Performance analysis of TCP and UDP using Opnet Simulator

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***Abstract* — the transport layer protocols provide connection-oriented sessions and reliable data delivery services. This paper seeks to reflect a comparative analysis between the two transport layer protocols, which are TCP/IP and UDP/IP, as well to observe the effect of using these two protocols in a client server network. The similarities and differences between TCP and UDP over the Internet are also presented in our work. We implement a network structure using Opnet Modeler and finally, based on the practical results obtained we present the conclusions-showing the difference between these two protocols and how they work.**

***Index Terms* — Computers, Internet, Network, Protocols, Testing.**

I. INTRODUCTION

The transport layer is not just another layer. It is the heart of the whole protocol hierarchy. Its task is to provide reliable, cost-effective data transport from the source machine to the destination machine, independently of the physical network or networks currently in use.

TCP and UDP are transport layer components that provide the connection point through which applications access network services. TCP and UDP use IP, which is a lower-layer best effort delivery service. IP encapsulates TCP packets and UDP datagrams and delivers this information across router-connected internet works.

The ultimate goal of the transport layer is to provide efficient, reliable, and cost-effective service to its users, normally processes in the application layer. To achieve this goal, the transport layer makes use of the services provided by the network layer. Without the transport layer, the whole concept of layered protocols would make little sense e.g. [4]. The Transport Layer prepares applications data for transport over the network and processes network data to be used by applications. It is responsible for the end-to-end transfer of data over the network and is the four of the OSI model. The Transport layer meets a number of functions:

- enabling the applications to communicate over the network at the same time when using a single device;
- ensure that all amount of data is receive by the correct application;
- responsible for fragmentation and reassembly;
- develop mechanism for handling errors.

II. RELATED WORK

Jingyi He e.g. [9] study the impact of mechanism as employed in OPS (optical packet-switched) networks of the performance of upper layer Internet protocols represented by TCP and UDP. Andro Milanović e.g. [10] describe how different hardware and software components of PCs affect the performance of TCP and UDP for transferring data on internet. R. Les Cottrell e.g. [11] characterize and evaluate the achievable throughput, stability and intra-protocol fairness of different TCP stacks (HSTCP, HTCP, Fast TCP, Reno and LTCP) and a UDP based application level transport protocol (UDTv2) on both production and tested networks. Xiangning Liu e.g. [12] conduct some experiments to measure the data communication performance of the TCP and UDP protocols on both currently-existing computer networks and the ATM network of the future. Charles R. Simpson, e.g. [13] present empirical models of end-user network traffic derived from the analysis of NETI@home data, first one for a specific TCP or UDP port and second one models all TCP and UDP traffic for end-user. Mostfa M. Kaytan, e.g. [14] describe how to establish UDP and TCP connection in the same network simulation, using four types of TCP, which are TCP Tahoe, Reno, New Reno and Vegas.

III. PROTOCOLS CONCEPT

Transmission Control Protocol (TCP) is one of the main transport protocols which is described e.g. [1]. Is a connection-oriented protocol and the data transmission is performed in a full-duplex mode for the highest performance. TCP provides more facilities for applications than UDP, like error recovery, flow control and reliability.

The primary purpose of TCP is to provide reliable connection service between pairs of processes. Before any data can be transferred, a connection should be established between the two processes. Each side of a TCP connection has a socket that can be identified by the TCP, IP address and port number. TCP is a protocol for managing end-to-end connections, but since end-to-end connections may exist across a series of point-to-point connections, they are often called virtual circuits e.g. [8].

TCP can be characterized by the facilities it provides for the applications using it: stream data transfer- TCP transfers a contiguous stream of bytes through the network, grouping the bytes in TCP segments which are passed to IP and transmitted to the destination; reliability between sender and receiver using acknowledgments (ACK); flow control; multiplexing; full-duplex and logical connections based on sockets, sequence numbers and window sizes. A comparison of the most important services offered by TCP and UDP is presented in Table I, web page e.g. [15]:

TABLE I. COMPARISON BETWEEN TCP AND UDP

Service	TCP	UDP
Flow controls	The receiver can signal the sender to slow down.	ACKs, which are used in TCP to control packet flow, are not returned.
Connection setup	It takes time, but with TCP reliability is ensured.	No connection is required.
Guaranteed message delivery	Returns acknowledgments.	UDP does not return ACKs, the receiver can't signal that packets have been successfully delivered.
Congestion controls	Network devices can take advantage of TCP ACK to control the behavior of sender.	If ACK, are missing, the network cannot signal congestion to the sender.

A big difference between TCP and UDP is the congestion control algorithm. For the TCP, congestion algorithm prevents the sender from overrunning the network capacity, while TCP can adapt the sender's rate with the network capacity and attempt to avoid potential congestions problems.

User Datagram Protocol (UDP)**,** another transport protocol in IP networks, is described e.g. [2].

The User Datagram Protocol (UDP) provides an unreliable connectionless delivery service using IP to transport messages between machines e.g. [5]. It uses IP to carry messages, but adds the ability to distinguish among multiple destinations within a given host computer. Is a connectionless protocol which doesn't provide flow control, reliability or error recovery and the retransmissions of data in case of errors must be ordered by other protocols. UDP is designed for applications that do not have to recompose the data segment that arrives from the sender. In another way, application-level protocols are directly responsible for the security of data transmitted.

Difference from the TCP is that there is no mechanism for error detections. If applications that use UDP doesn't have their own mechanism for information retrieval can lose those data and be forced to retransmitted again. On the other side this applications are not slow down by the confirmation process and the memory will be available for work much faster.

IV. SIMULATED NETWORK TOPOLOGY

This paper has examined the behavior of an internet network based on the client-server configuration, using the two protocols mentioned above. The application was realized in OPNET as in Fig. 1 and the network consist in a WAN, which support almost 32 serial line interfaces through which the IP traffic can be modified, connected on one side to a LAN network composed of 10 PC workstations, on which we can run client-server applications using SLIP with a variable transfer rate, connected to a gateway. The switching speed for the LAN is by default 500,000pkts/sec. Packets are routed on a first-come-first-serve basis, and may face delays at the ports, depending on the output interface transfer rate. On the other side, the WAN is connected to a server which supports TCP/IP and UDP/IP over a SLIP connection. The WAN is connected using a duplex link, with a speed rate of 1.544 Mbps and supporting a PPP protocol. The LAN is connected using Ethernet 100BaseT link. All the interfaces over the network where assigned with IP addresses.

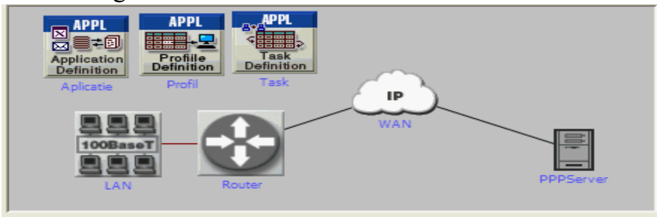

Fig. 1 Network components

Profile definitions is use to create users profiles to be specified in different nodes on the network. The start time (in seconds) defines when during the simulation the profile session will start, and is set to a constant value of 3. The inter repetition time (seconds) is set to a value of 20 and the number of repetitions to a constant value of 1. That means our profile will run every 20 seconds during the simulation period. We used one Task Configuration model to define/create tasks characterizing application. This task will cause the computer inside the LAN network to send one request packet every second, with the packet dimension of 1024 bytes. The request processing time, in seconds, will make the server to respond immediately to LAN request. Application_config specify the type of application to be used: HTTP, FTP, E-mail and Voice. The type of service is set to best effort, which means the network doesn't support QoS. In TCP/IP, IP provide a best effort delivery service for packets and TCP provide guarantee delivery. The design of this network was to study the response time for a network data transfer, when using the TCP and UDP protocols.

V. SIMULATION RESULTS

The simulation time is set for two hours data transfer between LAN network and the server with no packet latency and packet discard ratio of 0% while packets traverse thru the WAN. The task response time, in seconds, Fig. 2, shows how long the application need to be completed. The time when using TCP to complete the task is greater that the one using UDP. When using TCP, source and destination need to perform a three-way handshake before starting sending data and all amount of data need to be acknowledge by the destination when it is receive, so is taking more time than UDP, which doesn't perform this tasks.

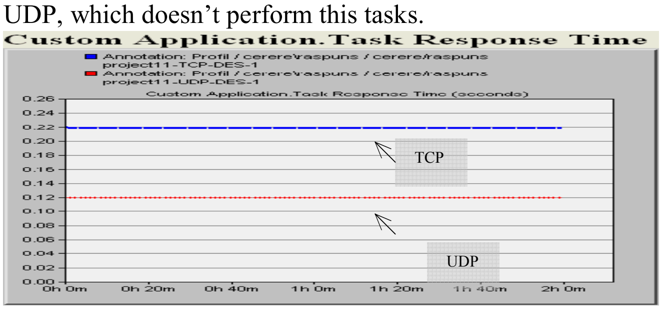

Fig. 2 Response time for TCP and UDP

The traffic received (packets/sec) for the server is shown in Fig. 3 for both TCP and UDP scenarios. The server receive a larger amount of packets per second in the TCP case than the UDP, because the TCP need to establish the connection with the server first, and only after the connections is set up, the packets can be sent to the destination.

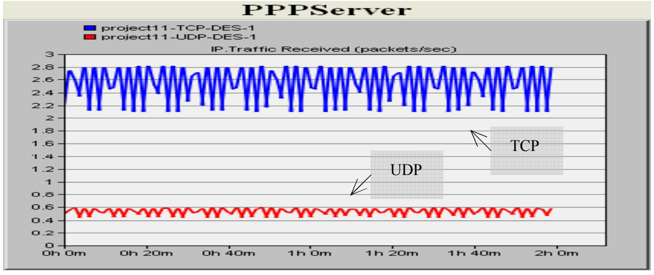

Fig. 3 Traffic received (packets/sec) for the server

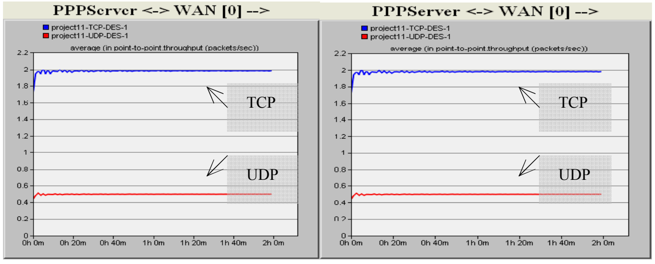

Fig. 4 Traffic/Link utilization from the WAN to the server

Fig. 4 contains the average results of the traffic received for the application server, on the left side, when using TCP and UDP. The server receives more packets when using the TCP, because in UDP case there is no need to send connection setup. On the right side is shown the utilization for the link between server and WAN. As we can see, when using UDP (red color), there is a lower utilization for this link, because UDP is saving in terms of delays and bandwidth use.

If we increase the packet dimension size to 10000 bytes, and we set a packet discard ratio of 0.5%, what would cause TCP to retransmit 0.5% of the sent packets, the link between server an WAN has a higher throughput/utilization in TCP scenario, as in Fig 5, so TCP protocol will be more heavily affected, therefore UDP will allow data to transfer faster and without the identification of a connection.

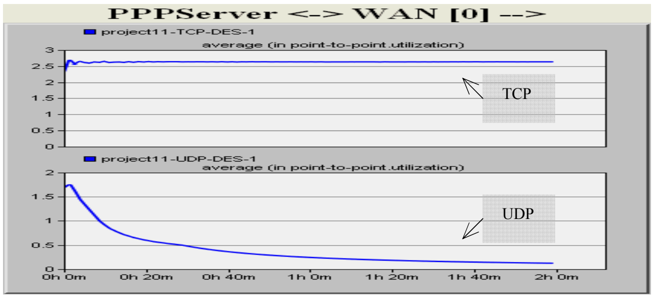

Fig. 5 Link utilization with a 0.5% packets discard ratio

VI. CONCLUSIONS

The Transport layer role is to accept data from the session layer, decompose them if necessary in small packets, transfer them to the network layer and to ensure that all the packets arrive correctly to the other end of the network, more of that, all of these must be done efficient and in a way that isolates those layers from the changes made in the equipment technology. The transport layer is a real end-to-end layer, from source to destination.

The main difference between these two protocols is that TCP provides reliability and congestion control services, while UDP is orientated to improve performance.

The most important and common thing that TCP and UDP are using is the ability to set a host-to-host communication channel, so the packets will be delivered between processes running on two different computers. UDP is the right choice for application where reliability is not a must but the speed and performance is. Instead, TCP, even if it takes more time for the processes, has additional functions like same order delivery, reliability and flow control. As future work, we plan to conduct several studies regarding packets routing in computer networks to improve the fairness of data transmissions using different network protocols.

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