MONROE: Measuring Mobile Broadband Networks in Europe

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ABSTRACT

There is a strong need for objective data about stability and performance of Mobile Broadband (MBB) networks, and for tools to rigorously and scientifically assess their performance. In particular, it is important to measure and understand the quality as experienced by the end user. Such information is very valuable for many parties including operators, regulators and policy makers, consumers and society at large, businesses whose services depend on MBB networks, researchers and innovators. In this paper, we introduce the MONROE measurement platform aimed to address this need. MONROE[1] is an open, European-scale, and flexible platform with multi-homing capabilities to run experiments on operational 3G/4G Mobile Broadband networks. The MONROE platform enables accurate, realistic and meaningful monitoring and assessment of the performance of MBB networks. MONROE also provides WiFi connectivity mimicking multi-homing in smartphones with both MBB and WiFi interfaces, to allow experimenting on different access technologies as well as to explore new ways of combining them to increase performance and robustness.

1. INTRODUCTION

Mobile broadband (MBB) networks underpin numerous vital operations of modern society and are arguably becoming the most important piece of the world's communications infrastructure. The use of MBB networks has exploded over the last few years due to the immense popularity of mobile devices such as smartphones and tablets, combined with the availability of high-capacity 3G/4G mobile networks. According to Cisco's Global Mobile Data Traffic Forecast [1], the number of mobile devices in 2014 grew to a total of 7.4 billion, exceeding the world's population. Mobile data traffic grew 69% in 2014 and is expected to grow almost tenfold by 2019. Given the importance of MBB networks, there is a strong need for objective information about their performance and reliability.

During the past few years, there has been a growing interest from regulators, policy makers and the networking community on measuring the performance of home and mobile broadband networks. Several regulators have translated this into ongoing nationwide efforts, for example, the FCC's Measuring Broadband America initiative [2] in the USA. Assessing the quality experienced by end users requires foremost thorough systematic end-to-end measurements. There are several possible approaches to performing systematic measurements of MBB performance. Operators and independent agencies sometimes perform drive-by tests to identify coverage holes or performance problems. These tests are, however, expensive and do not scale well [10]. Another approach is to rely on end users to run performance tests by visiting a website [7] or running a special measurement application [4]. The main advantage of this approach is scalability: it can collect millions of measurements from different regions, networks and user equipment. However, with such an approach, repeatability is hard and one can only collect measurement data at users' own will, with no possibility to either monitor or control the measurement process. Furthermore, mostly due to privacy reasons, these measurements do not provide important context information and metadata, e.g., location, type of user equipment, type of subscription, and connection mode (2G/3G/4G); however, metadata is critical when analyzing the results. Also, such a setup does not provide active measurements that

[1]MONROE is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 644399. The MONROE platform is currently being developed by a consortium of European academic and industrial partners and the first version of the platform will be operational in March 2016. For more information, please visit https://www.monroe-project.eu/

can reveal important information on stability and availability of a network, since this requires long and uninterrupted measurement sessions. Finally, with this approach, it is very difficult to test novel applications and services since this might require configuration changes (e.g. customized kernels).

In contrast to this framework, *MONROE is the first European platform for independent, multi-homed, large-scale monitoring and assessment of performance of mobile broadband networks in heterogeneous environments.* Access to such a platform allows for the deployment of extensive measurement campaigns to collect data from operational MBB networks. The availability of this vast amount of data allows us to advance our understanding of the fundamental characteristics of MBB networks and their relationship with the performance parameters of popular applications. This is crucial not only for improving the user experience for services that are running on the current 3G/4G infrastructure, but also for providing feedback on the design of upcoming 5G technologies.

2. THE MONROE PLATFORM

MONROE's approach is to build a dedicated infrastructure for measuring and experimenting in MBB and WiFi (IEEE 802.11) networks, comprising both fixed and mobile nodes. A dedicated measurement infrastructure can complement other approaches by overcoming many of the challenges discussed in the previous section. It can be used to run measurements at regular intervals over long time periods under similar conditions. It also gives full information about the context in which the measurements are collected, and allows targeted experiments triggered by the observed behavior. Most importantly, it allows users of the platform to test their novel applications and services that run on MBB networks with WiFi connectivity.

The MONROE platform complements the existing experimental platforms such as RIPE[8] by providing unique features in the field of network-controlled mobile measurements. MONROE builds on the existing NorNet Edge (NNE)[2] [5] and extends its functionality, scale and coverage. The main features of MONROE are:

1) Large-scale and wide geographical coverage: MONROE is composed of 450 nodes that are widely distributed across Norway, Sweden, Italy and Spain as illustrated in Figure 1. MONROE is able to collect measurements under diverse conditions, from major cities to remote islands (including one node in Svalbard, in the Arctic). There is a dense deployment of nodes in a few main cities (e.g. Oslo, Stockholm, Madrid, Torino, etc.), giving a more detailed view of network conditions in urban areas. At the same time, to have coverage in remote rural areas, MONROE specifically deploys 20 nodes in North Sweden.

Figure 1: Distribution of MONROE Nodes

2) Mobility: 150 MONROE nodes are deployed on trains and buses in order to cover both rural and urban areas. These nodes are instrumental to provide insights on the mobility characteristics of MBB.

3) Multihomed: Each MONROE node is connected simultaneously to three mobile broadband networks, which makes it possible to conduct a wide range of measurements and experiments that compare the performance of each network, or explore novel ways of combining resources from each network. Along with MBB networks, MONROE also provides WiFi connectivity to allow experimenting on different access technologies and explore methods such as traffic offloading.

4) Flexible and powerful MONROE nodes: The MONROE nodes are designed such that they are flexible and powerful enough to run most measurement and experiment tasks, including demanding applications like adaptive video streaming. Furthermore, MONROE enables experimenting novel services and applications on MBB networks by allowing configuration changes such as kernel modifications.

5) Rich context information: In addition to information about network, time and location for experiments, MONROE nodes have built-in support for collecting metadata from the externally connected modems such as cell ID, signal strength and connection mode.

6) Open access: MONROE is open to external

[2]NNE is currently in an operational state, with a functioning system for node management, deployment of experiments, handling of data etc. as well as real-time visualization of measurements (demo available at http://demo.robustenett.no)

users and makes it easy to access the system and deploy experiments on all or a selected subset of the nodes. Through the Open Calls of MONROE Project, the external users can also seek funding.

7) Visualization and Open Data: The MONROE platform has a measurement system that collects experiment results and then store them in a database. The measurement results are presented through a real time visualization system. Furthermore, the results are provided as *Open Data* in regular intervals.

3. MBB MEASUREMENTS

MONROE platform is designed to fulfill the expectations of different stakeholders by supporting a variety of MBB use-cases. However, a platform would be of no use if experimenters were not provided with a powerful choice of MBB parameters to monitor. Therefore, in what follows, we first present the methodology to identify appropriate MBB parameters and Key Performance Indicators (KPIs) considering different stakeholders. Those parameters are made accessible through the platform in order to build the relevant statistics for different use-cases. Afterwards, the section continues with a brief illustration of a set of representative MBB use-cases that are supported by the MONROE platform.

3.1 Identifying key MBB Parameters

Different use-cases require different measurements, involving a subset of potentially relevant MBB parameters that could be monitored via the MONROE platform. Indeed, different project stakeholders might require to look into different parameters within the data collected in the very same experiment, e.g., depending on whether the goal of the stakeholder is to assess coverage or compare QoE levels. Therefore, the MONROE platform has to be able to harvest a variety of operational MBB parameters and allow to flexibly combine such measurements into relevant KPIs.

Moreover, to measure the network in a reliable and fair way, it is crucial to identify the metrics that accurately capture the performance and the conditions under which these parameters should be measured. Again, the requirements on the metrics to support with the MONROE platform might be different for different stakeholders. For example, on the one hand, regulators need connectivity, coverage and speed information collected from a third-party, independent platform to monitor how operators fulfill their obligations, and as a baseline for designing regulatory policies. On the other hand, operators are interested in time series reporting operational connectivity data, to identify instability and anomalies. Furthermore, application developers need to cross-check QoS parameters against the behavior of the underlying network, to design robust services and protocols. From the above considerations, it is clear that the collection of data cannot be limited to transmission- and packet-level statistics, but there is an urgent need for rich meta-data to be associated to the measurements.

So far, there are only limited studies in the literature that focus on identifying relevant parameters to monitor [9]. Therefore, one of the main objectives and unique features of MONROE consists in its ability to experimentally verify measurement methodologies in order to accurately reflect the performance and reliability of MBB networks from the perspective of different stakeholders.

MONROE platform enables measurements with the right performance and reliability parameters under realistic traffic patterns. By doing so, the MONROE platform can accurately identify KPIs and then allow experimenters to measure and experiment with them as realistically as possible. Moreover, by providing these measurement results as Open Data in public repositories such as the Zenodo repository provided by the OpenAIRE[3] project, MONROE also enables users to analyze and extract value from these results.

3.2 Potential Use-cases

In the following, we give a few relevant examples of use-cases, spanning from service and protocol assessment to the evaluation of middleboxes' impact, to generic yet very powerful knowledge discovery methods.

3.2.1 Service-oriented Measurements

A first dimension to explore in MONROE comes from the great interest in understanding how users perceive individual services and applications (e.g., video/audio streaming, gaming, conferencing, etc.) over different terminals (e.g., mobile phones, tablets, and computers). This explains the recent proliferation of user-centric measurement tools like Netalyzr [4] to complement available network-centric measurements. Indeed, service-level information is of great importance to operators and service providers for them to understand the key factors that affect user experience. MONROE enables experiments of essential services and applications, including video streaming, web browsing, VoIP, and file transfer services.

3.2.2 Protocol Assessment

A second dimension to explore in MONROE consists in the assessment of existing and new protocols in MBBs on a scale that was previously not possible. The large availability of experimental resources in MONROE is indeed well suited to assess networked applications under a wide range of network conditions, while still giving experimenters strong control of the testing environment. Furthermore, the multi-homing aspect of

[3]https://www.openaire.eu/

MONROE measurement nodes makes it ideal for experimenting with protocols that exploit multiple connections opportunistically, e.g., in parallel or by picking the one with the best available service to increase robustness and performance, or to achieve the best cost-performance ratio. An example to this is the Horizon 2020 project NEAT[4] that is planning to use MONROE to evaluate their software and API for optimized transport protocol and network selection. Other examples of such protocols and services include, but are not limited to, Multipath TCP, Device-to-Device for offloading or public safety applications, portable video streaming services or e-health services.

3.2.3 Middlebox Impact

Another significant use-case for MONROE is related to the use of middleboxes. These can range from address and port translators (NATs) to security devices to performance-enhancing TCP proxies. Middleboxes are known to introduce a series of issues and hinder the evolution of protocols such as TCP; therefore, measuring and understanding their behavior is essential. Since middleboxes of different types are ubiquitous in MBB networks, a platform such as MONROE offers an excellent vantage point from which to observe and characterize middlebox operation in real-world deployments.

3.2.4 Knowledge Discovery

Beyond mere service and protocol assessment, MONROE offers the possibility to develop mechanisms to augment network performance by learning from the measurements. This use-case involves post-processing of data, to deepen the understanding of network behaviors. The goal is to identify causalities and correlation of different parameters that can individually or collectively affect the performance and reliability of the network. In order to identify unexpected data patterns that deserve attention, one should go beyond data-mining and correlation approaches, and rather use knowledge description techniques, such as the Kolmogorov complexity method [6] or the minimum description length theory [3]. Such approaches are instrumental for different stakeholders including operators, vendors, developers and service providers. Therefore, we envision MONROE to have a significant impact on different sectors of industry through these knowledge discovery approaches, while helping to improve the performance of their products leading to a better user experience for the end users.

4. CONCLUSIONS

MONROE's ambition is to provide a flexible, open and industry-grade platform for all its stakeholders with different interests and needs, hence paving the way to various new and better services and protocols. For example, results from MONROE can allow operators with more accurate radio resource and infrastructure planning, more cost-efficient investments, and better network utilization. Operators will also be able to explore differentiated and specialized services, their requirements and impact on applications. Application developers for mobile devices can use the platform to test various applications and services over MBB. With better knowledge about MBB and the ability to test services, MONROE will contribute to service providers innovating more and realizing these innovative services. Internet of Things and smart city services will lead in this direction as more vertical specific applications and services will be developed along with the evolution towards 5G. Due to multihomed support, innovations regarding network selection, handover and aggregation can be developed to make applications more robust with increased quality; for this, multipath TCP and Device-to-Device communications are instrumental. These are a few examples of the opportunities in MBB field that requires extensive research efforts from both industry and academia, and MONROE platform with its unique features is the key enabler to achieve them.

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