Poster: Decentralized Framework for Measuring End-to-End Performance in 5G Networks

Niladri Mondal*, Mario Niggemeyer*, Simon Welzel* and Florian Klingler*
*Dept. of Computer Science, TU Ilmenau, Germany
{mondal, niggemeyer, welzel, klingler}@wnc-labs.org

***Abstract*—5G communication networks have shown to be a promising technology for novel application domains in the context of connected mobility, industrial networks, as well as in the aviation domain. To evaluate the impact of the networking characteristics on the application performance, the state-of-the-art currently relies on simulation-based performance evaluation or real-world field tests where many approaches focus only on individual aspects of the 5G network. However, to the best of our knowledge, a system to measure the overall networking characteristics of private 5G campus networks to gather a holistic and reproducible view of the network is still missing. In this paper we introduce a distributed and scalable framework to measure the performance of 5G campus networks in a spatio-temporal domain. A first feasibility study indicates that our system enables practical and easy-to-use field tests for 5G systems as being used in the vehicular networking domain for teleoperated driving.**

I. Introduction and Related Work

Latest developments in 3GPP standards led to 5G cellular technology being used in different application domains such as vehicular communication, industrial automation, etc. These applications have a high dependency on the network characteristics such as latency and data rate, which can be defined by individual Quality-of-Service (QoS) profiles of the network. The architecture of 5G networks allows multiplexing on the same physical network infrastructure through network slicing allowing the same 5G network to handle multiple patterns of data traffic at the same time. Many of those envisioned application domains for 5G networks, e.g., in the context of connected vehicles, industrial automation, and aviation, need detailed testing and validation of networking protocols throughout their development.

Current state-of-the-art for performance evaluation of such applications is done by simulation studies [1] or employing field tests with prototypes. One of the main drawbacks for simulation studies is that the employed models often are not suitable to represent real-life scenarios, whereas field tests often lack reproducibility due to a slightly changed environment among different repetitions.

In order to achieve the goal of reproducible testing of novel application domains in the context of 5G and beyond networks, a framework to quantify the network characteristics in a scientific and reproducible manner is necessary. In that context, recent works have investigated those challenges: He et al. [2] present a design of a distributed test framework specifically for 5G networks. Their testing framework employs Remote Procedure Calls (RPC) with a client-server architecture to evaluate the network elements.

In order to scale such a system to larger number of independent services, Chai et al. [3] propose to use a distributed architecture with centralized control for services. Their approach specifically addresses testing of individual components of a 5G network, e.g., their interfaces, but without addressing end-to-end performance of 5G. Further, in [4] a distributed test framework was proposed for testing integrated modular avionics where the measurement server endpoint and the centralised control module reside on the same system. The entire framework is being executed on a single entity, making large scale concurrent tests of performance in multi-service based networks difficult to nearly impossible.

To summarize, current approaches of simulation and field tests for evaluating the performance of 5G networks have certain limitations to quantify the performance in a reproducible manner, e.g., being bound to computational efforts for simulation [1], or focusing only on Over-the-Air measurement challenges stressing on specific Electromagnetic Compatibility (EMC) issues like interference [5].

Our proposed architecture utilizes a GNU/Linux system and open-source tools to be portable across a large set of different platforms. Based on our concept to use an *orchestrator*, the proposed framework allows to measure the networking characteristics including data rate, latency and other important metrics of a 5G network in a practical manner. The system takes advantage of a distributed approach which enables conducting multiple concurrent measurements to ensure scalability tailored to the demands of specific application domains. From the context of vehicular networks, our system allows to quantify the performance of 5G systems which forms an important building block for applications like teleoperated driving.

II. Measurement Framework Architecture

In Figure 1 we outline the architecture of our system. We are utilizing a client-server architecture performing end-to-end measurements which is coordinated by an *orchestrator*. As the measurement client is a mobile device and can be moved to strategically relevant locations, our system allows us to collect spatio-temporal samples of measurements and annotate data with externally acquired location information.

A. Orchestrator

The orchestrator is the core entity that communicates and controls one or multiple measurement clients as well as the same number of endpoint servers. It stores the measurement

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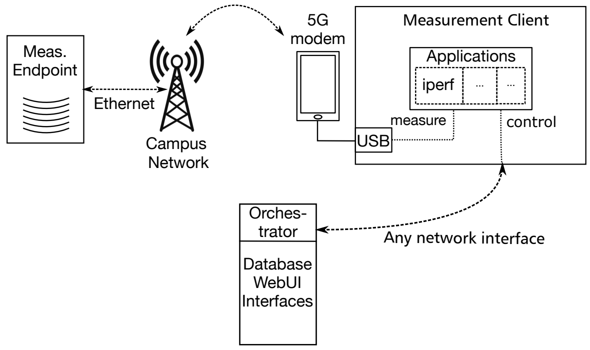

Figure 1. System architecture representing the *Orchestrator*, *Measurement Client* and *Measurement Endpoint* with the 5G Campus Network under test.

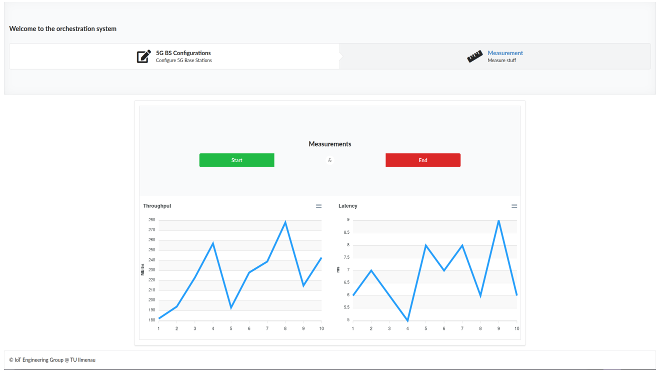

Figure 2. The dashboard view while measuring a the performance of 5G Campus Network.

data, which is collected from the test network, persistently in a SQL-based database. To avoid influences of networking overhead of control connections, we use a separate communication technology among all entities for coordination, called Out-of-Band (OOB) communication. This communication takes place through a different network interface than the one being tested, e.g., either WLAN or a different (and non-interfering) 5G network. Finally, the orchestrator hosts a web user interface that serves as a dashboard for the entire measurement framework.

This dashboard employs an interface to start and stop the network measurements and the measurement results are visualized on it.

B. Measurement Client

The measurement client gets instructed by the orchestrator to start a connection to the allocated measurement endpoint to start evaluating the network performance. To quantify the data rate as well as the end-to-end latency of the communication, we are using widely accepted tools like *iperf*[1] and *sockperf*[2]. Moreover, our architecture allows to integrate further tools, e.g., to evaluate the Packet Delivery Ratio (PDR). To achieve scalability of the system, multiple measurement clients and the same number of measurement endpoints can be used simultaneously.

C. Measurement Endpoint

This entity serves as the counter-part of the measurement client and and is responsible as endpoint of *iperf* and *sockperf* servers. The measurement endpoint gets instructed by the measurement client to start the individual tools for measuring the performance.

III. Prototypical Implementation

To show the feasibility of our approach, we implemented the three entities (Orchestrator, Measurement Client, Measurement Endpoint) on several Raspberry Pis. For simplicity, we use the onboard WLAN modules of the devices for OOB communication among all entities. The measurement client is connected via a smartphone (using USB tethering) to the 5G network. Further, the measurement endpoint is connected via ethernet to the 5G Core network under test. To ensure correct routing of traffic among the 5G network elements and our OOB communication, we use GNU/Linux network namespaces to separate the two communication links. We show the effectiveness of our approach by measuring the data rate and latency of a private 5G Campus Network as shown on the dashboard in Figure 2. This dashboard comprises of two tabs designed for configuration purposes and initiating or terminating network measurements, respectively.

IV. Conclusion and Future Work

We presented and and implemented an architecture to evaluate the characteristics of 5G and beyond networks to quantify important aspects of communication performance including data rate and end-to-end latency. Our system persistently stores the measurement data in a database for future use, e.g., to allow network emulation, mimicking the original network without the necessity to perform measurements in-place.

V. Acknowledgement

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