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*Nature: R-report, P-prototype, D-demonstrator, O-other
**Dissemination: PU-public, PP-restricted to programme, RE- restricted to a group, CO-confidential

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[1] Leader for these specific joint developments and experiments

CONTENTS

ABSTRACT

Concurrent multipath transport layer mechanisms have gained recently increasing interest in research and standardization because of the potential for bandwidth aggregation, load balancing and increased reliability. Multihomed end devices may benefit from IP-based multipath protocols like Multipath TCP or Concurrent Multipath Transmission via SCTP or on lower layers like proposed by the concept of Transport Virtualization.

However, the application and the performance of current multipath transmission and transport virtualization is complex and can't easily be characterized. In particular the selection of paths is non-intuitive. Prior work discusses, for instance, the theoretical impact of delay diversity of pooled paths on the concurrent data transmissions. The Multi-Next project achieved the validation of a theoretical model with measurements conducted in interconnected, i.e. federated, experimental facilities. As a result, the Multi-Next project provides not only a simple experimental validation of an analytical performance model, as to the knowledge of the participants, it provided one the first experimentally validated performance model for the federation of pooled transport resources.

1 INTRODUCTION

Multipath transmission techniques and protocols on transport layer and beyond have gained increasing interest in standardization and research. This trend is mostly driven by multihomed end user devices like smartphones, tablets or netbooks. The most popular protocols currently under development are Multipath-TCP (MPTCP), Concurrent Multipath Transmission-SCTP (CMT-SCTP) and Transport Virtualization (TV).The main benefits of these state-of-the-art transport protocols are their potential for bandwidth aggregation, increased reliability, load balancing, and joint congestion control. These concepts logically build a new, pooled transport resource out of several transport resources, typically with different resource characteristics like capacity or transmission delay. However, the impact of the dissimilarity of the different used resources on the pooled transport resource is a fundamental problem and motivates the design of appropriate functions for selecting the best set of available resources. Furthermore, different scheduling mechanisms on the utilized paths might influence the system performance.

These problems are typically addressed with analytical or simulative models. For the case of Transport Virtualization, such models were introduced enabling the analysis of packet re-ordering that occurs due to different path delays. Although first results on the impact of different varying path delays on the re-ordering probability have been attained, these theoretical models still lack validation and their limitations are still unknown.

Thus, the aim of Multi-Next is the validation of the theoretical models of Transport Virtualization with measurements conducted in experimental facilities.

FRAUNHOFER FOKUS (Fraunhofer, Partner 03)
The Competence Center Network Research (NET) under the direction of Dr.-Ing Tanja Zseby has long standing expertise in the development and operation of IP measurement technologies. Research topics in this area are cost-efficient active and passive measurements in IPv4 and IPv6 networks, statistical sampling methods, and the distributed control and adaptation of measurements for various applications. The group has developed own

measurement software including one of the first implementations of the future IP Flow Information Export protocol (IPFIX), has organized interoperability events for measurement related protocols and is active in IETF (IPFIX, PSAMP) and ETSI standardization in the field of network measurements. The group is working on measurement solutions for experimental facilities within the project Onelab2 where it leads the work package on packet tracking.

Chair of Future Communication, University of Vienna (UNI WIEN, partner 04)
Kurt Tutschku and Albert Rafetseder are both with the Chair of Future Communication at the University of Vienna. Kurt Tutschku holds the Chair of "Future Communication" (endowed by the Telekom Austria) at the University of Vienna. He is actively involved in multiple Future Internet projects such as GENI/Gpeni (USA) and AKARI (J). Albert Rafetseder is a co-worker and a PhD student at the Chair of "Future Communication" at the University of Vienna. The research interests of Kurt Tutschku and Albert Rafetseder include management, application and performance issues of the Future Internet.

University of Würzburg (UWUERZ, partner 10)
Thomas Zinner and Dominik Klein are researchers at the chair of distributed systems at the University of Würzburg. Their current research interests are within the Future Internet area and focus on evaluating the performance of network and transport virtualization techniques. Preliminary work discusses the performance of concurrent multipath transfer based on network virtualization.

The Iby and Aladar Fleischman Faculty of Engineering, Tel Aviv University (TAU, external participant)
Yuval Shavitt is an Associate Professor at the School of Electrical Engineering at the University of Tel Aviv. His research interests include multipath routing and internet measurements. In 2004 he started the DIMES project for mapping the Internet infrastructure. This project has revolutionized the field of Internet measurement, and is the world largest Internet topology measurement project.

2 JOINT DEVELOPMENTS AND EXPERIMENTS

2.1 Jointly performed integration tasks

Nr.	Task description	Partners involved
1	Setup of measurement infrastructure within the experimental facilities	TAU Fraunhofer UNI WIEN UWUERZ
2	Performing measurements of multipath transport within the experimental facilities and evaluation of the results	TAU Fraunhofer UNI WIEN UWUERZ
3	Analytical modelling and comparison of measurements, analysis and simulation	UNI WIEN UWUERZ

During the setup of the measurement infrastructure the partners cooperated very close. Active and passive measurement concepts were introduced and discussed, and the appropriate ones used for the measurements.

The measurements were performed mostly by UWUERZ with help from UNI WIEN and Fraunhofer. Nevertheless, the evaluation of the data was performed as joint activity.

The modelling of the mechanisms was performed by UWUERZ and UNI WIEN.

2.2 Modes of cooperation

The kick-off meeting of the project was co-located with Euro-NF NGI2010 in Paris. Regular phone conferences among all project partners are held roughly every four weeks and documented at http://www3.informatik.uni-wuerzburg.de/research/projects/multinext/. Beside that the partners kept close contact via skype and phone calls. A shared web repository is used for exchanging documents and documenting the progress.

Furthermore, the partners attend meetings of other projects (e.g. Fraunhofer and UWUERZ at GLAB Status Meeting) or other Euro-NF events (UWUERZ, Fraunhofer, UNI WIEN at Euroview) and use the time to discuss about Multi-Next also.

2.3 Results

During the course of the project concurrent multipath transmissions as implemented by Transport Virtualization were investigated. For that we focused on the impact of dissimilar paths on the multipath transmissions and developed theoretical models using analysis [1] and simulations [2]. In order to link those theoretical findings with real world behaviour we developed an appropriate measurement methodology using active or passive measurement infrastructure. Further, we conducted measurements over several federated experimental facilities combining their capabilities since one single facility did not fulfil our requirements [3]. Based on this we measured the relevant input and output parameters of our simulative and analytical models and validated them [4].

2.4 Joint publications

Nr.	Reference	Type	Status*			Partners involved
			P	A	S	
[1]	Using Concurrent Multipath Transmission for Transport Virtualization: Analyzing Path Selection. in Proceedings of the 22nd International Teletraffic Congress (ITC), Amsterdam, Netherlands, September 2010 http://www3.informatik.uni-wuerzburg.de/papers/conf_379.pdf	Proceedings	X			UWUERZ UNI WIEN
[2]	Performance Evaluation of Packet Re-ordering on Concurrent Multipath Transmissions for Transport Virtualization. in IJCNDS Special Issue on: Network Virtualization - Concepts and Performance Aspects, 2011. http://www3.informatik.uni-wuerzburg.de/papers/jour_74.pdf	Article		X		UWUERZ UNI WIEN
[3]	Multipath Routing Slice Experiments in Federated Testbeds FIA Book 2011 "Future Internet: Achievements and Promising Technology"	Book chapter		X		UWUERZ UNI WIEN Fraunhofer TAU

[4]	Performance of Concurrent Multipath Transmissions - Measurements and Model Validation to be published "7th Euro-NF Conference on Next Generation Internet (NGI 2011)", Kaiserslautern, Germany	Proceedings		X		UWUERZ UNI WIEN Fraunhofer TAU
		Total numbers:	1	3	0	

* P = published/presented; A = accepted/in press; S = submitted/under revision

2.5 Knowledge map entries

All entries under:

Future Networks and Service Architectures
↳ Overlays for network control and support of evolved services infrastructure
↳ Multinext: Measuring Concurrent Multipath Transmissions in Experimental Facilities

Nr.	Name
1	Performance Evaluation of Packet Re-ordering on Concurrent Multipath Transmissions for Transport Virtualization http://www.euro-nf.net/engidoc/G8RMBWDZ/G8RMBWDZ.pdf
2	Using Concurrent Multipath Transmission for Transport Virtualization: Analyzing Path Selection http://www.euro-nf.net/engidoc/BONAJ9GI/BONAJ9GI.pdf
3	Multipath Routing Slice Experiments in Federated Testbeds http://www.euro-nf.net/engidoc/2RREBF57/2RREBF57.pdf
4	Performance of Concurrent Multipath Transmissions - Measurements and Model Validation http://www.euro-nf.net/engidoc/5EEEYOUH/5EEEYOUH.pdf

2.6 Further dissemination activities

Nr.	Dissemination activity	Partners involved
1	One page article “Concurrent Multipath Transmissions”, Fire Brochure “Fire for Future Internet Success” http://www.ict-fire.eu/home/publications.html	UWUERZ UNI WIEN Fraunhofer TAU
2	Invited Talk at the First Future Internet Cluster Workshop in Euro-NF deliverable D.SEA.7.2.1	UNI WIEN
3	Talk at the 3rd EU-Japan Symposium on the "Future Internet and Next Generation Networks", Tampere, Finland, October 20th, 2010 http://www3.informatik.uni-wuerzburg.de/research/projects/multinext/Tutschku_EU-Japan_Oct10v2.pdf	UNI WIEN

2.7 Presentations

Detailed information on presentations, publications and further dissemination activities can be found at the project web page:
http://www3.informatik.uni-wuerzburg.de/research/projects/multinext/

Type	Number of presentations
Euro-NF IA events	0
Euro-NF JRA meetings	2
Euro-NF SEA events*	1[2]
Outside of Euro-NF	9
Total	12

* = including Ph.D. courses and summer schools

[2] The paper submission from the Multi-Next project has been accepted for publication at NGI2011. Thus, an additional presentation at an Euro-NF SEA event will be given.

3 STRATEGIC IMPACT

3.1 Quantum leaps

1) Multi-Next was the first project which performed future internet experiments across multiple testbeds. This was enabled through the federation of these testbeds.
2) Validation of the theoretical models for concurrent multipath transmission enhances the significance of these models and allows a broad investigation of the performance issues.

3.2 Spin-off project proposals beyond Euro-NF

Currently there is no spin-off project proposals submitted. However, the partners are currently discussing to form a follow-up consortium and to submit an substantial extension to FP7 call 8, which is the next open EU call for FI architectures.

3.3 Golden Eggs

1) The project successfully discussed and validated one of the first performance models for concurrent use of virtual resources and network federation.
2) The consortium demonstrated impressively the value of the federation of test facilities.
3) The consortium derived from FI experiment the requirements for the federation of test facilities.
4) The Multi-Next consortium submitted a FIA book chapter which got accepted showing the relevance of the discussed ideas.
5) During the course of the project Multi-Next became one of the OneLab use cases. This is reflected by an article in the Fire Brochure "Fire for Future Internet Success". Further, the Multi-Next architecture, measurements and results were presented in the keynote of Serge Fdida during the Baltic Conference on Future Internet Communications.

3.4 Recommendations

1) Performance models for network federation should be integral part in future research agendas or work package definitions.
2) Support follow-up project for Call 8
3) Deepen knowledge of usage of experimental facilities for future internet research.

4 FINANCIAL PART

4.1 Use of the budget per partner

Until April, 2011

Partner	Salaries	Mobility	Meetings	Presentations	Equipment	Consumables	Total
03	12.7 k€		0.3 k€				13.0 k€
04	8.6 k€		1.2 k€				9.8 k€
10	8.9 k€		1.1 k€				10.0 k€
TAU			2.5 k€				2.5 k€
Totals	29.3 k€	0	5.1 k€	0	0	0	34.4 k€