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Large-Scale Broadband Measurement Use Cases
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Abstract

Measuring broadband performance on a large scale is important for network diagnostics by providers and users, as well as for public policy. To conduct such measurements, user networks gather data instructed by a measurement controller, and then upload the measurement results to a designated measurement server. Understanding the various scenarios and users of measuring broadband performance is essential to development of the framework, information model and protocol. The details of the measurement metrics themselves are beyond the scope of this document.

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1 Introduction

This document describes some use cases for the Large-scale Measurement of Broadband Performance (LMAP), in particular use cases for ISPs and regulators.

1.1 Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2 Use Cases

The LMAP architecture utilizes metrics for instructions on how to execute a particular measurement. Although layer 2 specific metrics can and will be defined, from the LMAP perspective, there is no difference between fixed service and mobile (cellular) service used for Internet access. Hence, like measurements will take place on both fixed and mobile networks. Fixed services, commonly known as "Last Mile" include technologies like DSL, Cable, and Carrier Ethernet. Mobile services include all those advertised as 2G, 3G, 4G, and LTE. A metric defined to measure over-the-top services will execute similarly on all layer 2 technologies. The LMAP architecture covers networks utilizing both IPv4 and IPv6.

2.1 Internet Service Provider (ISP) Use Case

An ISP, or indeed another network operator, needs to understand the performance of their networks, the performance of the suppliers (downstream and upstream networks), the performance of services, and the impact that such performance has on the experience of their customers. In addition they may also desire visibility of their competitor's networks and services in order to be able to benchmark and improve their own offerings. Largely the processes that ISPs operate (which are based on network measurement) include:

- Identifying, isolating and fixing problems in the network, services or with CPE and end user equipment. Such problems may be common to a point in the network topology (e.g. a single exchange), common to a vendor or equipment type (e.g. line card or home gateway) or unique to a single user line (e.g. copper access). Part of this process may also be helping users understand whether the problem exists in their home network or with an over-the-top service instead of with their BB product.

- Design and planning. Through identifying the end user experience the ISP can design and plan their network to ensure specified levels of user experience. Services may be moved closer to end users, services upgraded, the impact of QoS assessed or more capacity deployed at certain locations. SLAs may be defined at network or product boundaries.

o Understanding the quality experienced by customers. Alongside benchmarking competitors, gaining better insight into the user's service through a sample panel of the operator's own customers. The end-to-end perspective matters, across home /enterprise networks, peering points, CDNs etc.

o Understanding the impact and operation of new devices and technology. As a new product is deployed, or a new technology introduced into the network, it is essential that its operation and impact on other services is measured. This also helps to quantify the advantage that the new technology is bringing and support the business case for larger roll-out.

2.2 Regulators

Regulators in jurisdictions around the world are responding to consumers' adoption of Internet access services for traditional telecommunications and media services by promoting competition among providers of electronic communications, to ensure that users derive maximum benefit in terms of choice, price, and quality.

Some jurisdictions have responded to a need for greater information about Internet access service performance in the development of regulatory policies and approaches for broadband technologies by developing large-scale measurement programs. Programs such as the U.S. Federal Communications Commission's Measuring Broadband America, European Commission's Quality of Broadband Services in the EU reports and a growing list of other programs employ a diverse set of operational and technical approaches to gathering data to perform analysis and reporting on diverse aspects of broadband performance.

While each jurisdiction responds to distinct consumer, industry, and regulatory concerns, much commonality exists in the need to produce datasets that are able to compare multiple Internet access service providers, diverse technical solutions, geographic and regional distributions, and marketed and provisioned levels and combinations of broadband Internet access services. In some jurisdictions, the role of measuring is provided by a measurement provider.

Measurement providers measure network performance from users towards multiple content and application providers, included dedicated test measurement servers, to show a performance of the actual Internet access service provided by different ISPs. Users need to know the performance that are achieving from their own ISP. In addition, they need to know the performance of other ISPs of same location as background information for selecting their ISP. Measurement providers will provide measurement results with associated measurement methods and measurement metrics.

From a consumer perspective, the differentiation between fixed and mobile (cellular) Internet access services is blurring as the applications used are very similar. Hence, regulators are measuring both fixed and mobile Internet access services.

Regulators role in the development and enforcement of broadband Internet access service policies also require that the measurement approaches meet a high level of verifiability, accuracy and provider-independence to support valid and meaningful comparisons of Internet access service performance

LMAP standards could answer regulators shared needs by providing scalable, cost-effective, scientifically robust solutions to the measurement and collection of broadband Internet access service performance information.

2.3 Implementation options

There are several ways of implementing a measurement system. The choice may be influenced by the details of the particular use case and what the most important criteria are for the regulator, ISP or third party operating the measurement system.

One way involves a special hardware device that is connected directly to the home gateway. The devices are deployed to a carefully selected panel of end users and they perform measurements according to a defined schedule. The schedule can run throughout the day, to allow continuous assessment of the network. Careful design ensures that measurements do not detrimentally impact the home user experience or corrupt the results by testing when the user is also using the broadband line. The system is therefore tightly controlled by the operator of the measurement system. One advantage of this approach is that it is possible to get reliable benchmarks for the performance of a network with only a few devices. One disadvantage is that it would be expensive to deploy hardware devices on a mass scale sufficient to understand the performance of the network at the granularity of a single broadband user.

Another approach involves implementing the measurement capability as a webpage or an "app" that end users are encouraged to download onto their mobile phone or computing device. Measurements are triggered by the end user, for example the user interface may have a button to "test my broadband now". Compared with the previous approach, the system is much more loosely controlled, as the panel of end users and the schedule of tests are determined by the end users themselves rather than the measurement system. It would be easier to get large-scale, however it is harder to get comparable benchmarks as the measurements are affected by the home network and also the population

is self-selecting and so potentially biased towards those who think they have a problem. This could be alleviated by stimulating widespread downloading of the app and careful post-processing of the results to reduce biases.

There are several other possibilities. For example, as a variant on the first approach, the measurement capability could be implemented as software embedded in the home gateway, which would make it more viable to have the capability on every user line. As a variant on the second approach, the end user could initiate measurements in response to a request from the measurement system.

3 Details of ISP Use Case

3.1 Understanding the quality experienced by customers

Operators want to understand the quality of experience (QoE) of their broadband customers. The understanding can be gained through a "panel", i.e., a measurement probe is deployed to a few 100 or 1000 of its customers. The panel needs to be a representative sample for each of the operator's technologies (FTTP, FTTC, ADSL...) and broadband options (80Mb/s, 20Mb/s, basic...), ~100 probes for each. The operator would like the end-to-end view of the service, rather than (say) just the access portion. So as well as simple network statistics like speed and loss rates they want to understand what the service feels like to the customer. This involves relating the pure network parameters to something like a 'mean opinion score' which will be service dependent (for instance web browsing QoE is largely determined by latency above a few Mb/s).

An operator will also want compound metrics such as "reliability", which might involve packet loss, DNS failures, re-training of the line, video streaming under-runs etc.

The operator really wants to understand the end-to-end service experience. However, the home network (Ethernet, wifi, powerline) is highly variable and outside its control. To date, operators (and regulators) have instead measured performance from the home gateway. However, mobile operators clearly must include the wireless link in the measurement.

Active measurements are the most obvious approach, i.e., special measurement traffic is sent by - and to - the probe. In order not to degrade the service of the customer, the measurement data should only be sent when the user is silent, and it shouldn't reduce the customer's data allowance. The other approach is passive measurements on the customer's ordinary traffic; the advantage is that it measures what the customer actually does, but it creates extra variability (different traffic mixes give different results) and especially it raises privacy concerns.

From an operator's viewpoint, understanding customers better enables it to offer better services. Also, simple metrics can be more easily understood by senior managers who make investment decisions and by sales and marketing.

3.2 Understanding the impact and operation of new devices and technology

Another type of measurement is to test new capabilities and services before they are rolled out. For example, the operator may want to:

check whether a customer can be upgraded to a new broadband option; understand the impact of IPv6 before it makes it available to its customers (will v6 packets get through, what will the latency be to major websites, what transition mechanisms will be most is appropriate?); check whether a new capability can be signaled using TCP options (how often it will be blocked by a middlebox? - along the lines of some existing experiments) [Extend TCP]; investigate a quality of service mechanism (eg checking whether Diffserv markings are respected on some path); and so on.

3.3 Design and planning

Operators can use large scale measurements to help with their network planning - proactive activities to improve the network.

For example, by probing from several different vantage points the operator can see that a particular group of customers has performance below that expected during peak hours, which should help capacity planning. Naturally operators already have tools to help this - a network element reports its individual utilisation (and perhaps other parameters). However, making measurements across a path rather than at a point may make it easier to understand the network. There may also be parameters like bufferbloat that aren't currently reported by equipment and/or that are intrinsically path metrics.

With better information, capacity planning and network design can be more effective. Such planning typically uses simulations to emulate the measured performance of the current network and understand the likely impact of new capacity and potential changes to the topology. It may also be possible to run stress tests for risk analysis, for example 'if whizzy new application (or device) becomes popular, which parts of my network would struggle, what would be the impact on other services and how many customers would be affected'. What-if simulations could help quantify the advantage that a new technology brings and support the business case for larger roll-out. This approach should allow good results with measurements from a limited panel of customers.

Another example is that the operator may want to monitor performance where there is a service level agreement. This could be with its own customers, especially enterprises may have an SLA. The operator can proactively spot when the service is degrading near to the SLA limit, and get information that will enable more informed conversations with the customer at contract renewal.

An operator may also want to monitor the performance of its suppliers, to check whether they meet their SLA or to compare two suppliers if it is dual-sourcing. This could include its transit

operator, CDNs, peering, video source, local network provider (for a global operator in countries where it doesn't have its own network), even the whole network for a virtual operator.

Through a better understanding of its own network and its suppliers, the operator should be able to focus investment more effectively - in the right place at the right time with the right technology.

3.4 Identifying, isolating and fixing network problems

Operators can use large scale measurements to help identify a fault more rapidly and decide how to solve it.

Operators already have Test and Diagnostic tools, where a network element reports some problem or failure to a management system. However, many issues are not caused by a point failure but something wider and so will trigger too many alarms, whilst other issues will cause degradation rather than failure and so not trigger any alarm. Large scale measurements can help provide a more nuanced view that helps network management to identify and fix problems more rapidly and accurately. The network management tools may use simulations to emulate the network and so help identify a fault and assess possible solutions.

One example was described in [IETF85-Plenary]. The operator was running a measurement panel for reasons discussed in sub use case #1. It was noticed that the performance of some lines had unexpectedly degraded. This led to a detailed (off-line) investigation which discovered that a particular home gateway upgrade had caused a (mistaken!) drop in line rate.

Another example is that occasionally some internal network management event (like re-routing) can be customer-affecting (of course this is unusual). This affects a whole group of customers, for instance those on the same DSLAM. Understanding this will help an operator fix the fault more rapidly and/or allow the affected customers to be informed what's happening and/or request them to re-set their home hub (required to cure some conditions). More accurate information enables the operator to reassure customers and take more rapid and effective action to cure the problem.

There may also be problems unique to a single user line (e.g. copper access) that need to be identified.

Often customers experience poor broadband due to problems in the home network - the ISP's network is fine. For example they may have moved too far away from their wireless access point. Perhaps 80% of customer calls about fixed BB problems are due to in-home wireless

issues. These issues are expensive and frustrating for an operator, as they are extremely hard to diagnose and solve. The operator would like to narrow down whether the problem is in the home (with the home network or edge device or home gateway), in the operator's network, or with an over-the-top service. The operator would like two capabilities. Firstly, self-help tools that customers use to improve their own service or understand its performance better, for example to re-position their devices for better wifi coverage. Secondly, on-demand tests that can the operator can run instantly - so the call centre person answering the phone (or e-chat) could trigger a test and get the result whilst the customer is still on-line session.

4 Details of Regulator Use Case

4.1 Promoting competition through transparency

Competition plays a vital role in regulation of the electronic communications markets. For competition to successfully discipline operators' behavior in the interests of their customers, end users must be fully aware of the characteristics of the ISPs' access offers. In some jurisdictions regulators mandate transparent information made available about service offers.

End users need effective transparency to be able to make informed choices throughout the different stages of their relationship with ISPs, when selecting Internet access service offers, and when considering switching service offer within an ISP or to an alternative ISP. Quality information about service offers could include speed, delay, and jitter. Regulators can publish such information to facilitate end users' choice of service provider and offer. It may also help content, application, service and device providers develop their Internet offerings.

The published information needs to be:

- Accurate - the measurement results must be correct and not influenced by errors or side effects. The results should be reproducible and consistent over time.

- Comparable - common metrics should be used across different ISPs and service offerings so that measurement results can be compared.

- Meaningful - the metrics used for measurements need to reflect what end users value about their broadband Internet access service

- Reliable - the number and distribution of measurement agents,

and the statistical processing of the raw measurement raw data, needs to be appropriate

A set of measurement parameters and associated measurement methods are used over time, e.g. speed, delay, and jitter. Then the measurement raw data are collected and go through statistical post-processing before the results can be published in an Internet access service quality index to facilitate end users' choice of service provider and offer.

The regulator can also promote competition through transparency by encouraging end users to monitor the performance of their own broadband Internet access service. They might use this information to check that the performance meets that specified in their contract or to understand whether their current subscription is the most appropriate.

4.2 Promoting broadband deployment

Governments sometimes set strategic goals for high-speed broadband penetration as an important component of the economic, cultural and social development of the society. To evaluate the effect of the stimulated growth over time, broadband Internet access take-up and penetration of high-speed access can be monitored through measurement campaigns.

An example of such an initiative is the "Digital Agenda for Europe" which was adopted in 2010, to achieve universal broadband access. The goal is to achieve by 2020, access for all Europeans to Internet access speeds of 30 Mbps or above, and 50% or more of European households subscribing to Internet connections above 100 Mbps.

To monitor actual broadband Internet access performance in a specific country or a region, extensive measurement campaigns are needed. A panel can be built based on operators and packages in the market, spread over urban, suburban and rural areas. Probes can then be distributed to the participants of the campaign.

Periodic tests running on the probes can for example measure actual speed at peak and off-peak hours, but also other detailed quality metrics like delay and jitter. Collected data goes afterwards through statistical analysis, deriving estimates for the whole population which can then be presented and published regularly.

Using a harmonized or standardised measurement methodology, or even a common quality measurement platform, measurement results could also be used for benchmarking of providers and/or countries.

4.3 Monitoring "net neutrality"

Regulatory approaches related to net neutrality and the open Internet has been introduced in some jurisdictions. Examples of such are the Internet policy as outlined by the FCC Preserving the Open Internet Report and Order [FCC R&O] and the Body of European Regulators for Electronic Communications Guidelines for quality of service [BEREC Guidelines]. The exact definitions and requirements vary from one jurisdiction to another; the comments below provide some hints about the potential role of measurements.

Net neutrality regulations do not necessarily require every packet to be treated equally. Typically they allow "reasonable" traffic management (for example if there is exceptional congestion) and allow "specialized services" in parallel to, but separate from, ordinary Internet access (for example for facilities-based IPTV). A regulator may want to monitor such practices as input to the regulatory evaluation. However, these concepts are evolving and differ across jurisdictions, so measurement results should be assessed with caution.

A regulator could monitor departures from application agnosticism such as blocking or throttling of traffic from specific applications, and preferential treatment of specific applications. A measurement system could send, or passively monitor, application-specific traffic and then measure in detail the transfer of the different packets. Whilst it is relatively easy to measure port blocking, it is a research topic how to detect other types of differentiated treatment. The paper, "Glasnost: Enabling End Users to Detect Traffic Differentiation" [M-Labs NSDI 2010] and follow-on tool "Glasnost" [Glasnost] are examples of work in this area.

A regulator could also monitor the performance of the broadband service over time, to try and detect if the specialized service is provided at the expense of the Internet access service. Comparison between ISPs or between different countries may also be relevant for this kind of evaluation.

5 Conclusions

Large-scale measurements of broadband performance are useful for both network operators and regulators. Network operators would like to use measurements to help them better understand the quality experienced by their customers, identify problems in the network and design network improvements. Regulators would like to use measurements to help promote competition between network operators, stimulate the growth of broadband access and monitor 'net neutrality'. There are other use cases that are not the focus of the initial LMAP charter

(although it is expected that the mechanisms developed would be readily applied), for example end users would like to use measurements to help identify problems in their home network and to monitor the performance of their broadband provider.

From consideration of the various use cases, several common themes emerge whilst there are also some detailed differences. These characteristics guide the development of LMAP's framework, information model and protocol.

A measurement capability is needed across a wide number of heterogeneous environments. Tests may be needed in the home network, in the ISP's network or beyond; they may be measuring a fixed or wireless network; they measure just the access network or across several networks, at least some of which are not operated by the measurement provider.

There is a role for both standardized and non-standardized measurements. For example, a regulator would like to publish standardized performance metrics for all network operators, whilst an ISP may need their own tests to understand some feature special to their network. Most use cases need active measurements, which create and measure specific test traffic, but some need passive measurements of the end user's traffic.

Regardless of the tests being operated, there needs to be a way to demand or schedule the tests. Most use cases need a regular schedule of measurements, but sometimes ad hoc testing is needed, for example for troubleshooting. It needs to be ensured that measurements do not affect the user experience and are not affected by user traffic (unless desired). In addition there needs to be a common way to collect the results. Standardization of this control and reporting functionality allows the operator of a measurement system to buy the various components from different vendors.

After the measurements results are collected, they need to be understood and analyzed. Often it is sufficient to measure only a small subset of end users, but per-line fault diagnosis requires the ability to test every individual line. Analysis requires accurate definition and understanding of where the test points are, as well as contextual information about the topology, line, product and the subscriber's contract. The actual analysis of results is beyond the scope of LMAP, as is the key challenge of how to integrate the measurement system into a network operator's existing tools for diagnostics and network planning.

Finally the test data, along with any associated network, product or subscriber contract data is commercial or private information and

needs to be protected.

6 Security Considerations

This informational document provides an overview of the use cases for LMAP and so does not, in itself, raise any security issues.

The framework document [framework] discusses the potential security, privacy (data protection) and business sensitivity issues that LMAP raises. The main threats are:

1. a malicious party that gains control of Measurement Agents to launch DoS attacks at a target, or to alter (perhaps subtly) Measurement Tasks in order to compromise the end user's privacy, the business confidentiality of the network, or the accuracy of the measurement system.

2. a malicious party that intercepts or corrupts the Measurement Results &/or other information about the Subscriber, for similar nefarious purposes.

3. a malicious party that uses fingerprinting techniques to identify individual end users, even from anonymized data

4. a measurement system that does not obtain the end user's informed consent, or fails to specify a specific purpose in the consent, or uses the collected information for secondary uses beyond those specified.

5. a measurement system that is vague about who is the "data controller": the party legally responsible for privacy (data protection).

The [framework] also considers some potential mitigations of these issues. They will need to be considered by an LMAP protocol and more generally by any measurement system.

7 IANA Considerations

None

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