**Andrzej PASZKIEWICZ** [1], Paweł WIĘCH [2], Zbigniew GOMÓŁKA [3]
[1] RZESZOW UNIVERSITY OF TECHNOLOGY, DEPARTMENT OF DISTRIBUTED SYSTEMS, 12 Powstańców Warszawy Ave., 35-959 Rzeszów
[2] ATOS IT SERVICES Sp. z.o.o, 1 Kraszewskiego St., 85-240 Bydgoszcz
[3] UNIVERSITY OF RZESZOW, FACULTY OF MATHEMATICS AND NATURAL SCIENCES, DEPARTMENT OF COMPUTER ENGINEERING, 1 Pigonia St., 35-959 Rzeszów

# Performance of a router based on NetFPGA-1Gb/s cards

**Abstract**

Providing a flexible platform that also allows prototyping new network solutions opens new possibilities for designers, researchers and administrators. This solution are NetFPGA systems. Their additional advantage is the possibility of testing new networking protocols in a real heterogeneous environment. Until now, it has been mainly possible by using software tools such as, e.g. Opnet Modeler. Despite the very good mapping network environment in this type of solutions, it is necessary to carry out tests in the real network for their correct evaluation. The paper focuses on the analysis of the solution performance based on NetFPGA-1G cards as an alternative to the network nodes based on ASICs. Therefore a series of tests was carried out. They demonstrated the applicability of the platform in different layers of the network, e.g. access, aggregation, or core. Thus, the paper goal is to show the possibilities of using NetFPGA solutions in a network environment mainly of enterprise class.

**Keywords**: NetFPGA, computer networks, routing protocols, performance.

## 1. Introduction

Computer networks, similarly to other areas of modern technology are being rapidly changing. New hardware and network protocols determine directions of changes in existing and planned networks. So far, designers and administrators of computer networks have been forced to use only solutions offered by global vendors producing network devices. The only alternative have been platforms based on e.g. Linux systems, with limited implemented network functionality. However, solutions of this type have not met the performance requirements for enterprise class networks or carrier networks. A specialized software for prototyping and simulation networks and network mechanisms, e.g. Opnet Modeler [1], can be an additional but only test environment. Despite the numerous advantages, these solutions cannot replace working conditions in real network infrastructure.

Currently produced network devices, such as routers and switches, allow performing routing and packet switching in hardware by using dedicated ASICs. Network engineers have the possibility to interfere only in the limited by producer device control plane using developed communications protocol implementations. Additionally, the implementation of standardized, innovative solutions requires long waiting times for software updates developed by the producer.

Accepting the openness principle, which allows for free development and customization environment, the mentioned above solution represents a significant limitation. To meet the challenges of the modern world in terms of the computer network openness, it is necessary to have the appropriate hardware and software platform. Network devices operating on the basis of network cards NetFPGA can be such a solution. They allow administrators for extensive modification of the device control plane by developing own implementation of any protocol [2].

This paper focuses on the analysis of the performance of routing based on a NetFPGA-1G card. Taking currently available reference projects for these cards into account, the user can develop the own dynamic routing protocol or mechanism that provides the possibility of determining the metrics of routes based on the parameters describing the current state of the network, in contrast to current solutions. Thanks to the obtained high-bandwidth of Gigabit Ethernet ports, the NetFPGA platform can be used to create an extensive network infrastructure, in which an IP prototype router can be the core of the network.

## 2. Characteristics of the test environment

One should remember that programmable circuits have been known for many years. However, they have found wider application in the field of computer networks in recent years. FPGAs have similar functionality as integrated ASIC from the designer point of view. However, the FPGA in contrast to the ASIC may be multiply reprogrammed, which allows speeding up the process of prototyping devices. A network device with defined characteristics and at minimization of costs can be designed with use of available software, reference projects and a NetFPGA platform. The control and data plane of a selected device may be flexibly modified using the created architecture [3].

At first, the creation of the NetFPGA environment was motivated by the need of using appropriate tools to familiarize students with the operation of network systems. However, with time, it turned out that this solution might have wider application in computer networks. Over the last 10 years the systems of this type have been constantly modernized and numerous corrections have been introduced to the architecture of the cards. Thanks to this, it has become an open platform that enables quick and efficient prototyping of network devices. Nowadays, there are four different models of the NetFPGA card which have several common features: the method of network traffic processing dependent on the user, delays in the data transmission equal to a few CPU clock cycles or ports bandwidth providing the line-rate performance [4, 5]. The available software allows academic community, designers and network administrators to develop, simulate, and verify prototypes of network devices at the hardware-level.

The NetFPGA platform can be successfully used as a part of a complex computer network. In the ideal case, it is possible to situate this platform in different locations of the network infrastructure: access, aggregation/distribution or core layer. Thanks to this, it is possible to apply this solution anywhere in the classic three layer network model (Enterprise system) including the access to carrier network resources. Thus the nodes with the NetFPGA card can be the key element of the accepted topology (Fig. 1). Such an approach may be an integral part of a heterogeneous network environment equipped with both switches and routers from different vendors, as well as nodes based on NetFPGA-1G cards. This will provide a suitable level of both redundancy and reliability. It also allows implementing these features in the physical layer, the data link layer and the network layer.

NetFPGA cards can be installed in computers/servers equipped with PCI or PCI Express [6, 7]. NetFPGA platforms are developed based on Linux and Windows [8]. However, the recommended system is a Fedora distribution.

## 3. The results of tests

Measurements were supposed to show the possibilities of using the hardware-software platform based on the NetFPGA-1G cards especially in the enterprise network environment. Therefore, there were carried out series of tests relating to various aspects of the packets transmission between both interfaces of the NetFPGA cards and with other network cards as well as the ability to apply this platform in various areas of computer networks.

Different network cards can be used in the computer system where the NetFPGA card is installed. Thanks to them, additional ports can be used to extend the existing infrastructure, e.g. as the access ports for the end devices. The available gigabit Ethernet ports can be also used to communicate with the ISP routers to exchange route by BGP or to ensure redundancy connections in the case of failure of the NetFPGA card ports. The PCI bus bandwidth plays a significant role in communication between the nodes connected to the ports of the NetFPGA-1G card and other network interfaces of the system. The process of carrying out the measurement bandwidth between the ports of Eth1 (standard network interface) and Nf2c0 (NetFPGA card interface) was automated using a written script. To these ports, there were connected hosts having the installed Ubuntu operating system and software 14.04.2 LTS iperf. Thus it was possible to generate the UDP traffic characterized by a constant rate.

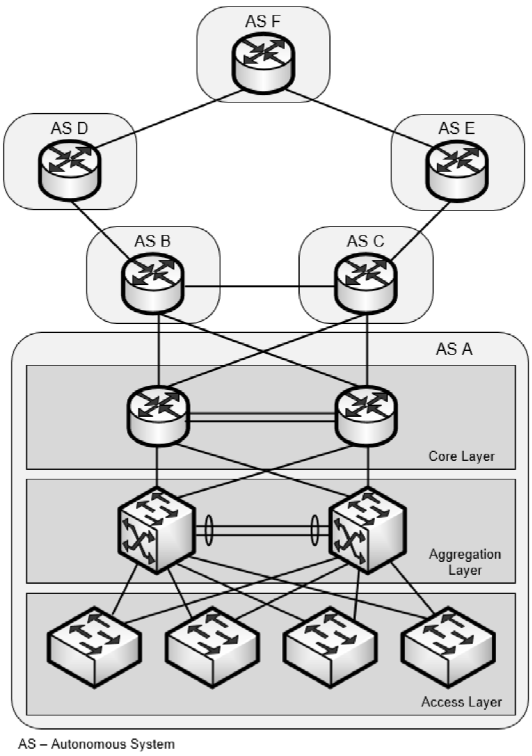


Fig. 1. Topology of the heterogeneous, routed network in which NetFPGA platforms and dedicated switches and routers are used

The throughput tests were performed for three scenarios:

- Environment No. 1: PC1 connected to the port nf2c0 sends the data to the host PC2 connected to the port Eth1.
- Environment No. 2: PC2 connected to the port Eth1 sends the data to the host PC2 connected to the port nf2c0.
- Environment No. 3: PC1 connected to the port nf2c0 sends the data to the host PC2 connected to the port Eth1 and simultaneously receives the generated traffic by the host PC2.

Based on the results shown in Fig. 2, a significant difference between the capacity of the traffic sent and received by the hosts connected to the nf2c0 NetFPGA card port and the computer system Eth1 port can be seen. The bandwidth for the traffic sent from the hosts connected to the ports of the NetFPGA card (environment No. 1) in relation to the received traffic (environment No. 2) increases with increasing the length of the UDP segment. For IP packets with a length of 1,514B (the largest packet size for which fragmentation did not occur) the ratio of the sent to the received traffic is 1.80.

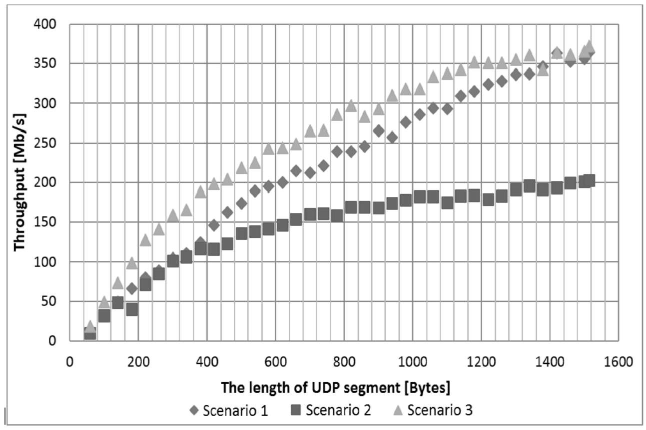


Fig. 2. Determined total throughput between the NetFPGA card and the Ethernet card

Depending on the proposed NetFPGA-1 card location in a building computer network, the PCI bus bandwidth may play a less important role. In the case of using home hosts, Ethernet ports as a connection to the ISP routers, the agreed bandwidth can never exceed the physical limitations of the bus. It should be noted that each next version of the NetFPGA card uses a more efficient PCI Express bus architecture, which minimizes the perceived problem.

The throughput measurement was also made for a more complex network. For this purpose, commercially available Enterprise class switches equipped with 1 Gbps interfaces were used. They played the role of an traffic aggregator from the hosts towards the ports of the NetFPGA-1G card. In order to examine the operation of the network, when each port of the card is fully loaded with incoming and outgoing traffic, each of the PCs played the role of both iperf server and iperf client.

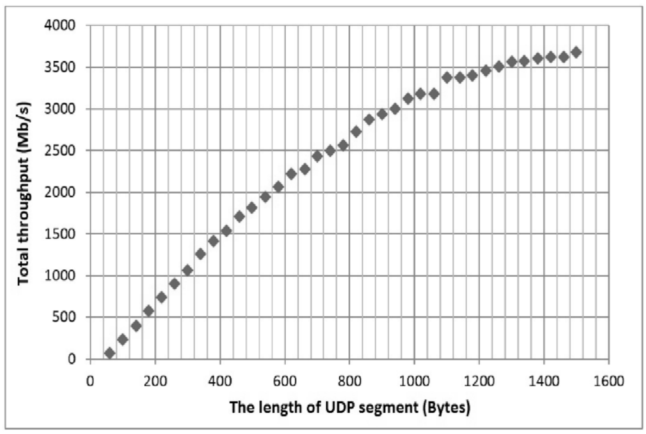


Fig. 3. The total throughput of the traffic received by Iperf servers depending on the length of the UDP segment

Despite the UDP traffic generated by iperf customers with a greater bandwidth for the maximum size of the IP packet, the total received traffic throughput was achieved at 3679Mbps. During the tests it was noted that the obtainable bandwidth was dependent on switch limitations aggregating the network traffic.

Further tests included the performance analysis of the NetFPGA platform in relation to reducing the need of retransmission of the sent data over the network. Therefore, the TCP protocol was taken into account. Its operation characteristic makes it widely used by applications running on IP networks. Thus, it is necessary to analyze the main characteristics of the network traffic depending on the established window size between the members of the transmission, or in the case of the competition, the bandwidth of the number of transmission at the same time, when using the NetFPGA platform.

The TCP window size is responsible for the maximum amount of data that can be transferred between the client and the server without waiting for receiving an ACK confirmation. The result obtained throughput in the conducted tests using the TCP protocol can be optimized by increasing appropriately the value of this parameter in the software configuration iperf. Fig. 4 presents a situation confirming that in the case of increasing the number of TCP streams the band saturation occurs much faster, at lower values of the transmission window.

Additionally, series of tests were carried out in order to check the routing node capacity based on the NetFPGA card in relation to commonly used products from different vendors ensuring their equipment capacity at wire speed. According to the obtained results of measurements, it can be concluded that the nodes of this type provide the equivalent throughput and the stability of data transmission at the time of routing.

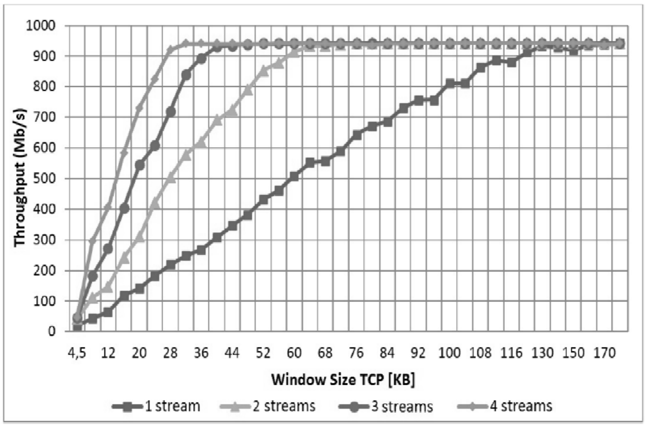


Fig. 4. The obtained throughput between PC1 and PC2 hosts connected to the ports accordingly NF2c1 and NF2c2 of the NetFPGA card

The main task of routing protocols implemented in both classical routers and NetFPGA platform is to build and maintain the routing table. One important issue is to ensure the state of network convergence. In the conducted tests, the topology shown in Fig. 5 was taken into account.

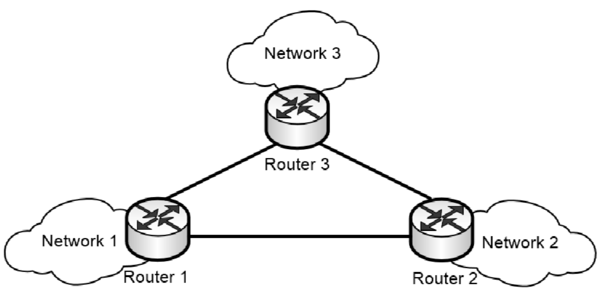


Fig. 5. The topology for which the time of convergence was carried out

The scope of the tests included a variety of routing protocols RIP, OSPF and PWOSPF available on the NetFPGA platform. Table 1 shows the results of the selected three scenarios:
Scenario 1: The value of counters for hello and dead interval was set accordingly 10 and 40 seconds.
Scenario 2: The value of hello interval was equal to 0.3 seconds, the dead interval was 1 second.
Scenario 3: The value of configurable counters were left at the level of default values for the used routing daemons, also enabled a link-state tracking.

Tab. 1. Convergence time for OSPF for three scenarios

| Measurement | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|
| Minimum | 41,213 | 41,352 | 0,920 s | 0,929 s | 0,570 s | 0,563 s |
| Maximum | 43,642 | 44,012 | 1,159 s | 1,167 s | 0,580 s | 0,577 s |
| **Average:** | **41,942** | **42,341** | **1,044 s** | **1,048 s** | **0,572 s** | **0,571 s** |

## 4. Conclusions

Using the NetFPGA environment, computer network administrators gain the ability of wide modification of data and a control plane of network devices, while not being limited to the solutions available on the market. Based on the shared projects, a network device implementing specific functionality in hardware can be created quickly.

The possibility of implementation of the most popular routing protocols on a platform equipped with the NetFPGA-1G card provides routing between it and the network devices from other manufacturers. Taking the results of benchmark tests into account it can be concluded that the platform can be successfully used in an enterprise-class network.

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**Andrzej PASZKIEWICZ, PhD, eng.**

He received a Ph.D. degree in Computer Science from Lodz University of Technology in 2009. His current research interests focus on widely under-stood processes in computer networks. He works at the Department of Distributed Systems Rzeszow University of Technology as an assistant professor.

*e-mail: andrzejp@prz.edu.pl*

**Paweł WIĘCH, MSc, eng.**

He received the B.S. and M.S. (with highest honors) degrees in Computer Engineering from Rzeszow University of Technology in 2014 and 2015, respectively. He is interested in network engineering and communications systems. He also hold amateur radio licence. He currently works for Atos in Bydgoszcz, Poland at a Network Engineer position.

*e-mail: pawelwiech123@tlen.pl*

**Zbigniew GOMÓŁKA, PhD**

Achieved PhD in computer sciences at Academy of Mining and Metallurgy in Cracow. Actually senior lecturer at University of Rzeszow. Head of Computer Graphics and Digital Image Processing Laboratory. Author more than 70 publications in journals and chapters in books. Main area of scientific interests: artificial intelligence, image processing, neural networks, 3D scenery restitution.

*e-mail: zgomolka@ur.edu.pl*