Measuring and assessing mobile broadband networks with MONROE

Measuring and Assessing Mobile Broadband Networks with MONROE

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***Abstract*—Mobile broadband (MBB) networks underpin numerous vital operations of the society and are arguably becoming the most important piece of the communications infrastructure. In this demo paper, our goal is to showcase the potential of a novel multi-homed MBB platform for measuring, monitoring and assessing the performance of MBB services in an objective manner. Our platform, MONROE, is composed of hundreds of nodes scattered over four European countries and a backend system that collects the measurement results. Through a user-friendly web client, the experimenters can schedule and deploy their experiments. The platform further embeds traffic analysis tools for real-time traffic flow analysis and a powerful visualization tool.**

I. Introduction

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 4G and 4G+ technologies. In 2014, the number of mobile devices grew to a total of 7.4 billion, exceeding the world's population [1]. Consequently, mobile data traffic grew 69 % in 2014 and is expected to grow almost tenfold by 2019 [1]. Given the importance of the MBB market, it is essential to monitor MBB networks and assess their performance and reliability.

Objective information on MBB behavior is crucial not only for mobile users, but also for regulators, policy makers, and operators. In the USA, FCC has launched the Measuring Broadband America initiative since 2013 [2], to assess the quality experienced by end users thorough end-to-end measurements for fixed broadband networks. Other systematic approaches to performing measurements of MBB performance are adopted by operators and independent agencies on small scales (e.g., by means of drive-by tests) [3]. In addition, a number of applications have sprout to run performance tests by mobile end users, e.g., by visiting a website like the one of OOKLA Speedtest[1] or by running a special measurement application [4]. The above mentioned approaches lack either scalability or repeatability of measurements, and there are no guarantees on the availability and the accuracy of the metadata collected (e.g., with location info, type of user equipment, type of subscription of the users), which is fundamental to correctly contextualize the measurements.

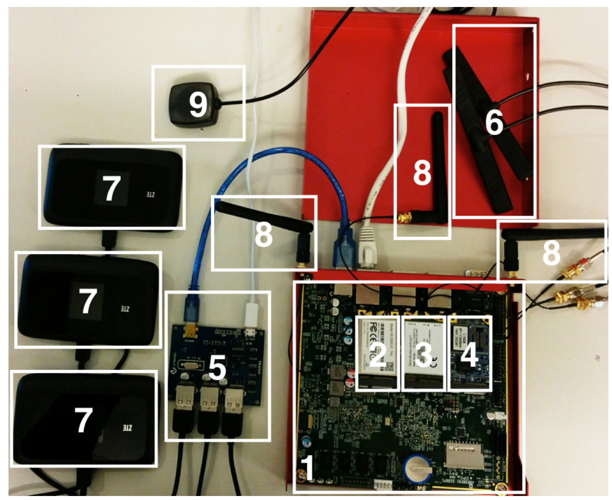

Fig. 1: MONROE measurement node.

In contrast, in the frame of the MONROE project,[2] we have developed a unique platform for independent, repeatable, multi-homed, large-scale measurements and experiments in operational MBB networks. 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.

In this interactive demo, our goal is to showcase the potential of the MONROE platform by allowing real-time user-defined measurements together with data analysis on a few selected nodes available at the demo booth and with many more

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[1] http://www.speedtest.net/

[2] https://www.monroe-project.eu/

remote nodes deployed across Europe. More specifically, in our live demo, first we will illustrate how to deploy experiments through a user-friendly web graphical interface that remotely controls hundreds of nodes scattered over four European countries. Second, we will demonstrate how to carry out data analysis using the passive data monitoring tool `Tstat` and MONROE's visualization tool. Possible experiments range from simple and continuous latency measurements, to more complex analysis of real-time flows combined with metadata collection.

II. The Measurement Platform

In the frame of the H2020 European project MONROE, we have designed and build a multi-homed MBB platform that supports 3 cellular network connections and embeds GPS and WiFi interfaces. The platform consists of a few hundred MONROE nodes and a software framework that is responsible for the orchestration of measurements and for the collection, analysis, visualization and sharing of measurements.

In Figure 1, we illustrate all main hardware blocks of the MONROE node. It includes: (1) an APU1D4[3] mini motherboard, (2) an 802.11ac/b/g/n Dual-Band mPCIe module, (3) an LTE mPCIe modem, (4) SSD M-SATA storage, (5) an externally powered USB hub, (6) LTE antennas, (7) 3 external USB modems connected to the hub, (8) WiFi antennas, and (9) a GPS antenna.

MONROE framework is illustrated in Figure 2 and is composed of six main parts:

i. *User access and scheduling system:* Measurements are handled by a scheduling system for which we provide a user-friendly interface through an AngularJS-based web portal. Moreover, since MONROE is federated with the Fed4FIRE initiative of the European Commission[4] in order to build a large-scale, distributed and heterogeneous platform, user access follows the Fed4FIRE specifications in terms of authentication and provisioning of resources.

ii. *Management and maintenance system:* The operations team uses this system to manage and maintain the MONROE testbed. It includes an inventory that keeps track of node status, connection states and location of nodes.

iii. *Node modules:* The software on the measurement node includes core components (watchdog, routing, network monitor, etc.) and a set of Linux containers,[5] in which experiments are handled and controlled in isolation. Specifically, one container is devoted to continuous background measurements (e.g., ping to predefined servers), another container handles periodic bandwidth-intensive measurements and a third container collects metadata from the node, MiFi modems and GPS. A fourth container has been implemented to import a traffic analyzer developed in the mPlane project, namely `Tstat`, which will be described in Section III. Using the container technology is particularly convenient because it allows agile reconfiguration and control of different components. Moreover, other containers can be implemented and deployed according to the need of the experimenters.

iv. *Remote repositories and data importer:* The framework also includes remote repositories to collect results after each experiment, remote "measurement responders" toward which active tests can be run and tools to filter and import the data to a non-relational database.

v. *Database:* The Cassandra database follows an experiment oriented design, where the experiment will play the central role, instead of the node. There will be two collections of tables, one for experiment measurements, and another one for metadata. Each experiment will have its own experiment measurements table (or set of tables).

vi. *Visualization:* A graphical representation of the MONROE platform in terms of deployment of the nodes, status of each device as well as the results of the selected experiments is provided through a near real-time visualization and monitoring tool.

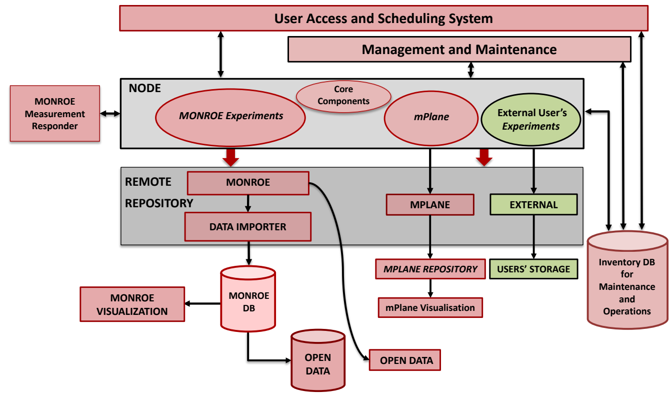

Fig. 2: Building Blocks of MONROE System.

Notably, the above-described framework not only allows to monitor and analyze the behavior of network connections in real-time, but also to store measurement data jointly with metadata in the form of open data for offline analysis.

III. Analysis and Visualization

The MONROE platform enables us to measure and analyze the behavior of MBB networks. Specifically, in the demo, we will show how to collect active traffic measurements from multiple MBB networks using both standard/well-known tools and project-crafted tools (e.g., ping, paris-traceroute and proprietary versions of such tools). We will further show how to use the passive traffic measurements tools, such as `Tstat`,[6] to analyze the traffic generated. `Tstat` will be run as a passive probe of mPlane [5] in a container on the MONROE nodes and the results will be collected in mPlane repositories for further analysis.

`Tstat` is a powerful monitoring tool that rebuilds TCP flows reporting more than 100 flow descriptors (e.g., client and server IP and port, RTT, number of retransmissions) with

[3] http://www.pcengines.ch/apu1d4.htm
[4] http://www.fed4fire.eu/
[5] http://www.docker.com
[6] http://tstat.polito.it/

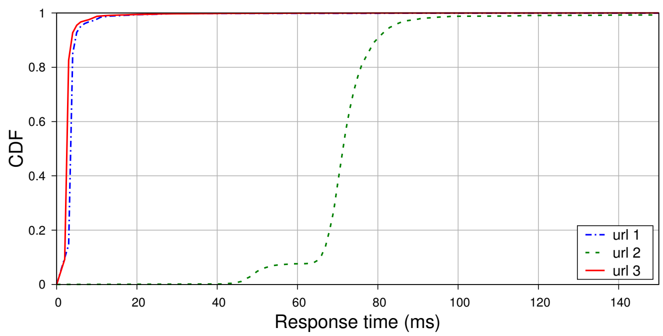

Fig. 3: `Tstat`: HTTP request-response time for a service.

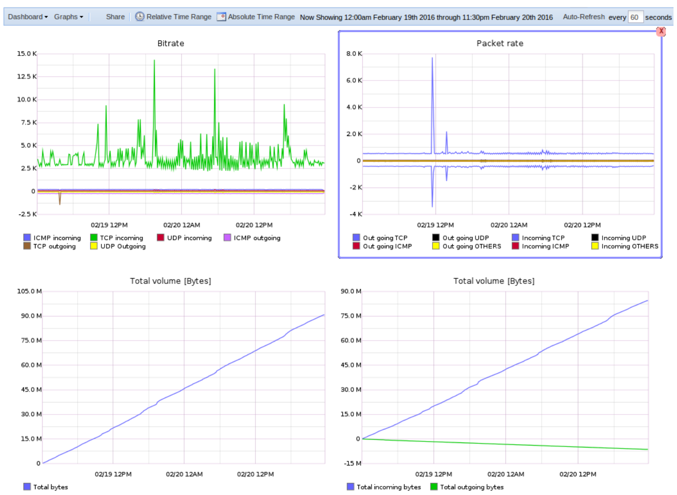

Fig. 4: Graphite dashboard with `Tstat` outputs showing packet rate for different flows at one node.

more than a thousand metrics. To give an idea of `Tstat` capabilities, Figure 3 depicts the HTTP request-response delay computed by `Tstat` for a test web page. Experimenters can use Graphite[7] to easily navigate through the logs and store a dashboard showing the relevant data within an adjustable time window (Figure 4). Demo attendees will be allowed to create their own dashboards using Graphite.

Moreover, data and metadata stored in the database can be visualized using MONROE's visualization tool that integrates both active and passive measurements into a user-friendly web interface. Such visualization tool shows the time-based performance measurements as line plots, or aggregated values as gauge or pie charts. At the same time, the visualization tool provides device tracking through the GPS information exported by each node and summarizes the metadata in form of regular tables with indexed columns. Figure 5 shows RTT and packet-loss graphs for a specific cellular connection in a remote testing node produced by our visualization tool. Demo attendees will be given the opportunity to browse the network of deployed MONROE nodes and pick specific nodes and connections for real-time visualization of connectivity and coverage statistics.

Finally, MONROE provides a flexible yet powerful Experiment-as-a-Service (EaaS) platform that allows external experimenters to create, deploy and execute their own containers in our nodes. In addition to the networking resources of the node (subject to a quota), each experiment has access to all the metadata information collected by our probes that may be useful to create correlations. The experiment results can later be easily retrieved from the repositories for further analysis.

[7]http://graphite.readthedocs.org/en/latest/index.html

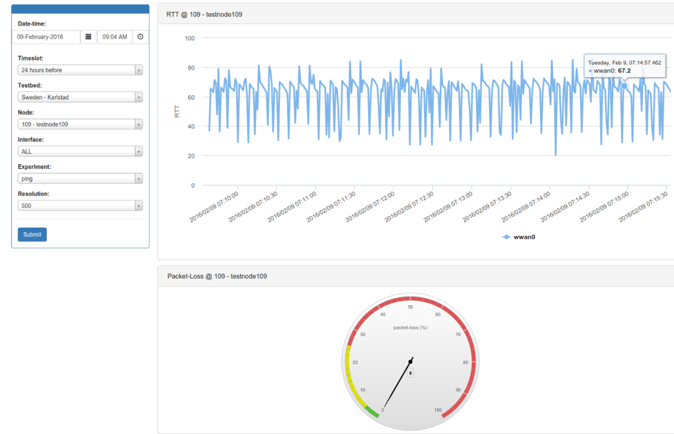

Fig. 5: Sample interactive charts generated by the MONROE visualization tool.

IV. Conclusions

This demo presents how to use the MONROE platform for the measurement and assessment of MBB networks. During the demo, we will first deploy active measurements on the deployed MONROE nodes. The focus of the demo, however, is to illustrate how to analyze and visualize the results of the measurements using `Tstat` and MONROE's visualization tool. The demo is interactive and allows to select and visualize connection and coverage statistics of MBB networks in 4 European countries in near real-time using MONROE's visualization tool. Furthermore, the demo illustrates how the traffic flows can be analyzed offline using `Tstat` and Graphite. Therefore, our platform and measurement framework offers all the components needed to deploy controllable and repeatable experiments on MBB networks, while enabling efficient and versatile data analysis.

References

[1] *Cisco visual networking index: Global mobile data traffic forecast update, 2014 - 2019*, Cisco Systems, Inc., February 2015.

[2] FCC, "2013 Measuring Broadband America February Report," FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, Tech. Rep., 2013.

[3] Tektronix, "Reduce Drive Test Costs and Increase Effectiveness of 3G Network Optimization," Tektronix Communications, Tech. Rep., 2009.

[4] C. Kreibich, N. Weaver, B. Nechaev, and V. Paxson, "Netalyzr: illuminating the edge network," in *Proceedings of the 10th ACM SIGCOMM conference on Internet measurement*. ACM, 2010, pp. 246–259.

[5] P. Calyam, C. Dovrolis, L. Jörgenson, R. Kettimuthu, B. Tierney, and J. Zurawski, "Monitoring and troubleshooting multi-domain networks using measurement federations: Part 2 [guest editorial]," *IEEE Communications Magazine*, vol. 52, no. 5, pp. 146–147, May 2014.