

Network Working Group
Internet-Draft
Intended status: Informational
Expires: September 20, 2016

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March 19, 2016

MPTCP Experiences in the NorNet Testbed
draft-dreibholz-mptcp-nornet-experience-02.txt

Abstract

This document collects some experiences of Multi-Path TCP (MPTCP) evaluations in the NorNet testbed.

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[1.](#) Introduction

[1.1.](#) Abbreviations

- o TCP: Transmission Control Protocol
- o MPTCP: Multi-Path TCP

[1.2.](#) Multi-Path TCP

The Multi-Path TCP (MPTCP) extension for the Transmission Control Protocol (TCP) has been defined in [\[3\]](#), [\[4\]](#), [\[1\]](#), [\[2\]](#), [\[5\]](#). There are also detailed introductions provided for example by [\[8\]](#), [\[9\]](#) as well as lots of further information material on [\[6\]](#). MPTCP is therefore not introduced in more detail here.

[1.3.](#) Scope

The scope of this document is to collect some experiences with the usage of MPTCP in the NorNet testbed, a large-scale Internet testbed for multi-homed systems.

2. Testbed Evaluation

2.1. The NorNet Testbed

The NorNet testbed (<https://www.nntb.no>) introduced in [11], [10] is a programmable testbed platform with focus on the evaluation of multi-homed systems. It consists of programmable nodes that are distributed all over Norway as well as further locations in other countries. NorNet is built and operated by the Simula Research Laboratory and financed by Forskningsraedet (the Research Council of Norway) through their INFRASTRUKTUR program (project number 208798/F50).

NorNet has two main components: NorNet Core and NorNet Edge. NorNet Core consists of currently 20 programmable sites (<https://www.nntb.no/pub/nor-net-configuration/NorNetCore-Sites.html>), most of them multi-homed to several network providers. Details can be found in [12], [14], [15] and [16]. NorNet Edge consists of several hundreds of smaller nodes connected to all mobile broadband providers in Norway (<http://robustennett.no/map>), details can be found in [13]. Together, these two components offer a unique platform for experimental networking research. NorNet is made available to the international networking research community.

Further details on NorNet can be found on the NorNet website [17].

2.2. Multi-Path TCP in NorNet

The NorNet nodes are Linux-based and therefore run the Linux MPTCP implementation by Universite catholique de Louvain-la-Neuve (see [18]). With support by all NorNet Core nodes (circa 100 nodes at currently 20 sites) and most NorNet Edge nodes (several hundreds), NorNet probably provides the world's largest MPTCP experimentation platform.

2.3. NetPerfMeter

NetPerfMeter [19], [7] is a network performance meter for the UDP, TCP, MPTCP, SCTP and DCCP transport protocols over IPv4 and IPv6. It simultaneously transmits bidirectional flows to an endpoint and measures the resulting flow bandwidths and QoS. The results are written as vector and scalar files. NetPerfMeter is provided in NorNet to allow for transport protocol comparisons and transport protocol performance evaluations.

3. Research Results and Work in Progress

So far, work has been done on evaluating MPTCP in the real-world Internet. The following list is a short overview of current research:

- o [20] examines the different properties of 3G paths (UMTS as well as CDMA2000) in NorNet Edge. These results provide an overview of the QoS characteristics that can be expected by multi-path transport protocols (and particularly by MPTCP) on different paths.
- o [21] analyzes the impact of buffer bloat on MPTCP connections over mobile broadband (2G, 3G) and WLAN paths. Furthermore, it proposes and evaluates Multi-Path Transport Bufferbloat Mitigation (MPT-BM), a bufferbloat mitigation algorithm to improve MPTCP performance in buffer-bloated wireless networks.
- o [22] examines the performance benefits of multi-path transport with MPTCP under heterogeneous wireless networks. It furthermore introduces and evaluates the Dynamic Relative Path Scoring (DRePaS) algorithm that optimizes the path management in such setups.
- o [23] examines the performance benefits of the state-of-the-art Linux MPTCP implementation in a large-scale NorNet setup, covering sites in multiple countries on different continents. It particularly also shortly introduces the NetPerfMeter measurement tool that is used to perform the measurements, and particularly its extension for MPTCP.
- o [24] examines how the IPv4/IPv6 identity duality can be utilized with MPTCP in order to improve performance even in case of only a single ISP connection.
- o [25] provides an introduction to the NetPerfMeter tool for MPTCP experiments.
- o [26] presents MPTCP's architecture and multi-path congestion control algorithm concepts. Then, it examines three test scenarios in the NorNet testbed, particularly highlighting the performance difference between using uncoupled and coupled congestion controls in multi-homed, real-world Internet setups.
- o [27] proposes a practical shared bottleneck detection (SBD) algorithm for MPTCP, namely MPTCP-SBD. Through extensive emulations, it is shown that MPTCP-SBD outperforms all currently deployed MPTCP coupled congestion controls by accurately detecting

bottlenecks resulting in throughput gains in the absence of shared bottlenecks, while remaining fair to TCP in shared bottlenecks scenarios.

4. Security Considerations

Security considerations on MPTCP are described in [3].

5. IANA Considerations

This document has no actions for IANA.

6. Acknowledgments

The authors would like to thank Hakim Adhari and Fu Fa for discussions and support.

7. References

7.1. Normative References

- [1] Raiciu, C., Handley, M., and D. Wischik, "Coupled Congestion Control for Multipath Transport Protocols", [RFC 6356](#), DOI 10.17487/RFC6356, October 2011, <<http://www.rfc-editor.org/info/rfc6356>>.
- [2] Ford, A., Raiciu, C., Handley, M., and O. Bonaventure, "TCP Extensions for Multipath Operation with Multiple Addresses", [RFC 6824](#), DOI 10.17487/RFC6824, January 2013, <<http://www.rfc-editor.org/info/rfc6824>>.

7.2. Informative References

- [3] Bagnulo, M., "Threat Analysis for TCP Extensions for Multipath Operation with Multiple Addresses", [RFC 6181](#), DOI 10.17487/RFC6181, March 2011, <<http://www.rfc-editor.org/info/rfc6181>>.
- [4] Ford, A., Raiciu, C., Handley, M., Barre, S., and J. Iyengar, "Architectural Guidelines for Multipath TCP Development", [RFC 6182](#), DOI 10.17487/RFC6182, March 2011, <<http://www.rfc-editor.org/info/rfc6182>>.
- [5] Scharf, M. and A. Ford, "Multipath TCP (MPTCP) Application Interface Considerations", [RFC 6897](#), DOI 10.17487/RFC6897, March 2013, <<http://www.rfc-editor.org/info/rfc6897>>.

- [6] Dreibholz, T., "Thomas Dreibholz's MPTCP Page",
Online: <http://www.iem.uni-due.de/~dreibh/mptcp/>, 2016,
<<http://www.iem.uni-due.de/~dreibh/mptcp/>>.
- [7] Dreibholz, T., "NetPerfMeter - A TCP/MPTCP/UDP/SCTP/DCCP
Network Performance Meter Tool", Online: <https://www.uni-due.de/~be0001/netperfmeter/>, 2016, <<https://www.uni-due.de/~be0001/netperfmeter/>>.
- [8] Becke, M., "Revisiting the IETF Multipath Extensions on
Transport Layer", November 2014,
<http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-37631/Thesis_online.pdf>.
- [9] Ruengeler, I., "SCTP - Evaluating, Improving and Extending
the Protocol for Broader Deployment", December 2009,
<<http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-23465/Diss.pdf>>.
- [10] Dreibholz, T., "The NorNet Testbed for Multi-Homed Systems
- Introduction and Status", Invited Talk at Princeton
University, Department of Computer Science, May 2014,
<<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2730.pdf>>.
- [11] Dreibholz, T., "NorNet at NICTA - An Introduction to the
NorNet Testbed", Invited Talk at National Information
Communications Technology Australia (NICTA), January 2016,
<<https://www.simula.no/sites/www.simula.no/files/publications/files/nicta2016-presentation.pdf>>.
- [12] Gran, E., Dreibholz, T., and A. Kvalbein, "NorNet Core - A
Multi-Homed Research Testbed", Computer Networks, Special
Issue on Future Internet Testbeds Volume 61, Pages 75-87,
ISSN 1389-1286, DOI 10.1016/j.bjp.2013.12.035, March 2014,
<<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2236.pdf>>.
- [13] Kvalbein, A., Baltrunas, D., Evensen, K., Xiang, J.,
Elmokashfi, A., and S. Ferlin, "The NorNet Edge Platform
for Mobile Broadband Measurements", Computer Networks,
Special Issue on Future Internet Testbeds Volume 61, Pages
88-101, ISSN 1389-1286, DOI 10.1016/j.bjp.2013.12.036,
March 2014,
<<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2434.pdf>>.

- [14] Dreibholz, T. and E. Gran, "Design and Implementation of the NorNet Core Research Testbed for Multi-Homed Systems", Proceedings of the 3rd International Workshop on Protocols and Applications with Multi-Homing Support (PAMS) Pages 1094-1100, ISBN 978-0-7695-4952-1, DOI 10.1109/WAINA.2013.71, March 2013, <<https://www.simula.no/sites/www.simula.no/files/publications/threfereedinproceedingsreference.2012-12-20.7643198512.pdf>>.
- [15] Dreibholz, T., "The NorNet Core Testbed - Introduction and Status in August 2014", Proceedings of the 2nd International NorNet Users Workshop (NNUW-2), August 2014, <<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2936.pdf>>.
- [16] Dreibholz, T., "An Experiment Tutorial for the NorNet Core Testbed", Proceedings of the 2nd International NorNet Users Workshop (NNUW-2), August 2014, <<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2938.pdf>>.
- [17] Dreibholz, T., "NorNet - A Real-World, Large-Scale Multi-Homing Testbed", Online: <https://www.nntb.no/>, 2016, <<https://www.nntb.no/>>.
- [18] Paasch, C. and S. Barre, "Multipath TCP implementation in the Linux kernel", Online: <http://www.multipath-tcp.org>, 2016, <<http://www.multipath-tcp.org>>.
- [19] Dreibholz, T., Becke, M., Adhari, H., and E. Rathgeb, "Evaluation of A New Multipath Congestion Control Scheme using the NetPerfMeter Tool-Chain", Proceedings of the 19th IEEE International Conference on Software, Telecommunications and Computer Networks (SoftCOM) Pages 1-6, ISBN 978-953-290-027-9, September 2011, <<https://www.wiwi.uni-due.de/fileadmin/fileupload/I-TDR/SCTP/Paper/SoftCOM2011.pdf>>.
- [20] Ferlin, S., Dreibholz, T., Alay, Oe., and A. Kvalbein, "Measuring the QoS Characteristics of Operational 3G Mobile Broadband Networks", Proceedings of the 4th International Workshop on Protocols and Applications with Multi-Homing Support (PAMS) Pages 753-758, ISBN 978-1-4799-2652-7, DOI 10.1109/WAINA.2014.123, May 2014, <<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2516.pdf>>.

- [21] Ferlin, S., Dreibholz, T., and Oe. Alay, "Tackling the Challenge of Bufferbloat in Multi-Path Transport over Heterogeneous Wireless Networks", Proceedings of the IEEE/ACM International Symposium on Quality of Service (IWQoS) Pages 123-128, ISBN 978-1-4799-4852-9, DOI 10.1109/IWQoS.2014.6914310, May 2014, <<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2722.pdf>>.
- [22] Ferlin, S., Dreibholz, T., and Oe. Alay, "Multi-Path Transport over Heterogeneous Wireless Networks: Does it really pay off?", Proceedings of the IEEE Global Communications Conference (GLOBECOM) Pages 5005-5011, ISBN 978-1-4799-3512-3, December 2014, <<https://www.simula.no/sites/www.simula.no/files/publications/Simula.simula.2884.pdf>>.
- [23] Dreibholz, T., Zhou, X., and F. Fa, "Multi-Path TCP in Real-World Setups - An Evaluation in the NorNet Core Testbed", 5th International Workshop on Protocols and Applications with Multi-Homing Support (PAMS), March 2015, <<https://www.simula.no/sites/www.simula.no/files/publications/files/pams2015-mptcp-web.pdf>>.
- [24] Livadariu, I., Ferlin, S., Alay, Oe., Dreibholz, T., Dhamdhere, A., and A. Elmokashfi, "Leveraging the IPv4/IPv6 Identity Duality by using Multi-Path Transport", Proceedings of the 18th IEEE Global Internet Symposium (GI), April 2015, <https://www.simula.no/sites/www.simula.no/files/publications/files/gis2015_0.pdf>.
- [25] Dreibholz, T., "NetPerfMeter: A Network Performance Metering Tool", Multipath TCP Blog, September 2015, <<http://blog.multipath-tcp.org/blog/html/2015/09/07/netperfmeter.html>>.
- [26] Fa, F., Zhou, X., Dreibholz, T., Wang, K., Zhou, F., and Q. Gan, "Performance Comparison of Congestion Control Strategies for Multi-Path TCP in the NorNet Testbed", Proceedings of the 4th IEEE/CIC International Conference on Communications in China (ICCC) Pages 607-612, ISBN 978-1-5090-0243-6, November 2015, <<https://www.simula.no/sites/www.simula.no/files/publications/files/fufa-mptcp-web.pdf>>.

- [27] Ferlin, S., Alay, O., Hayes, D., Dreibholz, T., and M. Welzl, "Revisiting Congestion Control for Multipath TCP with Shared Bottleneck Detection", Proceedings of the 35th IEEE International Conference on Computer Communications (INFOCOM), April 2016.

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