

# Throughput Performance Measurement of the MPT-GRE Multipath Technology in Emulated WAN Environment

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Internet architecture enables only a single data path between two communication endpoints within a communication session. On the other hand decent communication equipment (laptops, tablets, phones) are equipped at the factory with several network interfaces (Ethernet, Wi-Fi, 3G, 4G). It does not worth not to use these hardware-given possibilities, which could increase the performance of the communication between two devices, using two or more communication paths. In this paper we presented a possible solution by implementing the MPT-GRE software library. This software was developed under Linux and is based on a totally new architecture, in comparison with the classical TCP/IP model, providing an easy-to-use extension of the current TCP protocol stack (see Figure 1). In our previous papers we investigated its performance in various laboratory measurement environments. In this paper we tried to do it in a much more realistic environment, using the Dummynet WAN emulation software. The measurement results confirmed that the MPT-GRE multipath solution is able to efficiently aggregate the performance of physical connections in the emulated WAN environment as well.

*Keywords:* MPT-GRE, multipath communication, Dummynet, throughput, WAN Emulator.

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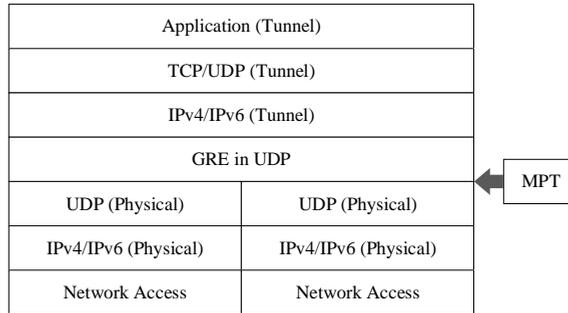


Figure 1: Layered architecture of the MPT-GRE

## 1. Introduction

Multipath communication technologies are one of the hot research topics nowadays. What better proof of this than Apple and Cisco integrating MPTCP<sup>1</sup>, considered as the flagship of multipath technologies, into their operating systems [1]. With the help of multipath communication, we can increase throughput, while also employing redundant data paths.

In our earlier publications (see e.g. [1–8]) we have presented a multipath communication technology (MPT-GRE<sup>2</sup> [9]) developed by our research group, which we have built on the standardized GRE-in-UDP tunneling technology<sup>3</sup>. We have examined its effectiveness with the help of numerous scenarios in our test environment, comparing results with MPTCP as a reference. All of the scenarios have showed that our MPT-GRE solution is capable of efficient path-aggregation both in Fast Ethernet and Gigabit Ethernet IPv4/IPv6 environments.

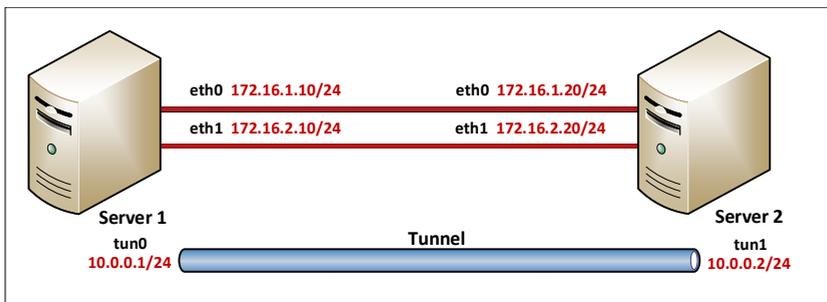


Figure 2: Our previous "ideal" testbed

The MPTCP Project official website: <https://www.multipath-tcp.org/>

The MPT-GRE Project official website: <https://irh.inf.unideb.hu/~szilagyi/index.php/en/mpt/>

GRE-in-UDP Encapsulation standard: <https://tools.ietf.org/html/rfc8086>

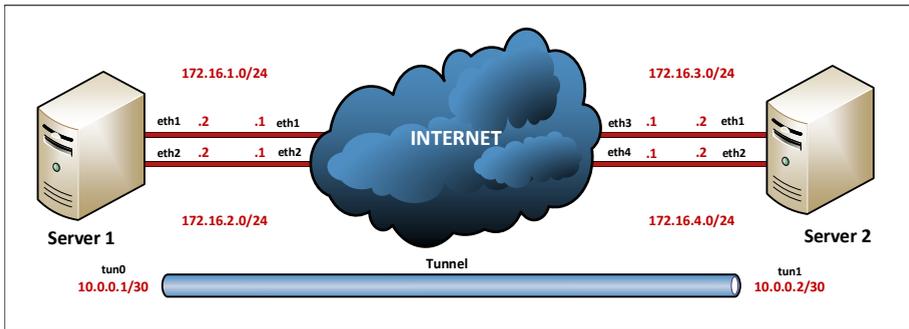


Figure 3: A real network testbed example

The testing environments we have used previously (see e.g. Figure 2) can be considered ideal in the sense that they did not contain any network environment parameters that could negatively affect network performance (e.g. delay, jitter, packet-loss). For this reason, we find it important to further examine the effectiveness of MPT-GRE in a more realistic environment (see e.g. Figure 3).

When wanting to test a newly developed networking software in a realistic environment, we practically have three possibilities:

- internet
- network simulation
- network emulation

Using the internet can be given in case of single-path communication. However, to be able to test multipath systems, the presence of dual-home technology is essential, i.e. we need to have multiple ISP connections available.

Network simulation aims to replicate the key parameters of desired network environments with the help of mathematical models, with greater or lesser success.

The essence of network emulation is to replicate real network behaviors. Two main types exist:

- hardware realization (see e.g. Figure 4)
- software implementation

The first contains advanced technological solutions, but it is in turn quite a costly method. The latter is not always capable of providing a reliable and precise test environment, but it is cost-effective. Some examples of network emulator software: Dummy Cloud<sup>4</sup>, Dummynet<sup>5</sup>, NETEM<sup>6</sup>, NIST Net<sup>7</sup>, SoftPerfect Connection

Dummy Cloud official website: <http://www.dummycloud.com/>

Dummynet Project official website: <http://info.iet.unipi.it/luigi/dummynet/>

NetEm's manual page: <https://man7.org/linux/man-pages/man8/tc-netem.8.html>

NIST Net home page: <https://www-x.antd.nist.gov/nistnet/>

Emulator<sup>8</sup>, WANem<sup>9</sup>.



Figure 4: Hardware-based network emulators (Source: <https://www.apposite-tech.com>)

Given that a hardware implementation of a WAN emulator sufficient for our goals would be around 6000 EUR + VAT<sup>10</sup>, after having reviewed the software solutions, our choice was Dummynet.

The Dummynet WAN emulator was developed in 2010 at the University of Pisa, and later got integrated into the FreeBSD operating system<sup>11</sup>. It provides a suitable framework for testing multipath solutions, enabling the setup of packet-delay, jitter and packet-loss network parameters [10]. It also has good documentation, including numerous code examples<sup>12</sup>.

## 2. Measurement environment

We created a dual-path Fast Ethernet IPv4 WAN emulated measurement environment (see Figure 5). We downloaded a 1 GB file from the fileserver on the left onto the server on the right. Network parameters were controlled on the intermediate server that had Dummynet installed on the kernel level.

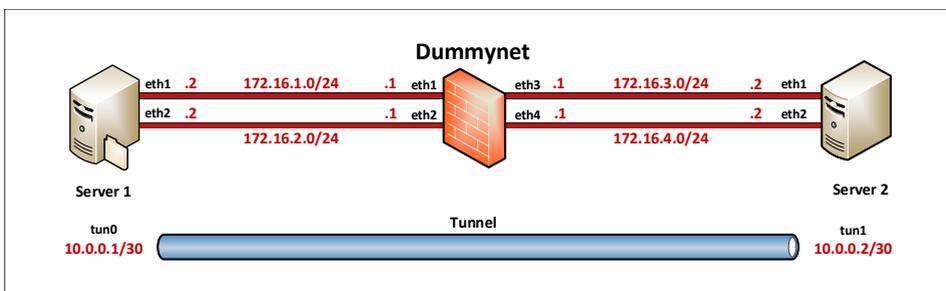


Figure 5: Our new measurement testbed with Dummynet

SoftPerfect Connection Emulator: <https://www.softperfect.com/products/connectionemulator/>  
 WANem official web page: <http://wanem.sourceforge.net/>

Linktropy Mini-G's price at November 2020: <https://www.digital-hands.eu/products/apposite/linktropy-mini-g/>

FreeBSD Manual Pages: <https://www.freebsd.org/cgi/man.cgi?dummynet>

Using Dummynet in FreeBSD: [http://noahdavids.org/self\\_published/using\\_dummynet.html](http://noahdavids.org/self_published/using_dummynet.html)

All three machines were running the Linux Ubuntu operating system. We examined the effect of packet-delay, jitter and packet-loss on file download speed, download time, and CPU performance. Bash and Python scripts – available on our website<sup>13</sup> – were used to automate the measurement process. We repeated each series of measurements ten times.

### 3. Measurement results

First, we checked how packet-delay affected download speed (see Figure 6).

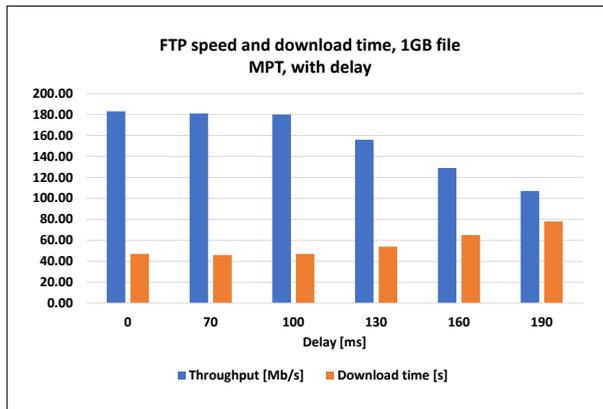


Figure 6: The effect of the delay on the FTP throughput and download time

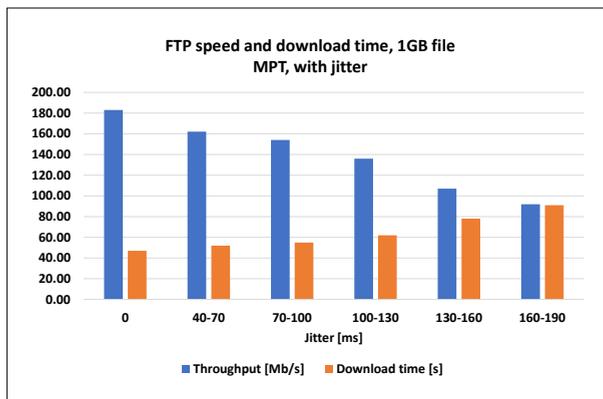


Figure 7: The effect of the jitter on the FTP throughput and download time

Our test scripts can be downloaded from: <https://nas01.inf.unideb.hu/share.cgi?ssid=03Csnis>

We gradually increased delay values on a scale of 0-190 ms using Dummynet. Everything proved to be stable until 100 ms. Above 100 ms, we experienced a continuous decrease in file download speeds. Using the 190 ms delay value, the download speed decreased to 107 Mb/s, while download time increased from 47 seconds to 78 seconds.

A similar effect could be experienced in the case of increasing jitter values (see Figure 7). With a 160-190 ms delay fluctuation, the download speed practically decreased by half, while the download time doubled.

Applying even a minimal data-loss rate (1 ‰), we witnessed a drastic performance decline (see Figure 8). The download speed fall to a quarter, while the download time quadrupled. Therefore, we did not experiment with further data-loss rate values.

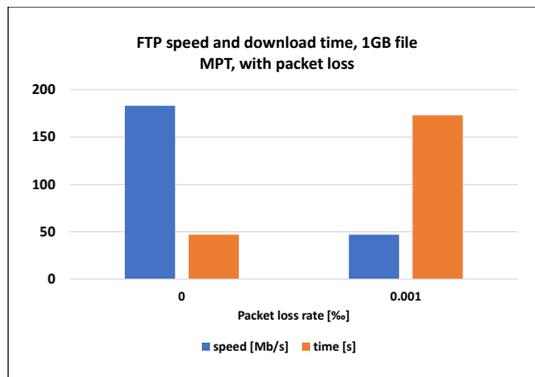


Figure 8: The effect of the packet loss on the FTP throughput and download time

Regarding the effect of packet-delay on CPU performance, we did not experience significant fluctuation (see Figure 9). CPU utilization hovered between 15-22% in every case.

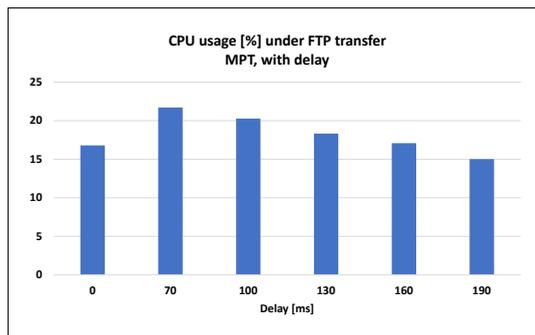


Figure 9: The effect of the delay on the CPU usage

Introducing jitter however, had noticeable effects on CPU utilization (see Figure 10). With higher jitter values, we experienced a drop in CPU utilization.

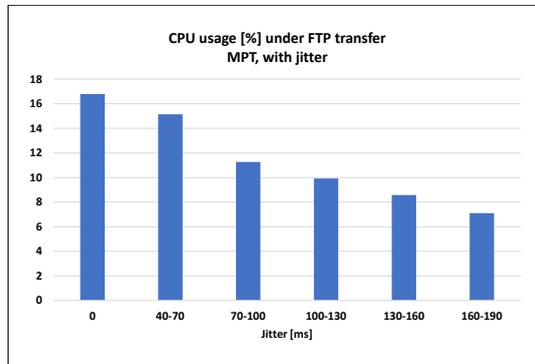


Figure 10: The effect of the jitter on the CPU usage

While examining CPU loads, the effect of packet-loss also proved to be drastic (see Figure 11). Using a data-loss rate of 1 ‰, utilization dropped from 17 to 5.7 percent.

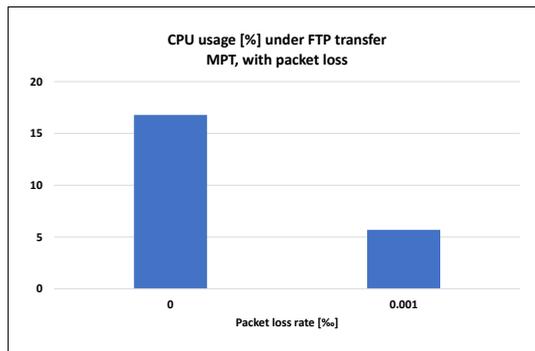


Figure 11: The effect of the packet loss on the CPU usage

We also carried out further measurements, mixing the parameters of the different paths. E.g. using only delay on one path, while using only jitter on the other. These scenarios brought similar results as well.

## 4. Conclusions

In our current paper, we extended the performance-analysis of our own multipath solution, MPT-GRE, using an emulated WAN environment. We examined the effect of different network parameters, like e.g. packet-delay, jitter and data-loss

rate on file download speed, download time, and CPU utilization. The worst performance we experienced was with the application of the 1 % packet-loss rate. Among our future goals we plan to extend our measurements to Gigabit Ethernet IPv4/IPv6 environments, and we would also like to get hands-on experience with the capabilities offered by hardware WAN emulators.

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