more appreciated because of its independent nature and harmonised methodology across different technical and geographic factors.

One of the strengths that official measurement services may have is that they are generally oriented to more substantial comparisons of ISPs in terms of actual performance and the differences between advertised and achieved speeds. At the same time, while some private sources show results by individual or aggregated ISPs they may not relate that to specific offers or locations. In addition, the results can reflect factors that are beyond the control of an ISP. On the other hand, some official measurement services focus on the difference between advertised and actual speeds. They can also aim to reveal statistics at more detailed geographical level, sometimes by showing them on a map. They can also make allowances or control the performance an ISP can manage with the aim of making available more substantial and reliable information for consumers to compare different Internet access services before selecting them.

An official measurement service may be able to better overcome any challenges experienced with a selection bias. Generally, users who are more interested in service quality are likely to do more speed tests than other user meaning that the results could have a bias. If an official project chooses or deploys measurement points by itself, it can be less reliant on voluntary speed tests. It is also possible that any bias is mitigated if the project actively attracts participants, for example, through an advertised campaign under a name of the government, as is the case in Germany.

Taking advantage of this aspect, an official measurement project may be able to provide evidence to verify whether an Internet access service complies with a minimum standard of quality of service, depending on the objectives or rules implemented by policy or regulation. Italy has placed links from their measurement project to legal consumer protection: the results of official measurement can be used as evidence in cases where promised speed is not realised and thus the user wishes to exercise the right of withdrawal from a contract to shift to a new supplier. However, if the aim is to use results for taking action, such as withdrawing from a contract or economic compensation, the requirements for measurement quality could be higher than for other applications. This is because, in some cases, the measurement may have to provide a reliable indicator developed specifically for each individual subscriber in addition to average aggregated statistics.

Official measurement services can play an important role, as even in highly competitive markets there are transaction costs associated with shifting operators. For fixed broadband services, it may take some time to install the facilities necessary to switch to a new operator and there may be minimum contract periods associated with introductory or on-going offers. In mobile markets long-term contracts can be associated with upfront discounts for handsets. For all these reasons independent information can empower consumers in their initial selections.

The OECD Council Recommendation on Principles for Internet Policy Making (OECD, 2011) calls for the need to develop capacity to bring publicly available, reliable data into the policy-making process.[6] If raw data and detailed data sets are made available, in addition to publicised reports summarising measurement results, with due consideration for privacy, then transparency and accountability of performance indicators can be made more robust and useful. Provision of more comprehensive datasets is also beneficial for any other individual or entity wishing to use them for their private, business or research activities. As a result making such data available can be viewed as in line with other government initiatives in the area of open data and the decimation of public sector information. Currently, the official projects in Austria and the United States provide raw datasets of individual tests on their websites, in addition to aggregated statistics.

An official measurement project can co-operate with private sources, which have developed methodologies for measuring Internet connection performance. In Denmark, Greece and Sweden, EAM is implemented by the adoption of the measurement platforms of Ookla or M-Lab. In Austria, while Internet speed is measured by its original platform, M-Lab’s diagnostic tool can be run on the website of the official EAM to provide more comprehensive analysis on a user’s own experienced performance. In the United States, the official performance tests accessed measurement servers deployed by M-Lab, although the project also requested that the measured ISPs put “on-net” servers in operation for reference.

A certain amount of public financial support will be required in many cases to undertake projects. The amounts depend on factors such as scale. To provide some indication, however, according to public information, USD 244 500 was used in Germany for its official measurement project for fixed and mobile services.[7] The European Union area fixed broadband measurement, commissioned by the European Commission, with EDM required USD 3 350 000. The United Kingdom awarded USD 319 000 for the official measurements it is undertaking from 2012-2015. In Korea, in 2012, USD 649 595 was used to fund the official project, which employed PSM to measure fixed and mobile broadband performance.[8] Information on the costs of the EAM approach is more limited but application development on both the user-side and server-side capabilities may not be expensive, as an official project can adopt existing platforms deployed by measuring entities such as Ookla, as done in Denmark, Norway and Sweden. The official EAMs for mobile measurements in Austria and the United States even provide their source codes for the applications to the public although this is mainly to increase transparency rather than further adoption by others.

**Measured access types: Fixed, mobile or unspecified?**

The identification of a type of network being measured is not always a simple matter, particularly when an EAM approach is adopted. In some cases, a testing server cannot determine exactly whether a client is connected to a fixed broadband network, mobile access network (e.g. 3G or LTE), or a public Wi-Fi connection. This is especially when an ISP provides more than two of these services with a single network name that can be obtained by looking for a client’s IP address. Even if a measurement process is undertaken by a mobile device that is identified as equipped with Android or iOS, it may not be determinable whether the device is connected to a mobile access network, fixed network through home Wi-Fi signal, or other kinds of public Wi-Fi network. That being said a mobile app can distinguish mobile access from a Wi-Fi connection. These challenges could be considerable if authorities aim to develop a reliable indicator to compare ISPs as well as for international benchmarking.

Indicators provided by private entities such as Akamai, Ookla and M-Lab usually do not specify what type of broadband access was used for a speed test. Akamai releases certain statistics on mobile broadband networks that could be identified as mobile automatically on their servers, but not all of their data were distinguished into fixed or mobile or Wi-Fi. Some private sources are developing applications that specifically track the use of mobile services and report data on the type of access being used. One example is the firm Mobidia,[9] which reports data in areas such as 3G versus LTE, cellular versus Wi-Fi and so forth. Mobidia's data comes in part from details about data plans that end-users enter into the application to help them manage usage and spending. These users have an incentive, therefore, to be accurate.

When a measurement process is undertaken through an end-user application, it may be necessary to ask the operator of a client to input the ISP and broadband access type they use. This requirement is necessary if the measurement project aims to categorise data by such characteristics, although it leaves some uncertainty on accuracy of information (e.g. due to lack of knowledge or incentive). Nonetheless, an automatic identification process can be used to increase accuracy as implemented in Sweden.

In Norway, an ISP’s name is automatically determined by referencing a database with IP addresses and a user is asked to choose a subscription type (name of offer) from a list. Another approach is to explicitly show that statistics are unspecified by access type. For example, in Austria the official measurement site provides a series of data by these designations: “browser”, “WLAN (app)” and “mobile”. This equates to data being obtained by the tests on an Internet browser, by a mobile application run on a wireless LAN or by mobile applications run on mobile access networks, such as 3G and LTE. This means that the results from a mobile test are included in the category of “browser” and not in “mobile” if a test is conducted by accessing the website with a browser using a tablet, connected to a 3G network.

The End-user Device Measurement and Project Self Measurement approaches can both more effectively avoid this issue. If a specific measurement device is connected to a wireline LAN port of a home router, for fixed broadband access, it can be ensured that the performance of a fixed network is being measured.  This is the approach adopted in the United Kingdom and in the United States and favoured also by the European Commission. Project Self Measurement, of course, can also determine what type of broadband access is employed.

Given the different methodologies employed, by some official approaches, it would be currently inadvisable to compare results across these OECD countries. It is, for example, necessary to specify how mobile tests are identified and how Wi-Fi networks are treated by each measurement project.  In relation to the type of access to the Internet, such as fixed or mobile, one preliminary proposal for discussion to categorize different indicators are the following domains:

- Unspecified access (such as browser collection in Austria),
- Fixed network access excluding Wi-Fi,
- Mobile network access excluding Wi-Fi,
- Wi-Fi access, and if possible
- Mobile device access including public Wi-Fi (excluding home and office Wi-Fi), to better understand the actual performance mobile users experience and to better take into account deployment of public Wi-Fi for offloading of mobile traffic.

To undertake international benchmarks further work would be required to consider how different national or international indicators can be categorised according to what access paths they measure. In the following sections, mobile broadband will be taken to mean the third and fifth categories above and further discussion on the treatment of “mobile” is provided in the section dedicated to it.

**Measurement origination: From router or user device? Where is the server located?**

If a measurement process is aimed at a comparison of specific networks, then any influence on performance that is beyond an ISP’s control should beallowed for or excluded as much as possible. If there are, for example, several users or devices making simultaneous use of a broadband subscription, through a router at a location, such as a residence, then the tested speed will be different than the potential capacity.

If the computer/device used for the test is connected to Wi-Fi but the maximum speed of that Wi-Fi connection is slow or the signal is weak, then the results will also be significantly affected. If the computer or device used for the test has insufficient CPU power and memory space allocated to the processing of the test this can also influence the results. All of these factors are generally beyond the direct control of an ISP as is the performance of other networks with which they exchange traffic through peering or via a transit provider.

In Germany, the official project measured the effect on speeds of simultaneous use of VoIP, IPTV and FTP uploads. The results showed that, regardless of the access technology used, data transfer rates for downloads fell when these services were used at the same time. Parallel use of VoIP and FTP upload affected DSL access more than it did cable access (a decline of 6.18% for DSL, compared to 2.69% for cable). It was noted that IPTV and uploading data using FTP, decreased download speeds for DSL by 13.11%. The study indicated that the influence on upload speed is more significant and even VoIP had an effect of 42.23% decrease on a DSL line. Therefore, factors such as these could be highly influential in measurement projects without due consideration.

PSM or EDM methods make greater allowance for or exclude issues on the “client side” than others and, therefore, are regarded by many as more reliable in terms of results. PSM can control all the factors listed in the above discussion. EDM can avoid influence from simultaneous network use by detecting traffic on a single network (e.g. a residential location) and conducting a test only when there is no traffic generated.

EAM is more oriented to measuring an extended part of a network between a user’s daily use of a device or computer and a server. Some consumers are undoubtedly interested in the factors that they control as well as those in the realm of their ISP. This type of measurement can also provide real time information on a user’s experience and frequently aggregate data. In sum, the EAM approach has significant advantages if statistics can be separately categorised among different client types.

It is noteworthy, however, that in Germany both the PSM and EAM approaches were undertaken with similar results. This was achieved after an extensive advertising campaign was undertaken, in a variety of media, to secure widespread participation. Volunteers were also required to do a relatively long test aimed at overcoming some of the technical issues, with provision of explicit information to users to exclude uncontrollable factors before measurements were undertaken.

The location of a server is relevant to the performance measured. If a project is designed to compare ISPs, then the server ideally should be located at a point as close as possible to a gateway to the public Internet from the relevant ISP’s networks. In most cases this means that servers are located inside a country. Many projects recognise the importance of this factor and sometimes install their servers in a point close to domestic Internet eXchange Points (IXPs) where the ISPs concerned are interconnected. In the United States, official projects have measured speeds using both domestic M-Lab servers and secondary on-net servers, which ISPs installed. The results did not find significant differences between these two measurement approaches suggesting that domestic placement is meaningful when compared with data for countries with no domestic servers. International factors are, of course, relevant to user experience. An example comes from New Zealand, where the servers are located abroad in Australia and in the United States in addition to domestic points, given the interest in international performance.

A significant amount of the most popular content in any country may be hosted in a foreign location and a user’s experience, accessing this content, can differ from the exchange of domestic traffic. To examine this area seven OECD countries are measuring performance related to web page loading or “web surfing”. Typically, these endeavours measure the time to load a page of a popular website. As some countries will have this content hosted domestically such data may be challenging to compare across different countries. Nonetheless, the approach can provide useful information to consumers and it also enables an indicator, if indirect, of international connectivity and quality of network routes to the most popular content.

**How is performance measured? – Technical issues**

The OECD *Communications Outlook 2013* (OECD, 2013) noted that the indicator developed by Ookla (speedtest.net) delivered systematically higher speeds than the other two sources referenced (Akamai and M-Lab). Thus, even if different projects have measured a single concept of Internet speed, on access networks, a question arises as to whether a comparison is valid for speed tests with each other, which were undertaken by various entities. This section and the following one examine how performance metrics have been measured and can be measured, with a particular focus on the measurement of download speeds.

Apart from the “user side” factors some technical configuration can affect measured performance. One of the examples is a client’s configuration of Transmission Control Protocol (TCP), which is used for HTTP sessions to download data from the Internet. Among the parameters related to such configurations, the size of a Receive Window (RWIN) determines how much data a server can send to a client without waiting for a confirming message from the client computer that indicates it properly received these data. If this size is too small compared to the potential capacity of broadband line, then it will limit the Internet speed significantly, even if an ISP provides a high quality access service. Theoretically, the maximum speed with which data is transferred by TCP is decided by the following formula, as long as the ISP provides larger potential capacity than this specification:

*Maximum Speed (bit/s) = RWIN (bit) / Round Trip Time (seconds)*

The Round Trip Time (RTT) or latency means how long it takes for data to go to the server and return to the client. The issue is that some previous versions of desktop operating systems have small size of RWIN as their default settings (e.g. maximum of 64 KB in Windows XP), which were suitable for dial-up lines or low speed broadband but not so for high speed broadband. For example, if the RTT is 50 milliseconds, which is normal for a DSL line, then a user’s Windows XP machine is limited to about 10 Mbit/s at most, if the default settings are not changed, which is too low for certain DSL services advertised such as a 20 Mbit/s headline speed or more. Fortunately, Windows Vista and later versions of Windows have already solved this problem by introducing an automatic tuning function, while Windows XP or earlier versions still require manual tuning to adjust the RWIN settings into appropriate values.

A study undertaken in MIT (Steve Bauer, et al. (2010)) examined this issue in relation to the speed indicators measured by private entities, namely ComScore, Ookla, Akamai, YouTube and M-Lab. It concluded that Ookla best accommodated this issue, with older Windows configurations, as it utilizes multiple TCP connections to collect data, which is key to avoiding the speed limitation caused by an unsuitable RWIN value.

In addition to the RWIN function, TCP has a complicated mechanism to adjust a data transfer rate so that reliability and speed are well balanced. At the beginning of a connection the speed starts at a low level, followed by an increase to a higher level and then slows down again if it is too fast for the receiving side or some error occurs. This means that it could take a long time or need some technique to understand an “average peak” speed. A too small size in transferred data and a too short time for a test could also affect the results by making a wide interval of errors of measured time to complete the transfer. A speed boosting technology that increases speed for a limited time, such as seconds, can also have an impact on measuring if only a small size of data is transferred.

In order to increase reliability in terms of these issues some projects specify the period necessary for a test to be conducted. For example, a 20 second length is used for tests in official projects in Germany both for End-user Application Measurement and Project Self Measurement. A period of 30 seconds was chosen by a measuring firm SamKnows, using the M-Lab platform, for projects it undertook in the United Kingdom, the United States and the European Union, for the measurement of download speeds. SamKnows also aims to effectively exclude the influence from the slower start of TCP connection by sending small sized amounts of data before a real test begins. As an example of a private source initiative, Ookla recalculates the raw data it collects from speed tests. As a result the influence from slower starts can be decreased and this may be one of the reasons why it distributes systematically faster results compared to other private source measurements.[10]

Official measurement projects have recognised these issues and they are robust against the RWIN limitation, in many cases, with the adoption of multithread TCP connections. It is good practice to provide information on how the TCP configuration and mechanism issue can affect results and is dealt with, so that an outsider can understand the characteristics of the measured indicators. It can be confirmed here that the measurement projects on fixed broadband networks in Austria, Denmark, Germany, Norway, Sweden, the United Kingdom, the United States and European Union have made such information public.

Choices can be influenced by the goals of a project. If the purpose is mainly to provide a user with specific information on their real performance and help them to solve any bottleneck, then it makes sense to measure a speed without excluding these TCP configuration factors. Such an approach is adopted by the M-Lab and for example by Greece where M-Lab methodology is utilised by the communication regulator. It can also be noted that the usual webpage loading for most users takes only a few seconds and with a relatively low size of data. Thus, a lengthy time for a test is not realistic if it is focused on the actual Internet use by consumers. That being said a high quality video download over FTTH may take some minutes or even more.

Most online speed tests, including official ones, require less than 10 seconds to finishing a measurement process. That means they generate more or less 10 - 100 MB of data to send and receive during a test even for a high speed broadband. This is perhaps a reasonable result of seeking balance between accuracy of measurement and convenience for end users who wish to spend as short a time as possible to do a test. In any case, careful examination is necessary to consider possible comparisons of speed indicators developed by different methodologies and for different purposes.

In addition to download speeds, other metrics are also usually measured by official projects, for example latency, jitter, packet loss, DNS response time and website performance. The latter indicator has been referred to in the previous section. Among the others, latency is important for VoIP because if it takes more time for data to travel from one user to another, then these users have to wait longer to receive a response from each other when calling.

Jitter means how stable latency is and packet loss means how much data is lost or broken in the course of a transmission. These factors can affect a variety of Internet services. For example video streaming can be disturbed even if a download speed is sufficiently fast when data transfer is unstable and data packets are frequently resent due to loss. A longer time for DNS response can be an obstacle to smooth browsing of websites, as it needs more time to convert from a URL to an IP address to start communication. Detailed methodologies to measure these metrics may have to be carefully considered for any international comparisons. For example, there is some variation on latency measurement such as whether ICMP or UDP is used and how many times a packet is sent and this can differ across projects.

From a more technical point of view, it can be noted that the Internet Engineering Task Force (IETF) has already commenced a project called the Large-Scale Measurement of Broadband Performance (LMAP).[11] This work endeavours to discuss and standardise a measurement system for accurate characterization of broadband performance. The project will specify an information model, the associated data models, and develop one or more protocols for the secure communication between devices and computers for measurement. Its draft framework for large-scale measurement, issued in January 2014, includes proposals on component structures, definition of technical terms, different implementations of clients and servers, and considerations on security and privacy. According to its announcement, information models and protocols will be submitted to the Internet Engineering Steering Group (IESG) for standardization as RFCs from June to December 2014. The European Telecommunications Standards Institute and the International Telecommunication Union have also provided certain standardizations on parameters and technical methodology for performance measurement. (ETSI (2005), ITU (2011))

**How is performance measured? – Sample selection issues**

Apart from a range of technical issues, methodology or criteria on data sampling or client selection also can affect statistics provided by each measurement project, sometimes significantly. This includes the month of the year, the day of the week, the time of a day, where in a country, which ISPs are chosen to measure performance and so forth. It is more important for End-user Device Measurements and Project Self Measurements to consider how they allocate measuring points and how they filter data obtained through measurements, as their usual purposes are to make reliable statistics to compare ISPs with a limited number of clients. On the other hand, End-user Application Measurements by their nature do not control who does a test and where it is done, and most of them just provide the aggregated results, which can be shown according to categories of ISPs, access technologies, speed tiers or regions.

In many cases, an EAM collects a sample, which has deviated to some extent from the sum of true performances received by all users, as it tends to measure indicators through a group of users who are interested in or sensitive to performance. This can bring about a selection effect that creates a difference from the more general Internet access experience, which policy makers and regulators may wish to measure. However, it is possible to monitor this effect. The EAM implemented in the official project in Germany checked the sampling structure several times on the basis of the collected parameter data and compared to the respective distribution in the population. This could be determined from market data available to the project. These parameters included ISP, region (Federal or Länder, area type (urban, semi-urban, rural), access technology, and advertised speed tiers. As a result, an approximation of the population distribution was achieved in the collected sample (zafaco GmbH 2013). This is a good example of how to deal with sample selection effects, which are embedded in the EAM approach.

In the official EDMs and PSMs, clients are selected to imitate the structures of populations as much as possible in general. For example measured Internet access services are chosen by such projects so that major ISPs are covered and the statistics can effectively represent the status of the market. For fixed broadband measurement, the United States selected the 14 largest ISPs. Italy selected ISPs with more than 3 000 subscriptions providing ADSL2+ services and measured – for each region – the two most popular ISPs offers in terms of previous year revenues in its PSM, whereas at the same time in its EAM whichever ISP could be measured by installing a software into a user’s computer. Korea selected ISPs with more than 150 thousands subscriptions. Germany selected the highest quality access services available for measuring points from the five largest ISPs. A unique approach of selection was adopted in the United Kingdom, where geographic market definition was made for each area of exchange depending on the number of ISPs and not on administrative geographical units.

The timing of measurement can affect results, although it is usual for EDM and PSM projects to cover almost all the days of a week over a few months. The German PSM project carried out its performance tests for the latest public release every hour except for 4am - 5am every day of its measurement period (May-December 2012). The data showed that DSL access performance was independent from the time of a day when tests were undertaken, while cable and fixed LTE access exhibited a slight decline of about 10% in evening hours. The United States project also measured performance every hour for every day of the period (September 2012) and found that performance of all technologies fluctuated slightly during the day. A 10% decline was observed during peak times of 20:00-22:00 for DSL and Cable, while less fluctuation was measured for FTTH. In any case, measurement results reported for each hour of the day and each day of week can provide useful information in assessing performance during peak usage times.

The periods between measurements vary from one month to eight months among official EDMs and PSMs. The intervals are not so different and most of them implement a series of tests on a yearly basis. Yet, for example, New Zealand carries out measurements every two months and the United States has a flexible interval of eight to 10 months. Although these variations do not have an influence on domestic ISP comparisons and measurement reliability, in terms of reflecting user experience, it would be better for international comparisons to have a harmonised period of data collection common among all the countries undertaking the projects. The OECD *Communications Outlook 2013* (OECD, 2013) listed the results of measurements on the amount of Internet traffic by country but did not graphically compare them, as methodologies and data collection periods differed.

The location of a measurement point matters, particularly for ADSL lines, which are affected significantly by the distance from telecommunication facilities such as an exchange or DSLAM (Digital Subscriber Line Access Multiplexer). In Chile, the government specifies that tests should be done at a point 1200 meters distant from an exchange for a DSL line and in Spain the distance also shall be more than that length. The United Kingdom projects record the distances for each measurement point and weigh the results so that the distances have little impact on the published results. There are trade-offs. Eliminating distance may not always be appropriate because it affects actual performance. On the other hand, if an incumbent ISP is required to provide services in less populated areas, where the average distance tends to be longer; this needs to be taken into account. Distance is not always reported in detail, even by official reports, but can add transparency to interpreting results.

A larger number of measurement points can make results more reflective of national experience but this adds to the cost of any project. In addition to the number of clients, it is very important to scatter measuring points over a country so that they can represent the whole national market by including most ISP services as well as sufficient data for each region. For these reasons, to encourage more diverse locations to be tested, generally End-user Device Measurement can be a better choice than Project Self Measurement. This is because there is a smaller selection effect expected as they can intentionally distribute a number of measuring devices and determine the places to put them with co–operation from a number of end users. However, there is no definitive answer for the question on the amount of clients and tests that are sufficient for reliable statistics.

To increase transparency, no matter which methodology – EAM, EDM, PSM or PSM-ISP – is employed, it is encouraged to provide as much information as possible on the characteristics of the sample structures described above. This includes measured ISPs, time and location, as well as distribution of the sample to see whether test results are relatively scattered over an interval or concentrated to a specific value. It is also good practice to the check structure of the sample by comparing it with market indicators such as the subscription share of ISPs and proportions of regional population. The calculation of confidence interval can be useful as well, although it requires some assumption on distribution of population.

## Mobile measurement

The need to have reliable information on mobile broadband networks, for Internet access, is rapidly increasing as OECD countries place greater reliance on these networks to meet policy objectives. This has been concurrent with the growth of smartphones. In 2008, the number of wireless broadband subscriptions overtook the number of fixed broadband subscriptions. In 2011, approximately 80% of individuals in Japan accessed the Internet via mobile devices and in an increasing number of countries they represent more than half of the mobile market. With greater use of smartphones and other Internet accessible portable devices, mobile users have been shifting from traditional communication services such as voice and text message to use of more data intensive services including video streaming, application downloading and online game playing.

For the purpose of this document mobile broadband is taken to mean any Internet access for an end user, through any access technologies that are available, when the user is moving, such as 3G, LTE and public Wi-Fi, unless the access is only sold for stationary use. Measurement at fixed points is included here if it covers Internet connections for mobile use. As of January 2014, 11 OECD countries, namely Austria, Chile, Denmark, France, Germany, Italy, Mexico, Norway, Spain, Sweden and the United States, have measured mobile broadband performance including Internet speed to provide statistics specific to mobile broadband access. Among them, the United States has recently commenced offering a mobile application to the public for its official measurement project in November 2013.

Among these countries there are three PSMs implemented by France, Germany and Italy respectively, two PSM-ISP by Chile and Spain, and six EAMs by the other countries. In addition, using the PSM methodology, Korea measures network success rates for sending data on mobile broadband. This project measured the proportion of connection attempts that could send 100 MB of data within a certain length of time to a server in an ISP's own network, as well as webpage loading time for the most popular 20 sites in that country. EDM has not yet been employed by official mobile measurements.

*Possibility of Wi-Fi measurement*

Wireless broadband networks can, like those for fixed networks, entail a number of aspects that can have effects on the accuracy, reliability and compatibility of performance indicators. First, methodologies need to distinguish between different generations of mobile networks (3G and LTE) as well as the role of public and private Wi-Fi. Currently, among the official projects, only the PSM in Korea explicitly covers public Wi-Fi as a part of its mobile measurement project, in addition to the measurement of mobile access technology. The offloading of traffic and complimentary role Wi-Fi plays (some private sources suggest between 70% to 80% of smartphone usage is over private Wi-Fi) suggest this is a key area for better information to be made available to all stakeholders.

There should be a clear delineation in what types of Wi-Fi are covered in any project. Private Wi-Fi can be regarded as that which is self-provisioned by the user (e.g. their residential or office fixed network Wi-Fi or that which is provided by their mobile service provider as part of their bundle but not open to the public). Should there be, however, a further split between the Wi-Fi provided by an operator as part of a bundle and that which is self-provisioned? Is this technically feasible and does it make sense given that many operators will provide both fixed and mobile services as part of a bundle?

Public Wi-Fi can be regarded as any service open to any user such as in cafes, parks or on transport networks (either paid or free). In Korea, there is delineation between Wi-Fi provided by a mobile provider and public Wi-Fi (i.e. cafes and so forth) in the official measurement.

A residential and office access point connected to fixed broadband may have to be separated as they are generally viewed as fixed access, while a Wi-Fi signal from a user's wireless router which is connected to a mobile access network should be included, if the measurement focuses on mobile Wi-Fi. In addition, if EAM or EDM is employed, co-operation with ISPs is necessary to identify the type of access points, as a measuring device may be unable to decide the type of access point based on the ID of a Wi-Fi network.[12]

*Dependency on location and time*

The medium for mobile broadband access, namely the radio spectrum, has a much more limited resource for the transmission of data compared to fixed lines of copper or fibre. If two mobile users share bandwidth, for example, then the best performance available for each user will decline to half of the case where only a single user exists. In a similar manner to DSL lines factors such as distance – namely distance from a base-station and other hindrance between it and a user – can affect performance. Although there are various techniques to address these aspects, wireless networks will always face greater challenges in some areas than fixed networks.

The potential interference across networks from base-stations or technologies such as femtocells needs to be considered, especially when they are intensely deployed. Wi-Fi can also be congested where multiple Wi-Fi access points are closely installed by different providers. All of these factors are strongly dependent on location and time, which determine the number of mobile users and allocation of base-stations that exist in each area. A study conducted in the United States revealed that mobile performance, such as the Internet speed over TCP connections and latency, vary widely even for a single ISP in measurements taken at different times and locations (Junxian Huang, et al. (2010)). For example, the download speed ranged from 50 kbps to 4 Mbps for AT&T, with the median value of about 1 Mbps according to the study.

Whether a user is stationary or in motion and, if moving, how fast they are travelling, also becomes a key factor determining mobile communication performance. A research entity in Japan measured how long a mobile user can receive 3G or LTE signals on moving trains of 11 commuter lines in the Tokyo region and showed that the extent of LTE coverage differed significantly depending on the line, time of day and ISP.[13] In Korea, an academic study of 3G networks found that moving clients on a highway and over a high speed train recorded far worse performance than stationary ones over the same network. Measuring performance in motion will be increasingly important as users increasingly access the Internet on the move. In 2011, in Denmark, Japan, Korea and Sweden, official statistics show more than 30% of Internet users accessed the Internet on the move or in a similar situation.[14]

In France (ARCEP 2012), 1 638 stationary sites were selected by the PSM to officially measure mobile broadband performance. Some 20 urban areas were chosen with a population between 10 000 and 50 000, the 20 urban areas with population between 50 000 and 400 000 and 14 urban areas with a population of more than 400 000. An additional nine towns out of agglomerations with more than 10 000 populations were also measured.

The project in France identified two types of areas of cities to balance the choice of location. One of them was among high-density areas, such as downtown, transport nodes including stations and airports, business districts and highways. The second group included other areas of density, which contained other city centres of significant size. Then each measurement location was chosen randomly but meeting the following criteria:

- The measurement locations were homogeneously spread over the urban area
- 50% of tests were done inside a building and the others outdoor
- For the top 14 cities two-thirds of tests were performed in the high-density areas and the rest in other density areas.
- For the other cities half of the tests were done in high density areas and the rest is in other density areas

The tests were undertaken in different time slots between 9h00 and 21h00, from Monday to Friday, according to the usage patterns of mobile customers. The ISPs and the public did not know the exact locations and time of tests. A total of 26 208 tests were performed between September and October 2012 to measure the download speeds of a file. In addition, the sample was monitored so that it can be representative of the current mobile market based on numbers of tests of each hour, each ISP and each location, taking into account difference densities.

In Germany, the official PSM for mobile broadband was conducted in October and November 2012 for one day at each of the 26 cities where the fixed broadband PSM had its measuring points. Outdoor locations with high levels of public traffic, such as train stations, airports, retail streets, educational institutions, hospitals, and industrial parks were chosen. A tester walked around those locations and performed 157 tests on average for each location. A photograph of the walking route, by way of example can be seen in its report but it is also unknown to the public where and what time the measurements were carried out exactly (zafaco GmbH, 2013). In Korea, 200 points covering major cities, small and medium cities and rural areas, were selected to measure mobile broadband performance but information on detailed locations were also not included in the published report (KCC, 2013). However, according to additional information provided by the government, population density and the number of complaints regarding Internet service quality were taken into account to choose 700 candidate areas for selecting measuring points, from a total 3500 sub-municipal areas. The 200 points were then selected from those 700 ones with random sampling based on statistical significance.

In Japan, aware of the growing interest among the public in the actual network performance of mobile broadband services, a private firm conducted measurements of LTE and 3G at some 1 147 of the most congested locations in the country, in March 2013 and at 2147 locations in July 2013 (Nikkei BP Consulting, 2013). These included such as railway stations and entertainment centres.[15] It published reports including detailed information on the location, day and time of measurement with corresponding results of speeds. In Norway, a researcher installed measurement points in 90 locations over the country where votes were made for regional elections, and then performed the tests to measure latency in the 3G networks for more than 6 months (Elmokashfi et al,.2012).

As observed, official PSMs generally do not publish the location and time of day for tests so they reflect the actual performance that would be achieved in their absence (e.g. excluding the chance of an ISP making special efforts to improve conditions of facilities in those locations). Rather than publishing this, it is more important to make information available on the choices made and why they properly reflect performances consumers actually receive. In this regard, the practice in France is one of the best examples as it set out clear criteria to allocate clients over the country in addition to testing sample structures. On the other hand, unofficial mobile measurements could provide more specific information on the locations and times of day for tests, as often this information is not made available.

Still, as for PSMs, it is very challenging to distribute mobile measurement points so that the results would effectively represent the population effectively, mainly because location of use can move and change frequently. Only a few current measurement projects could likely explain how their samples resembled the structures of the populations in terms of where mobile users are. Therefore, in parallel with efforts to develop and implement measurement methods, it is perhaps helpful to better understand the actual usage pattern of consumers of mobile broadband services. This includes patterns of use in areas such as movement, for example through surveys by EAM, questionnaires or “apps” that provide information with a respondent’s consent. The location databases developed by mobile ISPs, which only contain records on location of mobile phones and not on their communication, can also be one source of information with such consent or due regard to privacy, although it will not directly show mobile broadband usage.

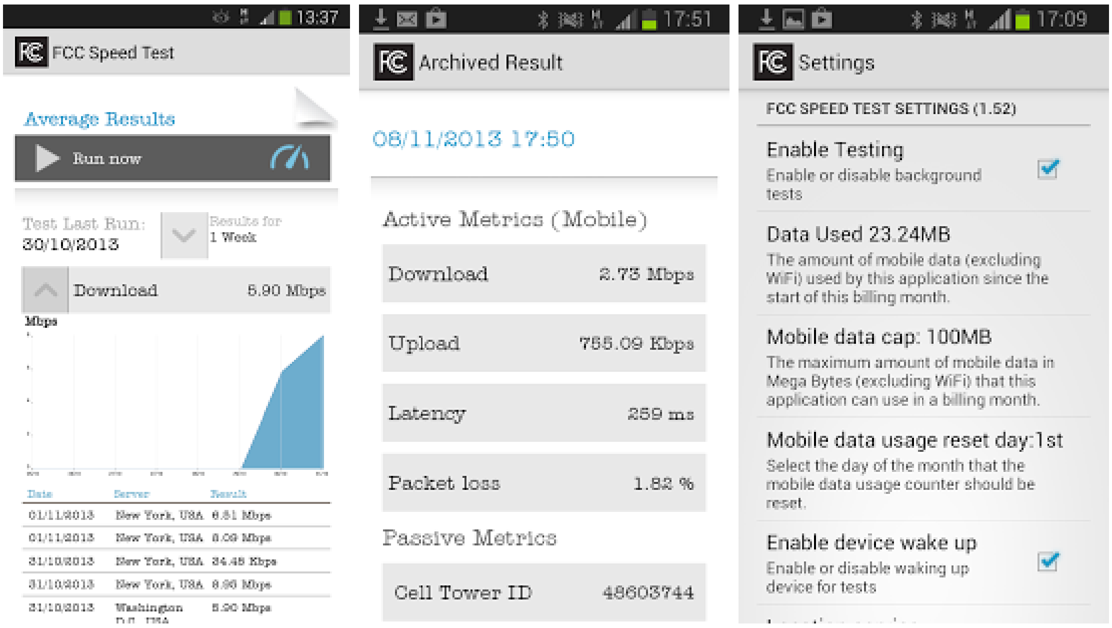
An EAM (and an EDM) do not need to consider where the tests should be undertaken. As noted for fixed broadband measurements, one of the best practices to overcome the sample selection effect for EAM could be to collect clients through advertising and to check the structure of sample by comparing parameters with indicators from other data sources such as market data. An official project could also co-operate with a private source, which has developed a technology for speed tests application to mobile networks.

An EAM (and an EDM) can reflect a market structure almost perfectly if it actively recruits participants and checks the sample structure carefully, just as a fixed measurement can do. However, even if the structure of the group of the test clients are very similar to the whole group of mobile users in terms of market parameters, such as ISP share and regional population, it is not fully sure such tests can really represent actual use of mobile data communication. This is because a user client could only undertake measurement when they do not use a mobile Internet capability for themselves.

This is more significant for mobile measurement, than for fixed measurement, because performance can change dramatically depending on time and location. The automatic scheduling of tests and a larger number of participants can be helpful to decrease this kind of difference between actual use and tested performance. The official mobile speed test application in the United States runs the tests periodically in the background when users are not using their smartphones. Users’ have the ability to adjust or limit the data volume consumed by the application (Box 1). Ideally, it is better to make the test prioritized to the user's own use but this may mean that mobile users would be less inclined to participate in the measurement project.

**Box 1: "Crowdsourced" mobile measurement in the United States**

In November 2013, the Federal Communications Commission (FCC) released a free speed test application for Android smartphones on the Google Play Store. The goal of providing this application is to accurately measure mobile and Wi-Fi network access and to enable consumers to have an in-depth and real time view of performance. Anonymous data will be collected and shown on a map to allow consumers to compare speeds and technologies in their regions, which will be followed by the provision of more detailed information and graphics, including comparisons between ISPs. An iPhone app has also been released. The initiative aims to provide transparency by making the source code for verification available to third parties.




Sources: www.fcc.gov/document/fcc-unveils-mobile-broadband-speed-test-app-empower-consumers; https://play.google.com/store/apps/details?id=com.samknows.fcc.

An advantage of EAM (and EDM) may be their potential ability to collect a large dataset diversified in terms of location and time of day/week from a number of clients. The mobility pattern of consumers can also be inferred by the location detection function. The official mobile EAM in Sweden shows the data measured through iPhones on a map using the Google Map API, so that someone can take a visual overview on geographical distribution of mobile broadband speeds. On the map, geographical variations can be seen in performance even in the central areas of Stockholm[16]. For example, some places recorded 1.5Mbps-3.0Mbps while some other well-conditioned points had over 6.0 Mbps speeds. Such detailed and subtle variances can likely be checked particularly through an EAM approach in which any mobile user can participate. The Swedish service is also able to provide the most update information nearly on real time basis while a PSM usually requires a yearly interval of measurements.

*Dependency on device and offer*

Another significant factor affecting performance in mobile broadband connections are the types of a user's mobile devices. In addition to the differences in mobile access technologies supported by a variety of devices, performance can depend on hardware or application design embedded in a device. One study showed that even for the same combination of network and applications, such as web browsing through a specific ISP connection, certain types of phones consistently outperform others due to the differences in factors such as downloading behaviour, customized content, and page rendering (Junxian Huang, et al., 2010). For example, given the same content and network condition, the page loading time of a Windows Mobile phone was consistently twice that of an iPhone according to the study. As such choosing a common mobile device, to measure different ISPs is required in a PSM to ensure fairness and exclude the effects of hardware and operating systems, if the purpose is to compare ISPs rather than reflecting the actual experience of consumers.

The official PSM in France employed Samsung Galaxy SII and iPhone 4, which were common among the four major ISPs at the time, as well as an iPad3, which seemed to be able to provide optimum performance particularly in terms of data transfer rates. In Germany and Italy, USB sticks were used for the official PSMs. The research measurement in Norway employed a mini PC card, USB modem and wireless router to connect a PC to multiple mobile access networks.

If the bundling of devices with services represents a large share, in any market, it could be rational to conduct a PSM with different devices for different ISPs. This case is strengthened in markets where smartphones are purchased with long-term contracts. In such a case, a consumer may be less able to switch a handset, even if they are unsatisfied with it, so a device can be seen as a substantial part of the ISP service rather than as a separate factor fully under the control of users. The unofficial measurement project in Japan, noted earlier, employed popular smartphones that were not always common among the ISPs in that country as bundled popular handsets varied among them. Yet, this may mean the results were less reflective of the experience of users of other devices such as the ones sold in the past.

For the EAM projects, it is useful to record a device name in each performance test and show the results aggregated by those names. This has been done in Austria and Sweden and there are clear variations of speeds, or diversified colours on the map established by Sweden, between different devices, because the supported mobile access technologies are different for each device. For example, the speeds measured by the iPhone 5 were apparently faster than those for the iPhone 4 for the same ISP. This may be because iPhone5 supports LTE in addition to 3G. It is remarkable that the most recent smartphones such as the iPhone 5S and iPhone 5C have already been recorded as the project adopted an EAM approach.

A further issue to be taken into account in relation to mobile speed tests are the structure of tariff plans. Under some tariff plans, the speed of a service may be limited when the amount of data consumption has exceeded the data cap offered by the ISP. This could, for example, be as low as 128 Kbit/s. It is also the case that some mobile operators tier offers by speed rather than data (e.g. Swisscom in Switzerland). These types of factors are not necessarily detected automatically by EAM projects. Thus, this approach (EAM) is not as well suited for measuring the gap between advertised speeds and actual speeds, compared to PSM. If, like fixed network projects, user input is required then the EAM may be able to control these factors.

Several further technical challenges remain for EAMs. As noted earlier, user location is an important factor but automatic detection of the location of mobile devices is not always granular. GPS can provide the most detailed level of information on positioning. However, if GPS is used, it will consume power and this is a greater issue than for fixed networks that have a permanent energy source. In addition, the area served by a base-station in a mobile network varies from hundreds of square kilometres to several square kilometres. Motion can be inferred by base-stations, using hand over status or the instability of performance but it is only an approximation. In addition, using an IP address is not effective for assessing location for a mobile connection (Mahesh Balakrishnan, et al. 2012).

Considering the wide variation of device and service plans provided by mobile ISPs, it is noted that an EAM has larger possibilities to collect more diversified data from a number of mobile users than other client types. A PSM approach can usually only choose a limited number of devices and offers.

Due to all these factors that can change frequently, aggregated statistics for mobile measurements generally show more scattered patterns than for the fixed broadband measurements. Therefore, average values have less meaning in assessing the overall status of measured performance. In Austria, the official statistics on the website[17] report 80 percentiles by default, which means 80% of the results are under the value reported. In France, the thresholds of 10%, 50% and 90% are reported for each metric of Internet speeds, which means a viewer can understand how much speed has been excessed by the best 10%, 50% and 90% of the results respectively. It also provides the rate of successful transfer for each ISP.

*Additional metrics and others for mobile measurements*

In addition to Internet access speeds, other metrics can also be measured as for many fixed network projects. Latency could, for example, be more relevant when measuring mobile broadband, which is relatively unstable compared to a fixed connection. In particular, considering VoIP or video messaging applications are widely used as an alternative to traditional voice calling, these indicators are increasingly becoming important as they affect the service quality for these applications. The PSMs in Germany and Korea measure the loading of websites while the successful connection rate to popular websites is measured in France. The quality of video streaming and MMS are measured by the French PSM. In fact, video streaming is also one of the growing services on mobile Internet access and jitter could affect its quality in addition to the other factors influencing most data communications.

The technical issues regarding TCP, described for fixed broadband measurement, is less relevant for mobile devices as mobile operating systems are generally well prepared for RWIN automatic adjustment. That being said the slower start of a connection still matters as long as TCP is deployed. However, with the existence of data caps it is more unusual on mobile access networks to download large amounts of data especially for a single connection. Therefore, a smaller size of data and shorter length of testing time can be more acceptable in mobile measurements, from the perspective of reflecting actual use of the mobile Internet, as long as Wi-Fi is excluded from the scope of a project. The PSM in France employed 1 MB and 5 MB as the size of data to be sent in its file transfer tests. The official project in Germany adopted the same methodology as in the PSM of fixed broadband, meaning that it transferred a relatively large size of data to measure mobile Internet speeds. The distance from a server could also affect results but it is believed that all the current official projects put them close enough to domestic clients for mobile measurements.

It can be noted that in measuring connectivity status, for example, how often a mobile device can keep a connection with a server for a certain length of time. This is important for mobile access networks, which can be more frequently unstable than fixed networks. The signal level can also be measured to indicate potential capacity for mobile broadband. One of the advantages these approaches have is that technical issues on IP level, such as the length of testing time and location of server will have little impact on results. Another advantage is that these metrics are easily measured even if a client is in motion, because a speed test requires a live connection for a certain length of time and an unstable connection will diversify the results of the speed tests significantly. In other words, a performance test that can be done instantly is more preferable for mobile broadband.

In official projects, the Czech authorities have decided to set obligations on mobile operators who will be allocated spectrum to measure signal levels in addition to Internet speeds. As noted earlier, Korea's approach was to measure the successful sending rate, meaning the proportion of connection attempts that could send 100 MB of data within a certain length of time, instead of the speed of mobile broadband. According to information provided by Korea, the reason was that the mobile transmission would often disconnect due to the distance between the BTS (Base Transceiver Station) and a user device and the number of mobile users. Thus, measuring stability of transmission rather than speed of data transfer is expected to be a more important criterion in the measurement of mobile networks.

Private sources also aim to be interactive and expansive. OpenSignal and Sensorly are examples of "crowd-sourced" projects that are measuring mobile signal levels with the co-operation of users and sharing their results on maps [18.] For OpenSignal, the data are collected by users of their Android and iPhone applications. Sensorly also relies on data provided by it users and, like OpenSignal, shows the results by country and by operator. There are also a number of apps that attempt to compare coverage strength for a user's operator and compare them with other results in those locations (e.g. CarrierCompare.[19])

**Summary**

This document has noted some of the challenges in performing official broadband speed tests as well as some of the benefits for all stakeholders in having such tools available. As a number of factors can influence results and only users can control some of them, measurement projects face greater potential hurdles than for traditional telecommunication networks. At the same time, new opportunities are emerging in terms of "crowd-sourced" data that have the potential to empower consumers by making unprecedented information available to them. These tests may, however, not always provide the information needed to inform specific policy and regulatory goals. For these reasons, it is commendable that authorities in a growing number of OECD countries are developing tools to fit their needs as well as providing greater information to all stakeholders.

This document has found that 19 OECD countries have commenced official projects to measure actual performance including Internet speeds and three others are planning future projects. Not all these projects utilise the same methodologies but good practices are starting to emerge. An objective of this report has been to begin to categorise these approaches so that OECD countries can work towards more harmonised methodologies. This has the benefit not only of sharing good practices and experience but also creating a potential basis for harmonised data sets that can be benchmarked.

Different approaches can be taken for official projects depending on policy target relevant to the measurements undertaken and other constraints such as resources, with due consideration to the advantages and disadvantages of those approaches. This report categorises the types of clients that initiate each performance test at the end-user side and examines their characteristics. They are End-user Application Measurement (EAM), End-user Device Measurement (EDM), Project Self Measurement (PSM) and PSM by ISP (PSM-ISP). Their strengths and drawbacks are summarised inTable 1.

**Table 1: Measurement methodologies**

| | EAM | EDM | PSM | Relevant policy target |
|---|---|---|---|---|
| Identification of network, e.g. fixed or mobile? | + | ++ | ++ | ISP comparison |
| Exclusion of influence from user-side factors that are out of an ISP's control (Fixed measurement) | | ++ | ++ | ISP comparison |
| Inclusion of influence from the user-side to capture real experience and detect bottlenecks | ++ | | | User experience |
| Control of influence from TCP mechanism | + | + | + | ISP comparison |
| Exclusion of selection effect from collection of users who are interested in speed tests | + | + | ++ | ISP comparison |
| Exclusion of selection effect from arbitrary choice on client characteristics (ISP, region, time to test,…) | ++ | + | + | ISP comparison<br>User experience |
| Frequent update of data | ++ | + | | ISP comparison<br>User experience |
| Increased number of clients | ++ | ++ | | ISP comparison<br>User experience |
| Identification of type of Wi-Fi access point (Mobile measurement) | + | + | ++ | ISP comparison |
| Imitation of moving pattern of users<br>(Mobile measurement) | + | + | | ISP comparison<br>User experience |
| Wide variety of measured devices<br>(Mobile measurement) | ++ | + | | ISP comparison<br>User experience |
| Exclusion of influence from speed limitation by ISP price plan contracted by client<br>(Mainly for mobile measurement) | | ? | ++ | ISP comparison |
| Location detection<br>(Mobile measurement) | + | + | ++ | ISP comparison<br>User experience |

Note: ++ means the approach (client type) is well prepared for the issue without special technique or effort. + means the approach may require additional technique or effort to prevent the issue from having an effect on the measured result. A blank cell means the approach can face challenges in that point. PSM-ISP is included in PSM in this table.

In short, for fixed network measurements, EDM can be a better choice if the project aims at undertaking comparisons between ISPs in areas such as the differences between advertised and actual speeds. EAM can be appropriate for the purpose of comparisons between ISPs, if the measurement is actively advertised and sample structures are checked as well as ensuring that the results are compared with data from other sources such as PSM. For mobile network measurements, EAM and PSM both have their advantages and if possible, adoption of both approaches would be very desirable. This is because EAM can measure actual usage patterns to determine measuring points for PSM and can also reflect the latest situation in a timely manner. At the same time, the PSM approach can more effectively control the user-side factors that can affect the results and allow the project to confirm reliability of its dataset collected by EAM. If technically possible, EDM will be able to become another good choice as it will trace the usage patterns of consumers while handset dependent factors can be excluded. In any case, various factors specific to mobile measurement should be taken into account in addition to those related to fixed measurement.

As there is no clear standard yet in measuring actual broadband quality, official measurements are encouraged to provide as rich online information as possible on metrics and methodologies adopted. The information can include solutions or moderations of network identification issues, technical issues, sample selection effects and mobile specific issues as well as policy targets. In addition, provision of more detailed datasets is also encouraged, as it will benefit others who may wish to reuse data collected with sufficient consideration to privacy concerns.

For future work, from the perspective of making progress on the check list for broadband metrics – "Work towards the long-term goal of achieving a dataset based on common methodology of measuring actual speed, with the first step to agree principles of good practice of data collection" – particularly from the viewpoint of exploring good practices, it can be said that developments are at the first stage with respect to fixed network measurement. On the other hand, mobile network measurements are more nascent and good practice is still emerging. Therefore, as done for the OECD Broadband Maps[1], it is proposed to provide links from the OECD Broadband Portal[2] to the collected current official measurement projects to assist in making these practices available for convenient international reference, with periodical updates[3]. Similar measurements in key partner countries will be collected and linked to as available and reviewed periodically.

As for the long-term goal of achieving a dataset based on common methodology, this document takes the first steps in the area of classification to enable discussion. It notes that fixed network projects are more advanced and it may take longer to make progress in mobile networks. In the short term, private sources can continue to be reviewed noting the differences in methodologies and ensuring multiple sources. If international official data are required, it is appropriate to show statistics developed by each official measurement project in a table, not a graph, with explanations on the difference of methodologies and period of measurements adopted by each project with reference to information gathered in this report, at this stage. Multi-country aggregation and comparison of official measurements will become possible if they converge on a certain range of methodologies, provided that they aim at common policy goals such as developing comparable average indicators for consumers, policy makers and regulators.

# NOTES

[1] www.oecd.org/sti/broadband/broadbandmapping.htm

[2] www.oecd.org/sti/broadband/oecdbroadbandportal.htm

[3] Links are available at www.oecd.org/sti/broadband/speed-tests.htm

[4] Some of these numbers can be different from the number of official projects as some of them employ multiple methodologies.

[5] http://berec.europa.eu/eng/news_consultations/ongoing_public_consultations/.

[6] OECD (2011).

[7] Sources for European countries are found in ted.europa.eu. Exchange rate uses the rate of 2012 (same for Korea).

[8] www.kompass.or.kr/menu/news/selectBoardArticle.do?bbsId=BBSMSTR_K00102000000&nttId=1629.

[9] www.mobidia.com/.

[10] See this URL for details : https://support.speedtest.net/entries/20862782-How-does-the-test-itself-work-How-is-the-result-calculated.

[11] https://ietf.org/wg/lmap/charter/.

[12] Fukuda and Nagami (2013) includes a practice of estimation on access point type.

[13] www.ictr.co.jp/report/20130107000011.html.

[14] See Figure 8.26 of the Communications Outlook 2013 (http://dx.doi.org/10.1787/888932800672) for details.

[15] http://consult.nikkeibp.co.jp/consult/news/2013/0719lte/#hyo06.

[16] www.bredbandskollen.se/mobile.php.

[17] https://www.netztest.at.

[18] http://opensignal.com/ and http://.sensorly.com/.

[19] https://itunes.apple.com/us/app/carriercompare-compare-speed/id516075262?mt=8 .

## BIBLIOGRAPHY


Akamai (2012, 2013), "The State of the Internet (Quarterly reports of 2012 Q1 –2013 Q2)" www.akamai.com/stateoftheinternet/.

Australian Competition and Consumer Commission (ACCC) (2013), "Broadband performance monitoring and reporting in the Australian context", http://transition.accc.gov.au/content/index.phtml/itemId/1122243.

Autorité de régulation des communications électroniques et des postes (ARCEP) (2012), "La qualité des services de voix et de données des opérateurs mobiles (2G et 3G) en France métropolitaine", www.arcep.fr/index.php?id=11557&L=1.

Autorité de régulation des communications électroniques et des postes (ARCEP) (2013), " Décision no 2013-0004 de l'Autorité de régulation des communications électroniques et des postes en date du 29 janvier 2013 relative à la mesure et à la publication d'indicateurs de la qualité des services fixes d'accès à l'internet et de téléphonie ", www.arcep.fr/uploads/tx_gsavis/13-0004.pdf.

Balakrishnan, M., I. Mohomed and Venugopalan (2012), "Where's that Phone?: Geolocating IP Addresses on 3G Networks" Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference Pages 294-30.

Bauer, S., D. Clark and W. Lehr (2010), "Understanding Broadband Speed Measurements", http://mitas.csail.mit.edu/papers/Bauer_Clark_Lehr_Broadband_Speed_Measurements.pdf.

Body of European Regulators for Electronic Communications (2011), "A framework for Quality of Service in the scope of Net Neutrality", http://berec.europa.eu/eng/document_register/subject_matter/berec/reports/117-a-framework-for-quality-of-service-in-the-scope-of-net-neutrality.

Elmokashfi, A. A. Kvalbein, J. Xiang, and K. R. Evensen (2012), "Characterizing delays in norwegian 3G networks" Proceedings of the 13th international conference on Passive and Active Measurement Pages 136-146

European Commission and SamKnows (2013), "Quality of Broadband Services in the EU March 2012", http://ec.europa.eu/digital-agenda/en/news/quality-broadband-services-eu-march-2012.

European Telecommunications Standards Institute (ETSI) (2005), "ETSI EG 202 057-4 V1.1.1 Speech Processing, Transmission and Quality Aspects (STQ);User related QoS parameter definitions and measurements;Part 4: Internet access" www.etsi.org/deliver/etsi_eg/202000_202099/20205704/01.01.01_60/eg_20205704v010101p.pdf.

Federal Communications Commission (2013), "2013 Measuring Broadband America February Report", www.fcc.gov/measuring-broadband-america.

Fukuda K., and K. Nagami (2013), “A Measurement of Mobile Traffic Offloading” Passive and Active Measurement Lecture Notes in Computer Science Volume 7799, 2013, pp 73-82 http://dx.doi.org/10.1007/978-3-642-36516-4_8.

Goga, O., R. Teixeiral (2012), “Speed measurements of residential internet access” Proceedings of the 13th international conference on Passive and Active Measurement Pages 168-178

Huang, J. Q. Xu, B. Tiwana, Z. Morley Mao, M. Zhang and P. Bahl (2010), “Anatomizing Application Performance Differences on Smartphones” Proceedings of the 8th international conference on Mobile systems, applications, and services Pages 165-178.

ICT Research and Consulting (2013), “電車移動中のスマートフォンつながりやすさ実測調査（関東編）(Actual measurement of smartphone connectivity on moving trains in Kanto region, in Japanese) ”, www.ictr.co.jp/report/20130107000011.html.

International Telecommunication Union (ITU) (2011), “ITU-T Y.1540 Internet protocol data communication service –IP packet transfer and availability performance Parameters”, www.itu.int/ITU-T/recommendations/rec.aspx?id=9270.

Jang, K. M. Han, S. Cho, H-K; Ryu, J. Lee, Y. Lee and S. Moon (2009), “3G and 3.5G Wireless Network Performance Measured from Moving Cars and High-Speed Trains” Proceedings of the 1st ACM workshop on Mobile internet through cellular networks Pages 19-24 http://dl.acm.org/citation.cfm?id=1614261.

Korea Communications Commission (KCC) (2013), “2012 년도 통신서비스 품질평가 결과 보고서 (Results of telecommunications service quality valuation for the year of 2012, in Korean)” http://old.kcc.go.kr/user.do?mode=view&page=P05030000&dc=K04030000&boardId=1042&boardSeq=35925.

Ministry of Industry, Energy and Tourism, Spain (2013) “Informes de Seguimiento de los Niveles de Calidad de Servicio (Monitoring Reports of the Quality of Service Levels, in Spanish)”, www.minetur.gob.es/telecomunicaciones/es-es/servicios/calidadservicio/informes/paginas/informes09.aspx

Ministry of Internal Affairs and Communications, Japan (MIC) (2013), “スマートフォン安心安全強化戦略 (Smartphone Safety Enhancement Strategy, in Japanese) ”, www.soumu.go.jp/menu_news/s-news/01kiban08_02000122.html.

Nikkei BP Consulting (2013), “第 2 回全国 LTE/4G エリア調査 (The second nation-wide survey on LTE/4G areas, in Japanese) ”, http://consult.nikkeibp.co.jp/consult/news/2013/0719lte/.

OECD (2011), “OECD Council Recommendation on Principles for Internet Policy Making”, http://www.oecd.org/sti/ieconomy/49258588.pdf.

OECD (2012), “Summary of the Recommendations from Rapporteur Group’s 1, 2, 4 and 5 from the London Workshop on Broadband Metrics”, internal working paper.

OECD (2013), OECD Communications Outlook 2013, OECD Publishing. http://dx.doi.org/10.1787/comms_outlook-2013-en.

Ofcom (2013), "UK fixed-line broadband performance, May 2013", http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/broadband-speeds-may2013/.

Triukose, S., S. Ardon, A. Mahanti and A. Sethz (2012), "Geolocating IP Addresses in Cellular Data Networks" Proceedings of the 13th international conference on Passive and Active Measurement Pages 158-167.

zafaco GmbH (2013), "The Quality of Service of Broadband Accesses – Study conducted on behalf of the Bundesnetzarentur", www.bundesnetzagentur.de/cln_1931/EN/Areas/Telecommunications/Companies/MarketRegulation/QualityStudy/QualityStudy_node.html.

## ANNEX 1.1: List of current official measurement projects in OECD area, basics

U/C/P: Under consideration or planned

| Country or organization | Name of Project | Entity | Client type | Mobile(1) | URLs |
|---|---|---|---|---|---|
| Austria | RTR-Netztest (RTR-NetTest) | Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR) | EAM | Yes | https://www.netztest.at<br>www.nettest.at |
| Czech | Calculation and measurements for the purposes of controlling mobile broadband data network signal coverage | Czech Telecommunication Office | PSM-ISP | U/C/P (mobile only) | www.ctu.cz/ctu-online/elektronicka-uredni-deska/vyhlaseni-vyberoveho-rizeni-na-kmitocty-v-pasmech-800-mhz-1800-mhz-a-2600-mhz-2013/vyhlaseni-vyberoveho-rizeni-2013.html<br>www.ctu.cz/cs/download/vyberova_rizeni/invitation_to_tender_15_08_2013_appendix_3.pdf<br>www.ctu.eu/main.php?pageid=349<br>www.ctu.eu/164/download/Spectrum%20Auction/2013/invitation_to_tender_15_08_2013_summary_auction_results_20_11_2013.pdf<br>http://www.ctu.cz/cs/download/vyberova_rizeni/informace_o_ukonceni_aukce_20122013.pdf |
| Chile | Publication of quality of service indicators established by Act Net Neutrality | SUBTEL and ISPs | PSM-ISP | Yes | (Example) www.movistar.cl/PortalMovistarWeb/neutralidad-de-la-red |
| Denmark | bredbaandsmaaleren.dk | Danish Business Authority | EAM | Yes | www.bredbaandsmaaleren.dk |
| France | Quality of service for mobile networks | ARCEP | PSM | Yes | www.arcep.fr/index.php?id=11557&L=1 |
| Germany | Quality of Service of Broadband Access | Federal Network Agency and zafaco GmbH | EAM and PSM | Yes for PSM | www.initiative-netzqualitaet.de/<br>www.bundesnetzagentur.de/cln_1931/EN/Areas/Telecommunications/Companies/MarketRegulation/QualityStudy/QualityStudy_node.html |
| Greece | System for Performance Evaluation of Broadband Service | Hellenic Telecommunications and Post Commission (Greece) | EAM | No | http://hyperiontest.gr/?l=1 |
| Italy | Misura Internet Project<br>MisuraInternetMobile | AGCOM, Fondazione Ugo Bordoni and ISCOM | PSM and EAM for fixed, PSM for mobile | Yes | www.misurainternet.it/progetto.php (Fixed)<br>www.misurainternetmobile.it (Mobile) |
| Korea | Wise user quality valuation | Korea Communications Commissions, | EAM for | Yes | http://wiseuser.go.kr/quality2013/main.do |

| Country or organization | Name of Project | Entity | Client type | Mobile[1] | URLs |
|---|---|---|---|---|---|
| | | National Information Society Agency and Telecommunication Technology Association | fixed, PSM for mobile | | |
| Mexico | Bandwidth Meter | Cofetel | EAM | Yes | www.micofetel.gob.mx/micofetel/medidor |
| New Zealand | TrueNet | The New Zealand Commerce Commission and TrueNet | EDM | No | https://www.truenet.co.nz |
| Norway | Nettfart.no | Norwegian Post and Telecommunications Authority | EAM | Yes | http://nettfart.no |
| Portugal | NET.mede | ANACOM | EAM | No | www.netmede.pt |
| Spain | CALIDAD DE SERVICIO | Ministry of Industry, Energy and Tourism | PSM-ISP | Yes | www.minetur.gob.es/telecomunicaciones/es-ES/Servicios/CalidadServicio/Paginas/Calidad.aspx |
| Slovenia | Komuniciraj.eu | Post and Electronic Communications Agency of the Republic of Slovenia | EAM | No | www.komuniciraj.eu/test-hitrosti/lestvice |
| Sweden | Bredbandskollen | .SE (The Internet Infrastructure Foundation) | EAM | Yes | www.bredbandskollen.se |
| Turkey | Enhancing Quality of Fixed Broadband Services Through Communique On Quality of Internet Service Providers Service | Information and Communication Technologies Authority | PSM-ISP | No | N/A |
| United Kingdom | UK broadband speeds | Ofcom and SamKnows | EDM | No | http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/ |
| United States | Measuring Broadband America | FCC and SamKnows | Fixed EDM, Mobile EAM | Yes | www.fcc.gov/measuring-broadband-america |
| European Commission | Quality of Broadband Services in the EU | European Commission and SamKnows | EDM | No | http://ec.europa.eu/digital-agenda/en/news/quality-broadband-services-eu-march-2012 |

Note: (1) “Mobile” is Yes if any indicator is provided in publicised data to show performance of Internet access by a mobile access technology (LTE/3G/Wi-Fi…) which can be used in motion. Measurements can be undertaken at fixed points.

## ANNEX 1.2: List of current official measurement projects in OECD area, details (I)

U/C/P: Under consideration or planned

| Country or organization | Client type | Mobile (1) | Purposes (2) | Measured metrics (3) | Geographical and topological location of servers | Number of clients | TCP Peak Capacity (4) |
|---|---|---|---|---|---|---|---|
| Austria | EAM | Yes | Consumer protection,<br>Competition enhancement,<br>Network development (information on network quality),<br>Net neutrality (planned) | DATA,LT,JT,PL (DNSR and WEB are planned) | Immediate proximity to the Vienna Internet exchange (VIX) | Approx. 27 000 clients, 300 000 tests, (current value, on-going measurements) | Yes |
| Czech | PSM-ISP | U/C/P (mobile only) | Consumer protection<br>Network development(5) | Signal level calculation and measurement (Reference signal received power, Signal-to-interference-plus-noise ratio)<br>DATA is planned. | Czech territory | Czech territory, defined network of 100 × 100 m squares | |
| Chile | PSM-ISP | Yes | Quality of services indicators | DATA, DNSR and Aggregation rate. (parameters informed by operators, not necessarily verified by SUBTEL) | Depending on ISP<br>(Example: domestic on-net and off-net servers as well as an US server, statistics reported for each) | Depending on ISP | |
| Denmark | EAM | U/C/P | Consumer protection | DATA, LT | The Danish Internet Exchange (DIX'en) in Lyngby | 125 000 tests done in September 2013, Approx. 4000 test each day. | Yes (Ookla) |

| Country or organization | Client type | Mobile (1) | Purposes (2) | Measured metrics (3) | Geographical and topological location of servers | Number of clients | TCP Peak Capacity (4) |
|---|---|---|---|---|---|---|---|
| France | PSM | Yes | Verification of license obligations, consumer protection, competition enhancement, network development | Voice quality, SMS, MMS, data rates (DL and UL), web surfing, video service quality | off-net (dedicated to the study) for data rate measurement | Measures in 2000 different locations (for a total of about 20.000 tests for each operator) | |
| Germany | EAM and PSM | Yes for PSM | Consumer protection<br>Net neutrality | Platform measurement: DATA, DNSR, WEB, LT, HTTP response time<br>End user measurement: DATA | Off net with a direct connection to domestic points of interchange between the networks of different operators | Approx. 550 thousands end-users and 26 points of platform measurement | Yes |
| Greece | EAM | No | Consumer protection Competition enhancement, Net neutrality | DATA, LT, JT, PL, ISP's restriction on certain services such as P2P and video streaming | Nearest available M-Lab server | Approx. 10000 users | |
| Italy | PSM and EAM (fixed), PSM (mobile) | Yes | Consumer protection.<br>The results can be used as evidence in cases where promised speed is not realized and thus the user wishes to exercise the right of withdrawal of contract (only applied to fixed services) | DATA, LT, PL, error rate. Only for mobile: WEB, web failure rate, JT | Domestic points of interchange between the networks of different operators (Rome and Milan) | Fixed: 21 points for PSM, 25 535 end user software downloads for EAM<br>Mobile: 1013 points in 20 cities | |

| Country or organization | Client type | Mobile (1) | Purposes (2) | Measured metrics (3) | Geographical and topological location of servers | Number of clients | TCP Peak Capacity (4) |
|---|---|---|---|---|---|---|---|
| Korea | EAM for fixed, PSM for mobile | Yes | Consumer protection<br>Network development | Fixed : DATA, WEB<br>Mobile: WEB, Rates of "successful'' download and upload that were faster than certain speed, web loading time, (calling quality) | ISP on-net server | 200 points for mobile PSM, 2000 users from each ISP for fixed EAM | |
| Mexico | EAM | Yes | N/A | DATA, LT | Mexico city | (Approx. 1 million tests per month) | |
| New Zealand | EDM | No | Consumer protection<br>Competition enhancement | DATA, WEB (onshore and offshore), LT, JT, PL, DNSR | Auckland and Wellington in the country, Sydney in Australia, Dallas in the US | N/A | |
| Norway | EAM | Yes | Consumer protection | DATA, LT | Norwegian Internet exchange | (Approx. 8000 tests done in September 2013, if the tests for ISPs with more than 40 tests are counted) | Yes (Ookla) |
| Portugal | EAM | No | Consumer protection<br>Market supervision<br>Net neutrality | DATA, LT, traffic shaping | | | |
| Spain | PSM-ISP | Yes | Consumer protection | DATA, successful log-in ratio (probability of successful connections to the ISP for Internet browsing), unsuccessful data transmission ratio (probability of file transmissions without error) | Accordance with Section 5.2 of ETSI 2005 (ideally the server should be as near as possible to the gateway of the measured ISP to the access network but final choice has to be made by that ISP) | More than 210 clients (probes) deployed for each measured service. 5.6 million tests per year performed in total. | |

| Country or organization | Client type | Mobile (1) | Purposes (2) | Measured metrics (3) | Geographical and topological location of servers | Number of clients | TCP Peak Capacity (4) |
|---|---|---|---|---|---|---|---|
| Slovenia | EAM | No | Consumer protection Competition enhancement, Net neutrality | DATA, LT | Server is located in Ljubljana at the web hosting provider with a 1 Gbit/s connectivity to the internet. | Measurement is at the early stage. Currently 220 tests. | |
| Sweden | EAM | Yes | Consumer protection, self-help, ISP-statistics, reports | DATA, LT | 5 locations close to urban centers of Sweden. Stockholm, Malmö, Gothenburg, Sundsvall, Luleå | 100000 users/day, 100 million since launch 2007. | Yes (Ookla) |
| Turkey | PSM-ISP | No | Consumer protection and Competition enhancement | DATA | The cities are categorized into five groups according to internet traffic from high to low. ISPs pick two cities from each category. | Under development | |
| United Kingdom | EDM | No | Consumer protection | DATA, WEB, LT, PL, JT, DNSR | 5 servers located in London and its outskirts | Approx. 2000 devices | Yes |
| United States | Fixed EDM, Mobile EAM | Yes | Consumer protection | DATA, WEB, LT(UDP and ICMP), PL(UDP and ICMP), video streaming, VoIP, DNS R, DNS failures, latency under load, availability of connection, data consumption | Core measurement points: 9 geographically diverse off-net servers placed by M-Lab<br>Secondary points: 121 on-net servers placed by ISPs<br>(Results are based on off-net points only. On-net points are to check differences) | Fixed: Approx. 7000 devices<br>Mobile: (Just started) | Yes |
| European Commission | EDM | No | Network development (Digital Agenda for Europe) | DATA, WEB, LT, PL, DNSR, VoIP | 24 M-Lab test nodes and 11 SamKnows servers in 14 cities across Europe. All are off-net points and located at major peering points or IXPs | Approx. 9000 devices | Yes |

Notes: (1) See the notes of Annex 1-1. (2) “Purposes” means any announced purposes the project is aiming to accomplish. Major categories are as follows: Consumer protection is to provide consumers with more information on actual performance so that they can make better decisions or can be protected from unlawful behaviors; Competition enhancement is to provide data to regulator or policy maker in order to promote competition in the telecommunications market; Network development is to provide data to regulator or policy maker to check the status of network development such as progress of a broadband program. Effective investment by ISPs is also included in this category; Net neutrality is to provide information on whether specific network service such as P2P or video streaming is restricted or not. (3) Categories of metrics are as follows: DATA, also referred to as Internet speed, is amount of data transferred within a certain time such as a second between a client and a server; DNSR is DNS response time; WEB is length of time to load an webpage from a certain major website to a client; LT is latency; JT is jitter; PL is packet loss. (4) “TCP Peak Capacity” is Yes if it is confirmed based on public information that the project takes into account possible influence from TCP technical issues to estimate continuous peak capacity of connection. (5) The project seeks to provide data to regulator and policy maker in order to control mobile broadband data network signal coverage - for the purposes of assessing the compliance with the conditions laid down for the holders of authorizations to use radio frequencies in the 800, 1800 and 2600 MHz bands (obligation: coverage by LTE within 30 months in the most of the dedicated regions with low population density). It also will assess the quality of the publicly available electronic communications services for consumers.

## ANNEX 1.3: List of current official measurement projects in OECD area, details (II)

U/C/P: Under consideration or planned

| Country or organization | Client type | Mobile (1) | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics (3) | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| Austria | EAM | Yes | None | Results are open data (in line with privacy policy); there are some preselected statistics, further users are free to query other statistics (e.g. on upload, download, signal strength, latency of different technologies, operators, devices) | Yes | Continuous | Continuous |
| Czech | PSM-ISP | U/C/P | Holders of authorizations to use radio frequencies in the 800, 1800 and 2600 MHz bands (existing 3 mobile operators) | The measured parameters and their limits are related to the LTE and UMTS systems operated according to the current ETSI standards and the 3GPP specifications. In the case of use of another system (e.g. LTE-A) the equivalent parameters according to its specification will be measured and assessed. | U/C/P | Beta-testing of the system is ongoing and UMTS signal coverage has been measured. The start is planned after the allocation will come into effect (expected first half of 2014). | ISPs will submit the aggregate data to the Office with the initial period of 1 month (depending on the development of the situation of the coverage the frequency may be adjusted later on). |
| Chile | PSM-ISP | Yes | None | All measured metrics are available on web (Example: average speeds according to advertised speed tiers with standard deviation) | No | Depending on ISP | N/A |
| Denmark | EAM | Yes | None | Average DATA (actual and advertised) by access technology, by ISP and by region | Yes | Continuous | Continuous |

| Country or organization | Client type | Mobile [1] | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics [3] | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| France | PSM | Yes | For each operator : TOP 14 most populated urban areas / urban areas of more than 50 000 inhabitants (TOP14 excluded) /urban areas between 10 000 and 50 000 inhabitants /cities out of urban areas of more than 10 000 inhabitants<br>half indoor and half outdoor | For each operator : Statistical distribution of speeds, speed reached for 10%/50%/90% of the transfers | No | September-October 2012 (Public release : November 2012) | Year |
| Germany | EAM and PSM | Yes for PSM | For end-users no restriction to use test. Statistical monitoring of end-user results with regard to region, speed tiers and ISPs<br><br>ISP lines for platform are chosen by market share. | EAM: Distribution of ratio to advertised speed by access technology, regions, speed tiers, or ISPs. Consumer satisfaction on speed gap from advertised speed.<br>PSM for FBB: average by time and access technology, effect from managed service<br>Platform measurement for MBB: average by city | No | May - December 2012<br><br>Continuing measures until December 2013 for second report | Year<br><br>The 2nd report will reflect measurement for July-December 2013 |
| Greece | EAM | No | None | Averages on map by regions.<br>Measurement is only recorded and projected on the map when a registered user conducted at least three measurements. Detailed information is shown by pop-up for each measurement point | Yes | Continuous | Continuous |

| Country or organization | Client type | Mobile (1) | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics (3) | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| Italy | PSM and EAM (fixed), PSM (mobile) | Yes | Fixed: Measuring points are placed at regional regulator offices. Two major ADSL2+ ISPs are selected for each region according to last year's market share of revenue.<br><br>Mobile: The four infrastructured mobile access networks available in Italy have been measured | Fixed PSM: Average DATA and LT with standard deviation and confidence interval, by regions and ISPs.<br>Fixed EAM: Average upload speed with standard deviation, 5th and 95th percentile, average download speed with standard deviation, 5th and 95th percentile, average data transmission delay, 5th and 95th percentile. Some other KPI are measured such as packet loss, jitter, etc.<br><br>Mobile PSM: Several KPI indicators are measured such as: average upload speed with standard deviation, 5th and 95th percentile; average download speed with standard deviation, 5th and 95th percentile; jitter, packet loss, round trip time, etc. | Yes | Mid 2013 (Fixed)<br>January to May 2013 (Mobile) | Year (Fixed)<br>Half year (Mobile) |
| Korea | EAM for fixed, PSM for mobile | Yes | ISPs with more than 150,000 subscribers are measured. For fixed network measurement 2000 end-users from each ISP were randomly chosen. | Wireless: Successful download and upload rates by ISPs and regions, average WEB by ISPs. LTE, 3G, WiBro and Wi-Fi are separately reported.<br>Wireline: Average DATA, average WEB by ISPs, performance of international line | Yes | October 2012 to January 2013 | Year |
| Mexico | EAM | Yes | None | Total average, total median, averages by time of day, averages by days of week. Region and ISP can be selected for all metrics. | Yes | Continuous | Continuous |

| Country or organization | Client type | Mobile (1) | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics (3) | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| New Zealand | EDM | No | 6 criteria for volunteer tester selection, e.g.: 1. Existence of another probe from that ISP in that location, 2. Data use of 3GB/month or more with some exception, 3. Ensurace of suitable spread of technologies, service levels, ISPs and potentially by detailed location | Hourly change of download speed indexed to fastest hour by ISPs. Download speed of fiber connection by hours and ISPs and speed tiers. Average WEB, LT, and DNSR by ISPs and access technologies. All metrics are reported with separation of capped/unlimited services | No | August 2013 | 2 months |
| Norway | EAM | Yes | None | Averages by ISPs and regions | No | Continuous. Results can be checked by variety of data collection terms (e.g. Last 3 months, September 2013…) | Continuous |
| Portugal | EAM | No | None | Not yet | No | Continuous | Continuous |
| Spain | PSM-ISP | Yes | Selected ISPs have annual gross volume of sales higher than EUR 20 million. Selected services have more than 85% of the operator's total subscriptions provided that they use access technology with more than 85% of Internet access. Data are weighted by traffic volume at the measured time. DSL client shall have at least 1200 meters of local loop. Mobile client shall have less than -78dBm of signal strength. | Average successful log-in ratio, average unsuccessful data transmission ratio, average DATA, and percentiles 5% and 95% of DATA. A standard presentation form to be used by the ISPs when publishing their measurement results on their websites. Direct links to those ISP sites and a comparative summary of those results are provided by the ministry. | No | Continuous. Latest yearly report by the ministry was released in December 2013. | Continuous. Yearly report provided by the ministry |
| Slovenia | EAM | No | None | Statistics are available on the website. They provide DATA by fastest town, ISPs, users | Yes, partially | N/A | N/A |

| Country or organization | Client type | Mobile [1] | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics [3] | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| Sweden | EAM | Yes | ISP&location (auto using Geoip), access tech (auto from ISP using API, manual if selected from webfrontend). | Average per access technology, ISP, subscription type (speed), county | Yes | Continuous | Continuous |
| Turkey | PSM-ISP | No | ISPs locates their platforms such they reflects their average network. | Operators, having market share of more than 4% in fixed broadband internet services, reports their speed statistics quarterly to Information and Communication Technologies Authority of Turkey. | No | None of the quarterly reports is publicized since the application has been started in this year, 2013. | N/A |
| United Kingdom | EDM | No | Raw data are weighted in aggregation based on rural/urban, distance from exchange, geographic market definition and ISPs market share, to make the result representative of market and facilitate like-for-like comparison between ISPs | Averages and maximums of download speed by speed tiers, by access technology or by area type (rural/suburban/urban). Variation by time of day.<br>Average of upload speed by speed tiers<br>Web browsing speed, latency, packet loss, DNS failure, Jitter, DNS resolution | No | May 2013<br>(published August 2013) | Half year |

| Country or organization | Client type | Mobile (1) | Selection or weighting of client characteristics (ISP, access technology, region…) | Publicized statistics (3) | Map | Last time of measurement for public release of results | Interval of measurements for public release |
|---|---|---|---|---|---|---|---|
| United States | Fixed EDM, Mobile EAM | Yes | Service offerings from 14 of the largest ISPs were examined. Volunteers were selected according to a plan designed to generate a representative sample of desired consumer demographics, including geographical location, ISP, and speed tier. | Fixed: Average ratio to advertised speed by ISPs and time of day (peak time/24 hours), or by access technologies, or by speed tiers and ISPs. Peak time speed is reported unless otherwise noted. Increase of burst speed is reported by ISP. Latency by technologies and speed tiers. Web loading time by speed tiers and ISPs. Hourly changes of speeds by ISPs. Cumulative distribution of ratio to advertised speed by access technologies or by ISPs. Data consumption and actual speed.<br>Mobile: U/C/P (release planned in 2014) | Yes | September 2012<br>(Data collection is continuing)<br>Mobile: Continuous | Fixed: 8-10 months<br>Mobile Continuous (planned from 2014) |
| European Commission | EDM | No | Panelists (clients) are selected based on access, technology, speed tiers, ISPs, and rural/suburban/urban breakdown for each country. | Averages by access technologies and peak/24hr, cumulative distributions by access technologies, comparison with the US, comparison between EU countries | No | March 2012 | Year |

Notes: (1) See the notes of Annex 1.1. (3) See the notes of Annex 1-2 for acronyms.

## ANNEX 1.4: List of planned official measurement projects in OECD area

U/C: Under consideration

| Country | Entity | Purposes(2) | Metrics(3) | First measurement | Mobile (1) | Name of proposal document |
|---|---|---|---|---|---|---|
| Australia | ACCC | Consumer protection<br>Competition enhancement<br>Network development | DATA and others (U/C) | U/C | No | Broadband performance monitoring and reporting in the Australian context, August 2013 (consultation paper) |
| Chile | Subtel | Consumer protection, Quality of service enforcement and availability of services information for end users | DATA (national and international), LT, DNSR, drop out rate, connection attempt rate | U/C<br>(Under Public Consultation) | Yes | Plan Técnico Fundamental de Mantención y Gestión de Redes de Servicios de Telecomunicaciones<br>(Fundamental Technical Guidance for Management and Maintenance of Telecommunication Service Networks) |
| Chile | Subtel | Apps QoS on Smartphone | DATA (average) and LT | Expected for dec. 2013 | Yes | Plataforma de Medición de Internet y Telefonia móvil (Internet and Mobile Telephony Measurement Platform) |
| Czech | Czech Telecommunication Office and the Ministry of Industry and Trade of the Czech Republic | To provide mapping of existing/potentially exploitable infrastructure (as detailed as possible) which can be used for BB access provision within the CZ territory. The results of the mapping | Description of network infrastructure enabling user download at least 30 Mbps for all inhabitants until 2020. Mapping is over 729 operators/providers x part of network (subscriber lines, access | August 2013<br>Report expected Nov 2013. | No | Proposal of support (common program of the Ministry of Industry and Trade of the Czech Republic and the Czech Telecommunication Office, http://www.mpo.cz/dokument142496.html ) of projects focused on construction of NGA networks with respect to the EU guidelines (European Commission Communicate 2013/C 25/01, 26 Jan 2013).<br>Draft report for public consultation published on 5th Dec 2013 (deadline 24th Jan 2014): http://www.ctu.cz/ctu- |

| Country | Entity | Purposes[(2)] | Metrics[(3)] | First measurement | Mobile [(1)] | Name of proposal document |
|---|---|---|---|---|---|---|
| | | will be used for a support of projects focused on construction of NGA networks. | part, backhaul) x technology (FTTx, radio, CaTV) x element of settlement (circa 22430) | | | online/pruzkum-nga.html , http://www.ctu.cz/cs/download/pruzkum_nga/vysledky_mapovani.pdf |
| France | ARCEP | Consumer protection Competition enhancement Assurance of least quality | DATA, WEB, LT, PL, quality of online video, download speed of P2P file sharing | The first half year of 2014 | No | ARCEP decision No. 2013-0004 of 29 January 2013 related to measurement and publication of indicators of service quality of fixed Internet access and telephony |
| Japan | Ministry of Internal Affairs and Communications | Consumer protection | U/C | U/C | Yes | Smartphone Safety Enhancement Strategy, September 2013 |
| Turkey | Information and Communication Technologies Authority | Consumer protection and Competition enhancement | DATA, WEB | U/C | Yes | 3G Broadband Speed Tests |

Notes: (1) See the notes of Annex 1.1. (2) See the notes of Annex 1-2 for definition and explanation. (3) See the notes of Annex 1.2 for acronyms.

## ANNEX 2.1: Actual speed indicators developed by private measuring entities

| (Mbit/s) | Average peak connection speed by Akamai | | | | | | Average connection speed by Akamai | | | | | | Median download throughput by M-Lab | | | | | | Average download speed by Ookla | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 |
| Australia | 16.63 | 21.68 | 22.83 | 23.43 | 26.39 | 29.10 | 3.55 | 4.41 | 4.29 | 4.20 | 4.30 | 4.84 | 4.97 | 4.95 | 5.23 | 5.06 | 4.72 | 4.97 | 10.36 | 10.86 | 11.86 | 12.37 | 12.48 | 13.00 |
| Austria | 20.17 | 22.40 | 24.67 | 25.93 | 29.54 | 31.64 | 5.70 | 6.32 | 6.55 | 6.58 | 7.39 | 8.11 | 5.10 | 5.37 | 5.59 | 5.73 | 6.05 | 5.78 | 11.60 | 11.97 | 12.88 | 13.27 | 13.76 | 15.23 |
| Belgium | 29.20 | 29.51 | 32.71 | 33.38 | 36.93 | 39.92 | 7.10 | 6.53 | 6.66 | 6.68 | 7.59 | 8.39 | 10.94 | 13.74 | 14.97 | 14.13 | 14.79 | 15.54 | 16.99 | 19.55 | 21.96 | 20.61 | 21.55 | 24.21 |
| Canada | 25.37 | 25.23 | 27.18 | 28.65 | 33.50 | 34.44 | 6.47 | 6.52 | 6.71 | 6.81 | 7.56 | 8.22 | 5.40 | 5.47 | 5.83 | 6.20 | 6.17 | 8.04 | 12.25 | 12.73 | 13.60 | 15.09 | 16.14 | 17.23 |
| Chile | 19.66 | 19.50 | 20.59 | 20.12 | 19.83 | 19.34 | 3.41 | 2.98 | 3.03 | 2.93 | 2.84 | 2.94 | 1.59 | 1.56 | 1.64 | 1.78 | 1.72 | 1.74 | 7.23 | 7.95 | 8.36 | 8.93 | 9.40 | 9.28 |
| Czech Republic | 24.47 | 25.83 | 27.25 | 30.44 | 34.62 | 35.38 | 7.14 | 7.19 | 7.59 | 8.13 | 9.01 | 9.79 | 4.96 | 5.55 | 6.02 | 6.07 | 6.06 | 6.88 | 14.97 | 15.45 | 16.11 | 17.31 | 16.99 | 18.08 |
| Denmark | 21.54 | 22.80 | 26.45 | 26.11 | 28.59 | 29.87 | 6.71 | 6.68 | 7.25 | 7.02 | 7.67 | 8.11 | 9.91 | 10.09 | 10.41 | 10.74 | 12.30 | 13.19 | 17.60 | 18.16 | 19.54 | 21.86 | 24.48 | 26.60 |
| Estonia | 21.57 | 21.14 | 22.44 | 23.46 | 26.23 | 27.94 | 5.16 | 4.83 | 5.03 | 5.20 | 5.64 | 6.16 | 4.80 | 5.55 | 5.46 | 5.23 | 5.98 | 6.28 | 32.05 | 14.79 | 14.24 | 16.85 | 17.08 | 17.70 |
| Finland | 23.54 | 22.58 | 24.97 | 26.53 | 30.11 | 31.03 | 6.85 | 6.57 | 6.82 | 7.12 | 7.85 | 8.12 | 7.83 | 8.22 | 8.20 | 7.75 | 8.48 | 9.02 | 15.76 | 15.91 | 17.07 | 18.31 | 19.32 | 21.70 |
| France | 19.09 | 18.29 | 19.63 | 21.05 | 22.72 | 24.18 | 4.89 | 4.64 | 4.80 | 4.80 | 5.00 | 5.68 | 4.94 | 5.28 | 4.73 | 3.50 | 3.71 | 4.50 | 12.76 | 12.18 | 12.79 | 14.06 | 15.59 | 17.24 |
| Germany | 23.43 | 24.04 | 26.05 | 27.04 | 31.24 | 32.62 | 5.78 | 5.78 | 5.91 | 6.04 | 6.87 | 7.31 | 6.49 | 7.03 | 7.08 | 7.29 | 7.83 | 8.67 | 14.98 | 14.92 | 16.00 | 16.98 | 18.34 | 19.73 |
| Greece | 20.93 | 20.63 | 21.71 | 22.20 | 25.89 | 26.00 | 4.03 | 3.94 | 3.98 | 3.98 | 4.63 | 4.77 | 5.40 | 5.50 | 5.20 | 5.45 | 5.44 | 5.95 | 5.90 | 5.98 | 5.93 | 6.43 | 7.11 | 7.28 |
| Hungary | 27.95 | 28.03 | 29.98 | 30.96 | 35.11 | 36.31 | 5.93 | 5.64 | 5.80 | 5.86 | 6.38 | 6.48 | 5.77 | 6.63 | 6.96 | 7.50 | 7.98 | 9.37 | 14.47 | 15.18 | 15.67 | 16.92 | 16.99 | 18.21 |
| Iceland | 23.90 | 24.55 | 24.19 | 25.18 | 31.69 | 32.16 | 5.37 | 5.50 | 5.26 | 5.41 | 6.97 | 7.17 | 4.66 | 5.82 | 5.85 | 5.89 | 5.61 | 7.17 | 20.43 | 20.88 | 21.74 | 24.87 | 27.08 | 27.44 |
| Ireland | 25.24 | 22.40 | 26.43 | 26.96 | 30.48 | 30.92 | 7.34 | 6.22 | 6.70 | 6.61 | 7.24 | 8.00 | 5.37 | 5.75 | 5.92 | 6.36 | 6.32 | 7.50 | 8.08 | 8.25 | 10.34 | 10.82 | 10.89 | 12.45 |
| Israel | 23.55 | 26.13 | 30.89 | 32.25 | 37.67 | 40.08 | 4.61 | 4.98 | 5.64 | 5.79 | 6.93 | 7.35 | 2.15 | 3.18 | 3.17 | 3.57 | 4.57 | 4.91 | 9.09 | 9.47 | 9.78 | 10.15 | 12.29 | 15.91 |
| Italy | 17.68 | 17.37 | 19.18 | 19.41 | 22.01 | 23.25 | 4.15 | 4.03 | 3.93 | 4.00 | 4.43 | 4.94 | 3.41 | 3.78 | 3.85 | 3.57 | 2.67 | 3.72 | 4.94 | 5.30 | 5.50 | 5.62 | 5.85 | 6.37 |
| Japan | 39.54 | 40.50 | 42.17 | 44.77 | 47.37 | 48.84 | 10.92 | 10.74 | 10.51 | 10.80 | 11.23 | 11.96 | 9.55 | 11.04 | 15.99 | 21.23 | 18.76 | 19.04 | 14.55 | 19.46 | 29.28 | 36.42 | 34.84 | 29.46 |
| Korea | 47.79 | 46.90 | 48.75 | 49.25 | 44.93 | 53.31 | 15.75 | 14.21 | 14.68 | 13.97 | 14.18 | 13.29 | | | | | | | 30.92 | 27.76 | 33.30 | 33.95 | 34.30 | 32.70 |
| Luxembourg | 16.72 | 16.60 | 18.40 | 18.92 | 21.32 | 24.97 | 4.73 | 4.54 | 4.65 | 4.66 | 5.15 | 6.09 | 4.93 | 4.86 | 4.75 | 4.87 | 5.35 | 7.12 | 21.22 | 30.31 | 27.00 | 30.49 | 32.86 | 33.61 |
| Mexico | 13.53 | 13.75 | 14.35 | 15.13 | 17.34 | 18.90 | 2.79 | 2.73 | 2.80 | 2.94 | 3.22 | 3.56 | 1.97 | 2.42 | 2.66 | 2.70 | 2.37 | 2.43 | 4.77 | 5.23 | 6.17 | 6.89 | 7.31 | 9.29 |
| Netherlands | 29.39 | 27.91 | 30.65 | 31.95 | 36.49 | 38.82 | 8.82 | 7.97 | 8.55 | 8.55 | 9.52 | 10.11 | 9.64 | 9.63 | 9.80 | 10.67 | 11.72 | 12.40 | 24.25 | 25.22 | 27.41 | 29.79 | 29.95 | 32.48 |
| New Zealand | 16.06 | 16.50 | 17.78 | 19.23 | 20.27 | 20.98 | 3.86 | 3.85 | 3.92 | 4.04 | 4.29 | 4.61 | 5.23 | 5.21 | 5.41 | 5.24 | 5.21 | 6.06 | 8.92 | 9.15 | 10.47 | 11.13 | 11.31 | 12.60 |
| Norway | 20.07 | 19.69 | 23.15 | 24.85 | 28.05 | 28.74 | 5.73 | 5.49 | 6.20 | 6.60 | 7.21 | 7.35 | 7.51 | 8.46 | 8.88 | 8.52 | 8.66 | 8.81 | 16.66 | 19.24 | 17.64 | 19.87 | 19.97 | 20.61 |
| Poland | 22.03 | 22.69 | 25.06 | 26.85 | 31.25 | 30.96 | 4.95 | 4.95 | 5.34 | 5.57 | 6.01 | 6.29 | 4.20 | 4.33 | 4.60 | 4.52 | 4.37 | 5.59 | 9.18 | 10.39 | 11.46 | 11.85 | 11.80 | 13.12 |
| Portugal | 28.24 | 27.82 | 29.79 | 31.54 | 33.67 | 35.07 | 5.37 | 4.70 | 4.83 | 4.99 | 4.99 | 5.42 | 5.71 | 6.24 | 6.59 | 6.20 | 6.87 | 7.39 | 16.46 | 21.34 | 22.34 | 23.06 | 23.26 | 23.19 |
| Slovak Republic | 24.19 | 23.39 | 26.21 | 27.04 | 29.40 | 29.79 | 5.74 | 5.46 | 5.83 | 5.77 | 6.06 | 6.39 | 2.76 | 3.32 | 4.11 | 4.75 | 4.51 | 5.40 | 13.80 | 12.82 | 13.01 | 15.05 | 14.85 | 16.35 |
| Slovenia | 19.83 | 19.41 | 21.53 | 23.51 | 25.56 | 26.41 | 4.82 | 4.57 | 4.91 | 5.18 | 5.33 | 5.77 | 4.23 | 4.22 | 4.20 | 4.83 | 5.43 | 5.52 | 9.96 | 10.65 | 11.60 | 11.63 | 11.80 | 12.96 |
| Spain | 23.96 | 23.76 | 26.00 | 27.79 | 30.11 | 32.05 | 4.62 | 4.64 | 4.83 | 4.93 | 5.00 | 5.87 | 4.44 | 4.56 | 4.71 | 4.75 | 4.97 | 5.38 | 11.55 | 11.93 | 11.70 | 12.61 | 13.63 | 14.82 |
| Sweden | 24.13 | 23.58 | 26.95 | 28.36 | 33.02 | 33.73 | 6.34 | 5.85 | 6.77 | 7.27 | 8.39 | 8.45 | 8.95 | 9.67 | 10.08 | 9.68 | 9.56 | 10.49 | 24.91 | 24.03 | 26.51 | 26.43 | 27.65 | 30.28 |
| Switzerland | 28.66 | 29.91 | 32.41 | 34.15 | 39.88 | 41.42 | 8.10 | 8.43 | 8.69 | 8.74 | 10.09 | 11.01 | 7.55 | 8.71 | 9.35 | 9.86 | 10.41 | 11.02 | 19.75 | 19.63 | 20.75 | 23.36 | 30.49 | 30.98 |
| Turkey | 18.50 | 17.37 | 19.59 | 19.25 | 24.08 | 26.67 | 2.85 | 2.73 | 2.85 | 2.75 | 3.19 | 3.70 | 2.43 | 1.41 | 2.49 | 2.52 | 2.56 | 2.68 | 6.65 | 5.88 | 6.72 | 7.03 | 7.47 | 8.07 |
| United Kingdom | 23.67 | 24.49 | 28.14 | 30.49 | 35.26 | 37.14 | 5.58 | 5.66 | 6.30 | 6.47 | 7.59 | 8.40 | 5.20 | 5.80 | 6.39 | 6.76 | 7.16 | 7.94 | 12.26 | 15.15 | 17.56 | 18.19 | 19.39 | 21.09 |
| United States | 28.86 | 29.14 | 30.98 | 32.77 | 35.88 | 36.31 | 6.75 | 7.11 | 7.46 | 7.61 | 8.39 | 8.68 | 6.07 | 6.64 | 7.00 | 6.87 | 6.59 | 7.37 | 12.54 | 12.59 | 14.53 | 15.37 | 15.79 | 17.57 |

*Sources*: Akamai, "The State of the Internet", www.akamai.com; Measurement Lab (M-Lab), www.measurementlab.net; Ookla "NET INDEX", www.netindex.com. M-Lab indicators are medians of all tests done in the quarter using the M-Lab sites (servers) located in corresponding regions of countries. The regions are specified as Australia, Europe including Turkey, Japan, New Zealand, and North and South America. Ookla indicators are aggregations of daily data calculated by $\Sigma$(daily average speed * daily number of tests) / quarterly number of tests.

## ANNEX 2.2: Country ranks according to the private speed indicators.

Highlighted cells indicate fastest five countries.

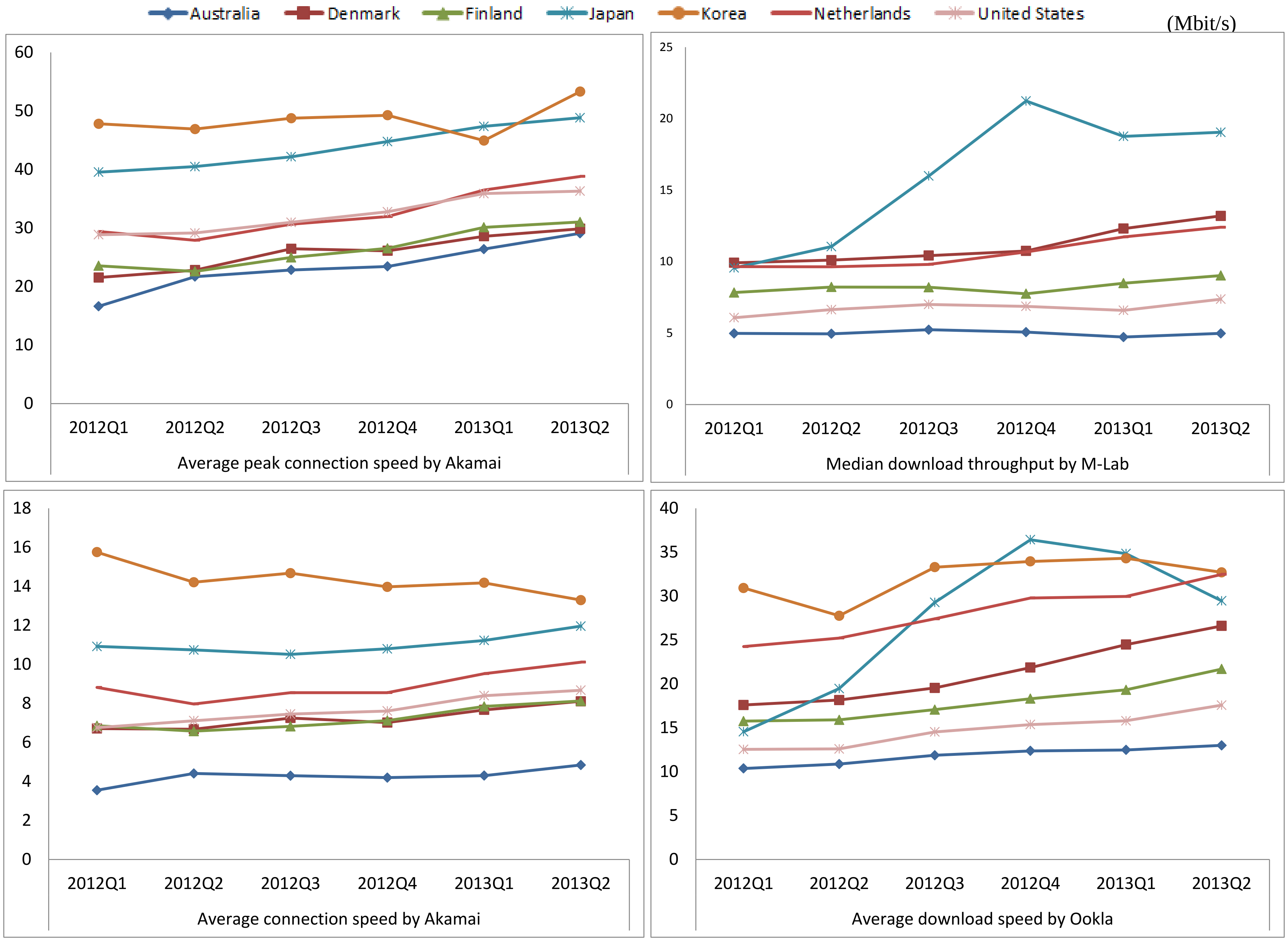
| | Average peak connection speed by Akamai | | | | | | Average connection speed by Akamai | | | | | | Median download throughput by M-Lab | | | | | | Average download speed by Ookla | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 |
| Australia | 32 | 23 | 24 | 26 | 24 | 23 | 31 | 28 | 28 | 28 | 30 | 29 | 19 | 23 | 21 | 22 | 25 | 27 | 24 | 24 | 23 | 24 | 24 | 26 |
| Austria | 24 | 22 | 21 | 21 | 20 | 17 | 17 | 11 | 13 | 14 | 13 | 12 | 18 | 20 | 18 | 18 | 17 | 22 | 22 | 22 | 21 | 22 | 22 | 23 |
| Belgium | **4** | **4** | **3** | **4** | **5** | **5** | 7 | 9 | 12 | 11 | 11 | 9 | **1** | **1** | **2** | **2** | **2** | **2** | 9 | 8 | 7 | 10 | 10 | 9 |
| Canada | 9 | 11 | 12 | 12 | 12 | 12 | 11 | 10 | 10 | 10 | 12 | 10 | 13 | 19 | 17 | 15 | 15 | 11 | 21 | 19 | 19 | 19 | 18 | 20 |
| Chile | 27 | 27 | 28 | 29 | 33 | 33 | 32 | 32 | 32 | 33 | 34 | 34 | 33 | 32 | 33 | 33 | 33 | 33 | 30 | 30 | 30 | 30 | 30 | 31 |
| Czech Republic | 11 | 10 | 11 | 11 | 10 | 10 | 6 | **5** | **5** | **5** | **5** | **5** | 20 | 16 | 14 | 16 | 16 | 18 | 14 | 13 | 14 | 14 | 17 | 16 |
| Denmark | 22 | 18 | 14 | 20 | 22 | 21 | 10 | 7 | 7 | 9 | 9 | 13 | **2** | **3** | **3** | **3** | **3** | **3** | 8 | 11 | 10 | 9 | 8 | 8 |
| Estonia | 21 | 24 | 25 | 25 | 25 | 25 | 21 | 22 | 22 | 22 | 22 | 22 | 23 | 17 | 19 | 21 | 18 | 19 | **1** | 17 | 18 | 17 | 15 | 17 |
| Finland | 18 | 20 | 20 | 19 | 18 | 18 | 8 | 8 | 8 | 8 | 8 | 11 | 6 | 8 | 8 | 8 | 8 | 8 | 12 | 12 | 13 | 12 | 13 | 11 |
| France | 28 | 29 | 29 | 28 | 29 | 30 | 23 | 25 | 26 | 26 | 25 | 26 | 21 | 21 | 24 | 30 | 29 | 29 | 18 | 21 | 22 | 21 | 20 | 19 |
| Germany | 19 | 14 | 17 | 15 | 16 | 14 | 14 | 14 | 16 | 16 | 18 | 17 | 9 | 9 | 9 | 10 | 10 | 10 | 13 | 16 | 15 | 15 | 14 | 14 |
| Greece | 23 | 25 | 26 | 27 | 26 | 28 | 29 | 30 | 29 | 31 | 28 | 30 | 14 | 18 | 22 | 19 | 20 | 21 | 32 | 31 | 33 | 33 | 33 | 33 |
| Hungary | 8 | 6 | 8 | 9 | 9 | 8 | 13 | 16 | 18 | 17 | 19 | 19 | 11 | 11 | 11 | 9 | 9 | 7 | 16 | 14 | 16 | 16 | 16 | 15 |
| Iceland | 15 | 12 | 22 | 22 | 14 | 15 | 20 | 17 | 21 | 21 | 16 | 18 | 24 | 13 | 16 | 17 | 19 | 16 | 6 | 6 | 8 | 6 | 7 | 7 |
| Ireland | 10 | 21 | 15 | 17 | 17 | 20 | **5** | 12 | 11 | 12 | 14 | 14 | 15 | 15 | 15 | 13 | 14 | 13 | 29 | 29 | 28 | 28 | 29 | 29 |
| Israel | 17 | 9 | 6 | 6 | **4** | **4** | 27 | 20 | 19 | 18 | 17 | 15 | 31 | 30 | 30 | 28 | 26 | 28 | 27 | 27 | 29 | 29 | 25 | 22 |
| Italy | 30 | 30 | 31 | 30 | 30 | 31 | 28 | 29 | 30 | 30 | 29 | 28 | 28 | 28 | 29 | 29 | 30 | 30 | 33 | 33 | 34 | 34 | 34 | 34 |
| Japan | **2** | **2** | **2** | **2** | **1** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **4** | **2** | **1** | **1** | **1** | **1** | 15 | 9 | **2** | **1** | **1** | 6 |
| Korea | **1** | **1** | **1** | **1** | **2** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | | | | | | | **2** | **2** | **1** | **2** | **2** | **2** |
| Luxembourg | 31 | 32 | 32 | 33 | 31 | 29 | 25 | 27 | 27 | 27 | 24 | 23 | 22 | 24 | 23 | 23 | 22 | 17 | **5** | **1** | **4** | **3** | **3** | **1** |
| Mexico | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 32 | 32 | 33 | 32 | 31 | 31 | 31 | 32 | 32 | 34 | 34 | 32 | 32 | 32 | 30 |
| Netherlands | **3** | 7 | 7 | 7 | 6 | 6 | **3** | **4** | **4** | **4** | **4** | **4** | **3** | **5** | **5** | **4** | **4** | **4** | **4** | **3** | **3** | **4** | **5** | **3** |
| New Zealand | 33 | 33 | 33 | 32 | 32 | 32 | 30 | 31 | 31 | 29 | 31 | 31 | 16 | 22 | 20 | 20 | 23 | 20 | 28 | 28 | 27 | 27 | 28 | 28 |
| Norway | 25 | 26 | 23 | 23 | 23 | 24 | 16 | 18 | 15 | 13 | 15 | 16 | 8 | 7 | 7 | 7 | 7 | 9 | 10 | 10 | 11 | 11 | 11 | 13 |
| Poland | 20 | 19 | 19 | 18 | 15 | 19 | 22 | 21 | 20 | 20 | 21 | 21 | 27 | 26 | 26 | 27 | 28 | 23 | 26 | 26 | 26 | 25 | 26 | 25 |
| Portugal | 7 | 8 | 9 | 8 | 11 | 11 | 19 | 23 | 24 | 24 | 27 | 27 | 12 | 12 | 12 | 14 | 12 | 14 | 11 | **5** | 6 | 8 | 9 | 10 |
| Slovak Republic | 12 | 17 | 16 | 16 | 21 | 22 | 15 | 19 | 17 | 19 | 20 | 20 | 29 | 29 | 28 | 25 | 27 | 25 | 17 | 18 | 20 | 20 | 21 | 21 |
| Slovenia | 26 | 28 | 27 | 24 | 27 | 27 | 24 | 26 | 23 | 23 | 23 | 25 | 26 | 27 | 27 | 24 | 21 | 24 | 25 | 25 | 25 | 26 | 27 | 27 |
| Spain | 14 | 15 | 18 | 14 | 19 | 16 | 26 | 24 | 25 | 25 | 26 | 24 | 25 | 25 | 25 | 26 | 24 | 26 | 23 | 23 | 24 | 23 | 23 | 24 |
| Sweden | 13 | 16 | 13 | 13 | 13 | 13 | 12 | 13 | 9 | 7 | 7 | 7 | **5** | **4** | **4** | 6 | 6 | 6 | **3** | **4** | **5** | **5** | 6 | **5** |
| Switzerland | 6 | **3** | **4** | **3** | **3** | **3** | **4** | **3** | **3** | **3** | **3** | **3** | 7 | 6 | 6 | **5** | **5** | **5** | 7 | 7 | 9 | 7 | **4** | **4** |
| Turkey | 29 | 31 | 30 | 31 | 28 | 26 | 33 | 33 | 33 | 34 | 33 | 32 | 30 | 33 | 32 | 32 | 31 | 31 | 31 | 32 | 31 | 31 | 31 | 32 |
| United Kingdom | 16 | 13 | 10 | 10 | 8 | 7 | 18 | 15 | 14 | 15 | 10 | 8 | 17 | 14 | 13 | 12 | 11 | 12 | 20 | 15 | 12 | 13 | 12 | 12 |
| United States | **5** | **5** | **5** | **5** | 7 | 9 | 9 | 6 | 6 | 6 | 6 | 6 | 10 | 10 | 10 | 11 | 13 | 15 | 19 | 20 | 17 | 18 | 19 | 18 |

## ANNEX 2.3: Frequency of speed tests of each private speed indicator

| | Unique IP addresses by Akamai, per 100 broadband subscriptions of 2012Q4 | | | | | | Number of NDT tests by M-Lab, per 100 broadband subscriptions of 2012Q4 | | | | | | Number of tests by Ookla, per 100 broadband subscriptions of 2012Q4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 | 2012Q1 | 2012Q2 | 2012Q3 | 2012Q4 | 2013Q1 | 2013Q2 |
| Australia | 47.36 | 47.36 | 47.36 | 47.36 | 30.08 | 30.02 | 0.28 | 0.25 | 0.23 | 0.23 | 0.19 | 0.12 | 275.95 | 293.95 | 296.27 | 321.89 | 329.20 | 382.49 |
| Austria | 44.95 | 44.95 | 44.95 | 44.95 | 35.29 | 38.29 | 0.32 | 0.24 | 0.24 | 0.29 | 0.25 | 0.20 | 380.96 | 328.16 | 333.77 | 428.45 | 501.02 | 468.26 |
| Belgium | 58.93 | 58.93 | 58.93 | 58.93 | 60.88 | 64.14 | 0.82 | 0.83 | 0.83 | 1.03 | 0.90 | 0.63 | 311.22 | 290.23 | 271.00 | 302.46 | 303.68 | 330.68 |
| Canada | 52.11 | 52.11 | 52.11 | 52.11 | 52.36 | 52.45 | 0.88 | 0.73 | 0.85 | 0.85 | 0.71 | 0.55 | 615.43 | 537.47 | 533.49 | 634.90 | 662.38 | 588.96 |
| Chile | 46.09 | 46.09 | 46.09 | 46.09 | 43.92 | 58.55 | 0.18 | 0.25 | 0.37 | 0.47 | 0.39 | 0.34 | 358.70 | 397.95 | 466.70 | 441.47 | 373.82 | 467.34 |
| Czech Republic | 30.20 | 30.20 | 30.20 | 30.20 | 29.13 | 25.52 | 0.80 | 0.71 | 0.70 | 0.73 | 0.73 | 0.66 | 446.38 | 385.61 | 349.51 | 409.65 | 404.63 | 376.87 |
| Denmark | 41.36 | 41.36 | 41.36 | 41.36 | 36.27 | 38.13 | 0.66 | 0.61 | 0.57 | 0.58 | 0.48 | 0.42 | 196.16 | 184.78 | 177.40 | 195.29 | 205.60 | 196.10 |
| Estonia | | | | | | | 0.87 | 0.71 | 0.74 | 0.90 | 0.82 | 0.63 | 798.39 | 626.72 | 610.54 | 707.52 | 725.56 | 621.92 |
| Finland | 41.61 | 41.61 | 41.61 | 41.61 | 37.01 | 36.30 | 0.37 | 0.33 | 0.35 | 0.37 | 0.29 | 0.25 | 375.64 | 328.01 | 348.98 | 421.02 | 423.38 | 371.66 |
| France | 44.75 | 44.75 | 44.75 | 44.75 | 44.85 | 47.50 | 0.52 | 0.66 | 0.63 | 0.72 | 0.61 | 0.52 | 88.52 | 90.56 | 98.64 | 130.02 | 134.06 | 138.47 |
| Germany | 58.54 | 58.54 | 58.54 | 58.54 | 59.33 | 61.88 | 0.15 | 0.13 | 0.13 | 0.13 | 0.11 | 0.10 | 104.58 | 105.36 | 115.01 | 156.38 | 161.83 | 147.43 |
| Greece | 36.00 | 36.00 | 36.00 | 36.00 | 37.31 | 41.03 | 1.20 | 1.18 | 1.13 | 1.53 | 1.44 | 1.07 | 459.63 | 390.08 | 321.85 | 467.61 | 514.81 | 414.06 |
| Hungary | 71.27 | 71.27 | 71.27 | 71.27 | 71.99 | 78.46 | 3.79 | 3.19 | 3.14 | 4.03 | 3.79 | 3.19 | 1788.04 | 1395.16 | 1226.61 | 1523.46 | 1647.11 | 1287.60 |
| Iceland | 44.57 | 44.57 | 44.57 | 44.57 | 43.87 | 45.97 | 1.61 | 1.42 | 1.39 | 1.74 | 1.30 | 1.07 | 387.72 | 308.28 | 317.30 | 387.27 | 396.96 | 411.63 |
| Ireland | 39.49 | 39.49 | 39.49 | 39.49 | 39.88 | 42.10 | 0.51 | 0.55 | 0.51 | 0.55 | 0.52 | 0.48 | 563.74 | 514.36 | 545.13 | 595.20 | 612.87 | 659.02 |
| Israel | 47.23 | 47.23 | 47.23 | 47.23 | 37.95 | 39.78 | 0.50 | 0.54 | 0.61 | 0.66 | 0.51 | 0.47 | 517.21 | 323.01 | 242.08 | 265.26 | 258.42 | 298.80 |
| Italy | 37.39 | 37.39 | 37.39 | 37.39 | 40.19 | 44.61 | 0.93 | 0.86 | 0.80 | 0.98 | 0.96 | 0.77 | 426.84 | 365.72 | 296.76 | 449.15 | 455.83 | 430.70 |
| Japan | 28.08 | 28.08 | 28.08 | 28.08 | 27.93 | 28.28 | 0.005 | 0.005 | 0.005 | 0.003 | 0.002 | 0.002 | 7.12 | 5.44 | 5.40 | 6.64 | 6.93 | 10.89 |
| Korea | 28.39 | 28.39 | 28.39 | 28.39 | 28.34 | 30.58 | | | | | | | 9.25 | 6.50 | 6.81 | 7.34 | 8.41 | 9.88 |
| Luxembourg | 29.68 | 29.68 | 29.68 | 29.68 | 28.34 | 27.45 | 0.72 | 0.72 | 0.64 | 0.84 | 0.64 | 0.55 | 450.76 | 418.51 | 371.05 | 442.53 | 464.12 | 484.78 |
| Mexico | 44.05 | 44.05 | 44.05 | 44.05 | 47.78 | 46.27 | 0.19 | 0.24 | 0.29 | 0.23 | 0.19 | 0.20 | 424.87 | 432.97 | 435.68 | 438.84 | 427.34 | 479.29 |
| Netherlands | 48.42 | 48.42 | 48.42 | 48.42 | 51.45 | 54.82 | 1.05 | 0.83 | 0.83 | 0.97 | 0.82 | 0.64 | 315.60 | 304.01 | 276.12 | 352.16 | 339.55 | 309.80 |
| New Zealand | 42.73 | 42.73 | 42.73 | 42.73 | 42.15 | 44.94 | 0.18 | 0.20 | 0.29 | 0.20 | 0.16 | 0.10 | 218.96 | 252.06 | 257.82 | 275.16 | 264.94 | 305.02 |
| Norway | 61.29 | 61.29 | 61.29 | 61.29 | 58.33 | 62.15 | 0.53 | 0.49 | 0.49 | 0.49 | 0.36 | 0.31 | 386.45 | 330.37 | 340.83 | 412.78 | 410.28 | 351.28 |
| Poland | 27.22 | 27.22 | 27.22 | 27.22 | 28.50 | 31.61 | 0.47 | 0.36 | 0.36 | 0.45 | 0.43 | 0.32 | 404.79 | 308.88 | 288.03 | 388.28 | 425.00 | 336.08 |
| Portugal | 44.45 | 44.45 | 44.45 | 44.45 | 46.10 | 50.79 | 1.07 | 1.17 | 1.03 | 1.17 | 1.10 | 1.31 | 477.79 | 621.97 | 572.72 | 630.73 | 624.70 | 604.53 |
| Slovak Republic | 30.53 | 30.53 | 30.53 | 30.53 | 30.67 | 36.14 | 1.21 | 1.04 | 0.86 | 1.01 | 1.08 | 0.78 | 530.44 | 451.14 | 453.86 | 482.38 | 510.44 | 417.99 |
| Slovenia | | | | | | | 1.44 | 1.20 | 1.14 | 1.45 | 1.20 | 0.82 | 890.18 | 682.51 | 689.42 | 885.82 | 921.67 | 781.30 |
| Spain | 38.40 | 38.40 | 38.40 | 38.40 | 36.26 | 38.48 | 0.66 | 0.60 | 0.67 | 0.76 | 0.66 | 0.53 | 114.15 | 111.72 | 97.92 | 126.61 | 121.81 | 110.36 |
| Sweden | 49.51 | 49.51 | 49.51 | 49.51 | 49.70 | 51.82 | 0.61 | 0.59 | 0.61 | 0.62 | 0.50 | 0.39 | 84.42 | 75.57 | 81.72 | 96.14 | 96.18 | 79.15 |
| Switzerland | 39.73 | 39.73 | 39.73 | 39.73 | 40.88 | 43.08 | 0.29 | 0.32 | 0.28 | 0.33 | 0.27 | 0.25 | 123.39 | 106.36 | 111.66 | 150.83 | 183.45 | 180.98 |
| Turkey | | | 48.34 | 45.85 | 48.34 | 48.19 | 0.57 | 0.74 | 0.78 | 0.78 | 0.69 | 0.53 | 195.77 | 229.62 | 190.37 | 207.56 | 223.67 | 196.01 |
| United Kingdom | 38.34 | 38.34 | 38.34 | 38.34 | 39.38 | 43.43 | 0.63 | 0.67 | 0.67 | 0.69 | 0.61 | 0.47 | 485.64 | 551.52 | 494.43 | 546.31 | 498.83 | 438.82 |
| United States | 39.57 | 39.57 | 39.57 | 39.57 | 39.17 | 41.74 | 0.23 | 0.22 | 0.26 | 0.23 | 0.20 | 0.20 | 248.43 | 223.48 | 244.11 | 243.85 | 273.68 | 271.65 |

Note: Broadband subscription is OECD data of sum of fixed broadband subscription and wireless broadband subscription. Broadband penetration is number of broadband subscription per 100 inhabitants. See notes of Annex 2-1 for sources of other data.

**ANNEX 2.4: Trend of actual speed shown by each private speed indicator, selected OECD countries**



## ANNEX 2.5: Similarity of the private speed indicators for OECD countries, 2012Q1-2013Q2

| | | Correlation coefficients | | | |
|---|---|---|---|---|---|
| | | Average peak connection speed by Akamai | Average connection speed by Akamai | Average download speed by Ookla | Median download throughput by M-Lab |
| Probabilities of same population average (paired t-test) | Average peak connection speed by Akamai | | 0.88 | 0.61 | 0.69 |
| | Average connection speed by Akamai | 0.00 | | 0.68 | 0.78 |
| | Average download speed by Ookla | 0.00 | 0.00 | | 0.68 |
| | Median download throughput by M-Lab | 0.00 | 0.00 | 0.00 | |