MultiNext - Measuring Concurrent Multipath Transmissions in an Experimental Facility

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I. Introduction

A major feature of the Future Internet is the federation of resources, e.g. for forming application-specific routing slices. Currently this can be done by using overlay technologies. Network virtualization techniques, as investigated in the VINI project, further advances this concept to allow the combination of partial resources on network nodes and links. While we do not yet have standard solutions for the general Internet, federation concepts are currently tested across testbeds in Europe, USA and Asia in order to combine testbed resources for experiments like FIRE and GENI. As network scientists we need such testbeds in order to validate theoretical results for large-scale highly distributed environments and under real network conditions. But since testbeds nowadays are typically customized to particular user groups and offer different capabilities some experiments require the federation of testbeds to profit from a broader set of characteristics and functions.

We here present the Project MultiNext that aims at validating a buffer model for concurrent multipath transmissions. For that we conducted experiments over multiple federated testbeds. Since there was not a single testbed that could offer all the capabilities we needed, we combined capabilities from different experimental facilities (G-Lab, PlanetLab Europe, and VINI). While a measurement instrumentation of testbeds is essential to support operation, federation and experimenters, we additionally had particular demands for high precision measurements in our experiment. Therefore the contribution of the MultiNext project is threefold: a) detailing the conducted experiments (setup, results, findings) b) providing our experience with the usability of federated testbeds and c) illustrating the use of advanced measurement technologies in experimental facilities.

We believe that experiments of the MultiNext project provide a good example use case for the future Internet itself because we assume that the Internet will continue to consist of multiple different infrastructures that have to be combined in application specific overlays or routing slices, very much like the experimental facilities we used in this experiment. We also assume that the growing demands will push towards a much better measurement instrumentation of the future Internet. The tools used in our experiment provide a starting point for this.

II. Project Description and Link to the EuroNF - Vision

The main purpose of the MultiNext project is the validation of a model for buffer occupancy in a multipath transport setup, as introduced in [1], [2]. In this work, a re-sequencing buffer is used at the destination in order to cope with out-of-order arrivals which occur inevitably by concurrent transmissions over multiple paths. The model allows a computation of the occupancy of this buffer with regards to the path characteristics.

The proposed mechanisms is based on the concept of Transport Virtualization (TV), an alternative mode of Network Virtualization (NV) and Network Federation (NF). NV techniques allow the establishment of separated slices on top of a joint physical infrastructure (substrate) and thus enables the parallel and independent operation of multiple virtual networks. That way application-specific networks (e.g. for VoD, banking, gaming) offering their own virtual topology, naming, routing and resource management can be created. NF mechanisms aim at the composition of virtual networks administrated by different authorities, i.e. a combination of virtual links and virtual routers. Thus, these mechanisms enable the separation of network resources into building blocks and the recomposition of these blocks. For this reason, both techniques allow the creation of a new network fabric, as requested by the second update of the Euro-NF vision [3]. The achieved results of the MultiNext project enable the creation of performance models for resource combination techniques, in particular for resource pooling and network federation. Further, measurements within federated experimental facilities will enhance todays performance evaluation methodology. This is reflected in the EuroNF vision by the need for new methods for comparing and evaluating architectures.

III. Experiment Requirements, Setup and Results

In order to conduct the desired measurements the project has the following requirements concerning testbeds: a) the possibility to set up a routing overlay to emulate the multipath routing. b) a large distributed set of nodes in order to get a high diversity of different path delay values. This enables a verification of the model with an adequate amount of different configurations. c) advanced measurement methods for high precision and hop-by-hop one-way delay measurements.

Feature	G-Lab	PLE	PLC	VINI
Scope	Germany	Europe	World	Mainly US
Exclusive Reservation	Yes	No	No	No
Routing	with own tools	with own tools	with own tools	Yes
Bandwidth and QoS	with own tools	Planned	Planned	Yes (service)
Openness/Federation	No (tests planned)	Yes (SFA)	Yes (SFA)	Yes (SFA)
Tools/Packet Tracking	individually	Yes (service)	individually	individually
Clock Sync	NTP	NTP, some GPS	NTP	NTP

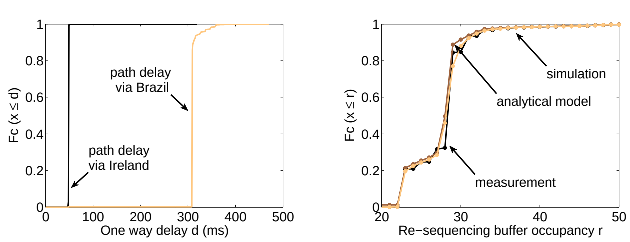
TABLE I
COMPARISON OF TESTBEDS

A. *Experimental Setup*

We investigated the capabilities of different testbeds in order to find a suitable testbed that fulfills the needs of our experiment. Table I describes the differences of PlanetLab Central (PLC), PlanetLab Europe (PLE), German Lab (G-Lab) and the VINI testbed. G-Lab allows exclusive reservation and installation of arbitrary software but is only distributed across Germany, has a limited access and currently provides no federation method. PLE, PLC and VINI can be federated by the Slice Federation Architecture (SFA), but only VINI provides a routing service. We therefore used manually configured overlay routing on application layer to combine PLE and G-Lab with VINI. PLE is the only network that additionally provides the advanced measurement tools that we require for our experiment. In order to verify results we used passive and active measurement tools. A discussion of the different experiments can be found in [4].

B. *Results of the Experiment*

This subsection presents the results of one experiment conducted in PLE with support of the ETOMIC measurement system. A more comprehensive presentation of the results can be found in [5]. The experiment investigates concurrent transmissions via two different paths. The measured one-way delays and the resulting re-sequencing buffer occupancy are depicted in Figure 1. The values obtained via the performed measurements and the theoretical simulative and analytical models are depicted in Figure 1(b). It can be seen, that the gap between the models and the results obtained by measurements is very small, i.e. the prediction of our models is very accurate for the investigated experiment.



(a) Oneway delay measurements (b) Re-sequencing bufffer occupancy

Fig. 1. Measured one way delays and resulting re-sequencing buffer occupancy for measurements, simulation and analysis

IV. SCIENTIFIC OUTCOME AND IMPACT ON OTHER INITIATIVES

The scientific outcome of the project is twofold. First the project successfully discussed and validated one of the first performance models for concurrent use of virtual resources and network federation. Second the consortium demonstrated the value of the federation of experimental facilities and derived from areal Future Internet experiments the requirements for the federation of these facilities as well as the use of several sophisticated measurement methods provided by the testbeds. Concerning the impact on other Future Initiatives the project achieved a high visibility within the Future Internet Assembly (FIA), the FIRE project Onelab and the German project G-Lab. The project submitted a book chapter to the FIA book 2011 indicating the importance of the investigations and results of project. During the course of the project it became one of the OneLab use cases. This is reflected e.g. by an article in the Fire Brochure [6]. Further, the project and its results were presented within G-Lab meetings and within the G-Lab Special Interest Group on multipath transport.

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