A Live Demonstration of HiPerConTracer 2.0

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***Abstract*—HiPerConTracer is an open source tool for large-scale, long-term, high-frequency Ping and Traceroute measurements. Using such measurements, it is possible to obtain information about latency in the network, as well as about the actual routing. This live demonstration provides an overview over the tool and its features, as well as an introduction of how to use it for performing measurements, storing the results, querying selected results, and post-processing them for visualisation.[1]**

Keywords: Internet, Round-Trip Time, Traceroute, Measurement, Tools, HiPerConTracer

I. Introduction

The well-known shell tools `ping` and `traceroute` provide basic network connectivity testing. Ping measurements just perform round-trip time (RTT) measurements between two end-systems, while Traceroute also probes the routers of the path in-between. However, these shell tools are made for simple interactive testing. They are unsuitable for large-scale, long-term, high-frequency measurements in distributed infrastructures like NorNet [1]–[3], with automatic processing of the results. For this purpose, the open source tool HiPerConTracer[2] [4], [5] (High-Performance Connectivity Tracer) has been developed.

Up to now, HiPerConTracer, has already been used for research works like RTT measurements [6], performance metric collection in 4G Enhanced Packet Core (EPC) [7], as well as long-term routing observation and visualisation for privacy aspects [8], [9].

As part of the live demonstration, it is intended to showcase this useful, open source tool to a broader researcher community. Particularly, it is also intended to show some of the latest features currently being added for the upcoming release 2.0.

II. The HiPerConTracer Framework

A. Architecture

Figure 1 presents the general architecture of HiPerConTracer: Measurements are run on arbitrary vantage points (regular Linux or FreeBSD machines). The collected results can be uploaded to centralised importer servers, where the results get imported into SQL or NoSQL databases (or database clusters) by the importer tool. From the database, the data can be queried by the query tool. Exported data – in the same, well-documented format as the original measurement data – can then be post-processed for analysis and visualisation.

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[2]HiPerConTracer: https://www.nntb.no/~dreibh/hipercontracer/.

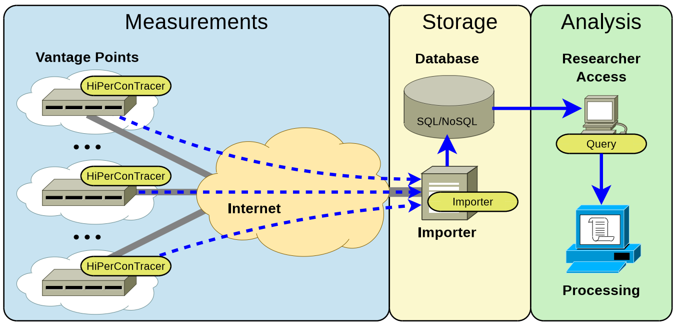

Figure 1. An Overview of the Architecture of HiPerConTracer.

B. Measurements

HiPerConTracer features multi-homing, i.e. it supports simultaneous connectivity to multiple networks (e.g. for redundancy, like connections to different Internet service providers). It can therefore run measurements over multiple networks simultaneously. This is particularly also useful to examine paths used by applications based on Stream Control Transmission Protocol (SCTP) or Multi-Path TCP (MPTCP), in order to support performance analysis. Of course, HiPerConTracer supports IPv4 [10] as well as IPv6 [11].

HiPerConTracer currently provides two kinds of measurements: Traceroute and Ping. Traceroute probes the routers to a remote endpoint, by sending packet sequences with IPv4 Time-to-Live/IPv6 Hop Limit from 1 to a given limit. Unlike the classic `traceroute` tool, HiPerConTracer Traceroute, also denoted as "Oslo Traceroute", sends probe packets as a burst to speed up the measurement (after initially probing the required Time-to-Live/Hop Limit in configurable steps). In addition, it ensures that the first 4 bytes of the Transport Layer header (ICMP, UDP) are the same for each probe packet, ensuring that load balancing – usually using these bytes for hashing a packet to a path – chooses the same path for all packets of a run. HiPerConTracer Ping is just a special variant of Traceroute, i.e. using a single, fixed Time-to-Live/Hop Limit to only contact the remote end-system.

For transport, HiPerConTracer 2.0 currently provides ICMP [12], [13] and UDP [14] modules. That is, unlike former versions, it allows to measure using different protocols, which may experience different behaviour in the network. Particularly, this allows to compare results of both protocols, or measurements of different infrastructures (some use ICMP, while others use UDP instead).

HiPerConTracer stores results data in well-documented, compressed (GZip, BZip2, XZ) text files, allowing easy import into arbitrary tools (simple spreadsheets, GNU R, Python, Jupyter, . . .) for analysis. However, it also supports advanced storage solutions for large-scale, long-term storage.

C. Storage

In measurement infrastructures like NorNet [1], [2], data is not processed directly on the vantage points, where storage may be limited to e.g. a couple of weeks or months. Instead, it can get uploaded automatically (e.g. via RSync/SSH) to an importer server with larger storage capacity. There, the HiPerConTracer importer tool runs, importing all arrived results into a structured database, like e.g. a MySQL/MariaDB, PostgreSQL, or MongoDB database (or database cluster). The database-specific part of the importer can be extended easily with support for further database management systems. This allows for long-term storage, as well as for structured queries. For instance, a researcher may usually want to query data of a specific time period and of specific vantage points, possibly with certain other conditions. A database management system allows such queries.

D. Analysis

For the researcher, HiPerConTracer 2.0 also provides a query tool, simplifying database queries for results. The output of the query tool is in the same format as the original input data. So, regardless of whether the data is directly obtained from HiPerConTracer (e.g. running a simple test) or via a database backend, the same code can be used to read the data for post-processing. Examples, e.g. for GNU R, are provided.

As example, Figure 2 presents a plot of a HiPerConTracer Traceroute measurement from Oslo, Norway to Haikou, China using 3 runs every 5 min between May 20 and July 1, 2023. The link colour corresponds to the mean RTT in μs between the measurement system in Oslo and the destination router of the link. The line thickness corresponds to a link's percentage of observations in the data.

A plot of the observed Autonomous Systems (AS) from the same measurement is provided in Figure 3. Different line colours represent different ASs, i.e. different network providers. The interconnection between two different ASs, i.e. exchanges between different network providers, is represented as dotted lines. On the other hand, intra-AS links are shown as solid lines.

III. Demonstration

The live demonstration of HiPerConTracer 2.0 is going to show:

- How to perform HiPerConTracer measurement runs.
- How to store results, i.e. a brief overview over the output format.
- Setting up the importer tool for database-based storage.
- Using the query tool for getting results from a database.
- Simple post-processing, particularly to produce a map plot from Traceroute data and RTT statistics plots from Ping data.

Clearly, as a live event, there will also be the possibility for discussion with the audience.

IV. Availability

HiPerConTracer is open source and available in the Git repository[3]. The enhancements are currently available as branch "dreibh/udpping"[4]. They are going to be merged into the next major release 2.0.

References

[1] T. Čičić, A. Kvalbein, A. S. Al-Selwi, F. I. Michelinakis, and T. Dreibholz, "Norske mobilnett i 2022 – Tilstandsrapport fra Centre for Resilient Networks and Applications," Simula Metropolitan Center for Digital Engineering, Centre for Resilient Networks and Applications (CRNA), Oslo/Norway, Tech. Rep., Apr. 2023.

[2] E. G. Gran, T. Dreibholz, and A. Kvalbein, "NorNet Core – A Multi-Homed Research Testbed," *Computer Networks, Special Issue on Future Internet Testbeds*, vol. 61, pp. 75–87, Mar. 2014. doi: 10.1016/j.bjp.2013.12.035

[3] F. Golkar, T. Dreibholz, and A. Kvalbein, "Measuring and Comparing Internet Path Stability in IPv4 and IPv6," in *Proceedings of the 5th IEEE International Conference on the Network of the Future (NoF)*, Paris/France, Dec. 2014. doi: 10.1109/NOF.2014.7119767. ISBN 978-1-4799-7531-0 pp. 1–5.

[4] T. Dreibholz, "HiPerConTracer - A Versatile Tool for IP Connectivity Tracing in Multi-Path Setups," in *Proceedings of the 28th IEEE International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Hvar, Dalmacija/Croatia, Sep. 2020. doi: 10.23919/SoftCOM50211.2020.9238278. ISBN 978-953-290-099-6 pp. 1–6.

[5] ——, "High-Precision Round-Trip Time Measurements in the Internet with HiPerConTracer," in *Proceedings of the 31st International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Split, Dalmacija/Croatia, Sep. 2023.

[6] S. Mazumdar and T. Dreibholz, "Secure Embedded Living: Towards a Self-contained User Data Preserving Framework," *IEEE Communications Magazine*, vol. 60, pp. 74–80, Nov. 2022. doi: 10.1109/MCOM.001.2200165

[7] F. I. Michelinakis, J. S. Pujol-Roig, S. Malacarne, M. Xie, T. Dreibholz, S. Majumdar, W. Y. Poe, G. Patounas, C. Guerrero, A. M. Elmokashfi, and V. Theodorou, "AI Anomaly Detection for Cloudified Mobile Core Architectures," *Transactions on Network and Service Management (TNSM)*, Aug. 2022. doi: 10.1109/TNSM.2022.3203246

[8] T. Dreibholz and S. Mazumdar, "Find Out: How Do Your Data Packets Travel?" in *Proceedings of the 18th IEEE International Conference on Network and Service Management (CNSM)*, Thessaloniki, Greece, Nov. 2022. doi: 10.23919/CNSM55787.2022.9965091. ISBN 978-3-903176-51-5 pp. 359–363.

[9] S. Mazumdar and T. Dreibholz, "Towards a Privacy Preserving Data Flow Control via Packet Header Marking," in *Proceedings of the 24th IEEE International Conference on High Performance Computing, Data, and Analytics (HPCC)*, Chengdu, Sichuan/People's Republic of China, Dec. 2022. doi: 10.1109/HPCC-DSS-SmartCity-DependSys57074.2022.00232. ISBN 979-8-3503-1993-4 pp. 1509–1516.

[10] J. B. Postel, "Internet Protocol," IETF, RFC 791, Sep. 1981.

[11] S. E. Deering and R. M. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," IETF, Standards Track RFC 2460, Dec. 1998.

[12] J. B. Postel, "Internet Control Message Protocol," IETF, RFC 792, Sep. 1981.

[13] A. Conta, S. E. Deering, and M. Gupta, "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification," IETF, Standards Track RFC 4443, Mar. 2006.

[14] J. B. Postel, "Transmission Control Protocol," IETF, RFC 793, Sep. 1981.

[3] HiPerConTracer master: https://github.com/dreibh/hipercontracer/.

[4] Branch: https://github.com/dreibh/hipercontracer/tree/dreibh/udpping/.

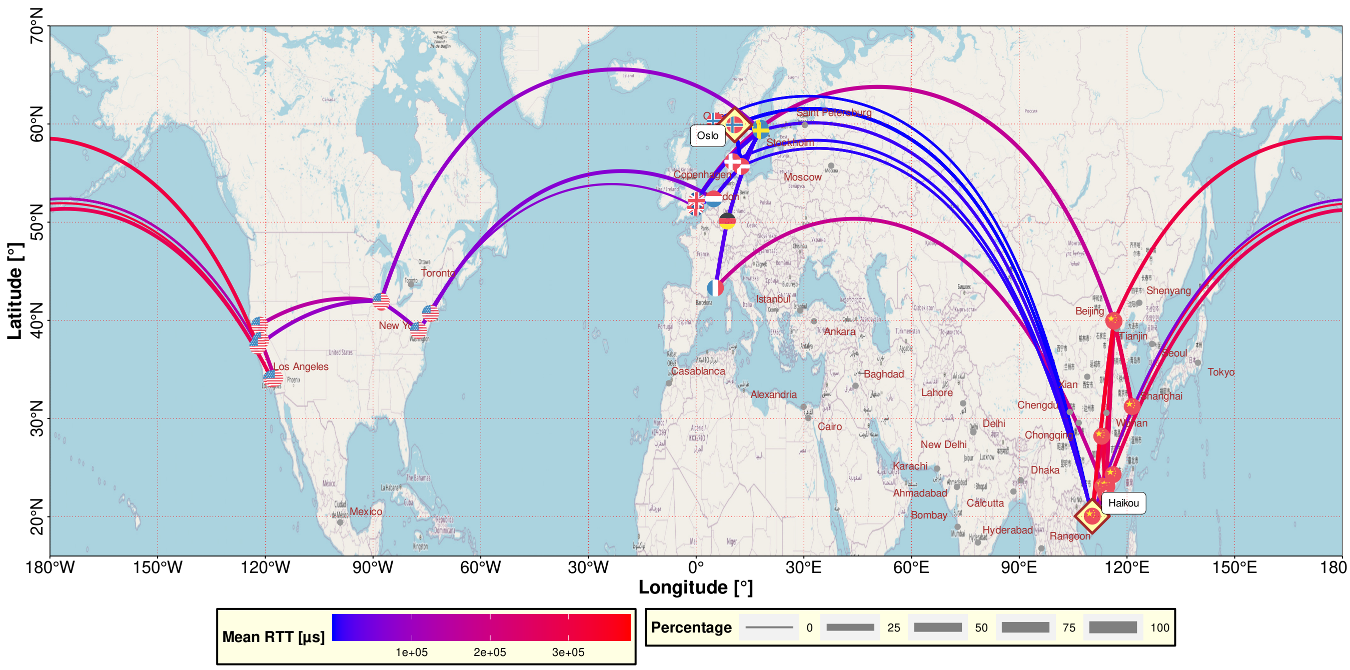

Figure 2. Observed Links between Oslo, Norway and Haikou China between May 20 and July 1, 2023, including RTT between Oslo and Remote Router.

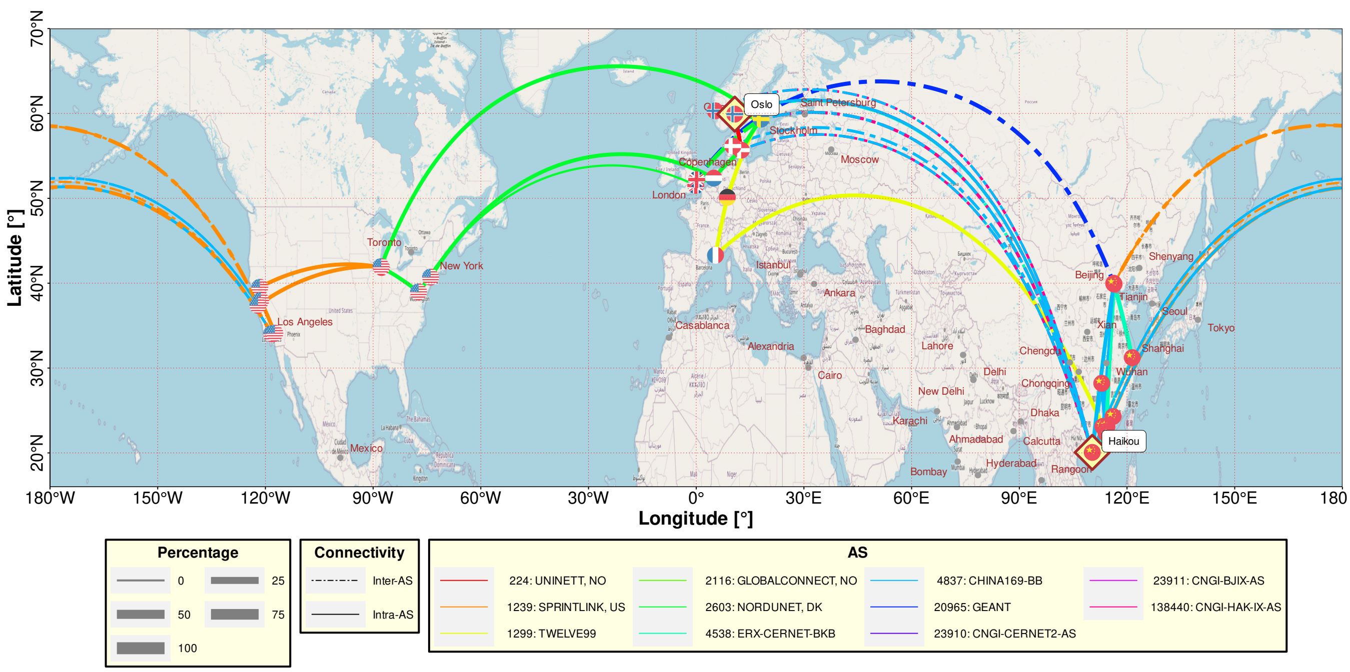

Figure 3. Autonomous Systems (AS) between Oslo, Norway and Haikou China between May 20 and July 1, 2023