Optimization of network delays through implementation of EIGRP routing protocol

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Abstract — Many applications that today operate within the network are enough sensitive in relation to network caused delays, including the end-to-end delays. Among the applications that are critical a lot regarding delays within the network are the Video and VoIP applications. This paper will deal precisely with analysing and providing a solution in relation to optimizing these delays that occur along the network. This paper will analyse network delays concerning three routing protocols, respectively for RIP, OSPF, EIGRP protocols. For analysis purposes we have used Video, VoIP, FTP, HTTP and e-mail applications. Results are obtained using OPNET software and will be graphically presented for the three routing protocols. Finally, based on the results obtained we will present concrete proposals regarding the optimization of network delays.

***Keywords* — Delays, EIGRP, E-mail, FTP, HTTP, OSPF, RIP, Video, VoIP.**

I. Introduction

Today we are witnessing a rapid development of information technology and this is expected to continue for many years in the future, involving all fields, such as: communication networks, media, various equipment, etc. In short, information technology has become inseparable part of human life itself (Internet, IPTV, video games, video conferencing, interactive applications, distance learning, etc.).

One of the technologies that is developing very fast today is without a doubt the sensors technology, the technology that is found today also involved in monitoring systems, such as video cameras. The sensors technology is a technology that is having an increasingly wider expansion. Today we can find the sensors technology in many places such as: securing the houses, traffic, various machinery, food industry, vehicles, etc. Regarding the development of sensors technology, many researches are oriented by using this technology in order to increase the performance of the National borders of the state. The sensors technology we can find today in the state borders, either as a stand-alone technology or incorporated within the cameras (moving detection cameras). On the other hand a technology such as video cameras requires a very large capacity for the transmission of video recordings at a monitoring point. For transmission of uncompressed video, required bandwidth requirements are around 300Mbit/s with latencies less than 200 ms [1]. The objective of this paper is to analyze the delays that are caused within the network in video and VoIP applications, since voice and video quality is also directly related with delays that are caused during transmission over the communications network.

Initially in this paper, we will elaborate security systems that are used at the state borders. Then in section III we will be present a brief discussion of SONET technology and routing protocols. In section IV will be described the network topology, which is used for simulations. Furthermore in section V, we will present a selection of applications and statistics for analysis purposes. Whereas in section VI, will be present the configurations summary, which are used for simulations. In the end discussion and analysis of the results obtained will be made.

II. Security Systems

Currently, every country objectives are to implement the most sophisticated systems for surveillance and monitoring of the state borders, in order to reduce or eliminate the misuse of border staff by people who tentatively will try to use interstate borders for criminal purposes, such as: smuggling, illegal crossing of immigrants, terrorism, etc.

Surveillance implementation at the border checks point systems are proven very efficient, affecting the efficiency of border staff themselves in performing their duties according to the law. This efficiency will be increased more if the monitoring is practiced not only by local monitoring, but by the head monitoring centre as well.

The main tasks of the central office will be permanent monitoring (online) of the state borders, border crossings and analysis of video recording, depending on the cases that will appear at the state borders. But a very important factor during this monitoring and analysis is that information collected from surveillance systems should be as clear as possible. One of factors that affects the visibility and performance of video recordings are delays that are caused during the network.

Moreover, in addition to video cameras and sensors, within a border check point, other electronic systems and services are used which use the network, such as: HTTP applications, FTP applications, and other systems for verification of passengers personal documents and vehicles, but for these systems delays caused during the network aren't crucial.

III. Basic Concepts of SONET Technology and Routing Protocols

Backbone network has a very important role in network performance and delays that are caused along transmission of information during the network. Backbone network consists of routers, as the central devices. Almost, every backbone network, as transmission medium, uses optical fibers. For each technology, there are standards, which create suitability and standards in relation with their use and operation, regardless of the manufacturer. Therefore, there are standards for optical networks, such as SONET and SDH. Both of these standards are very similar and have set standards for optical networks. In relation to transmission hierarchy of SONET/SDH standards and generally for these standards you can read more in [2], [3].

In [4] [5] losses caused are compared, depending on which wavelength is realized through optical fiber transmission. It is noted that if transmission is realized in wavelength $\lambda = 1550$ nm, the losses are smaller than if transmission is realized in wavelength $\lambda = 1310$ nm.

On the other hand, flow of information through networks is realized through routing protocols, as: RIPv1, RIPv2, OSPF, EIGRP, etc. RIP is a protocol that belongs to the distance-vector; OSPF is a protocol that belongs to the link-state, and EIGRP is a hybrid protocol. If for routing are used distance-vector protocols, routers will have a single routing table in which all the tracks about routing are kept. If for routing are used link-state protocols, then routers will have three routing tables. One of these tables will keep track of directly connected neighbors, and the other will determine the network topology at the entrance to the internet and the third is used as the current routing table. Based on the information collected about the network, estimated which is shortest path for routing information [6]. EIGRP protocol is referred as a hybrid routing protocol because it has both characteristics, the distance - vector and link – state protocols. For more about routing protocols refer to [7]. In the following, we will analyze the delays that are caused depending on which of these protocols are used for routing. To analyze delays a network topology will be presented as follows.

IV. SONET Technology and Routing Protocols

For simulation, the OPNET Modeler 14.5 software package is used. The network topology is built on the area of 30x15 km. In this case we have used the technology, respectively standard for optical networks, SONET.

The model used in our case study is presented in Fig. 1.

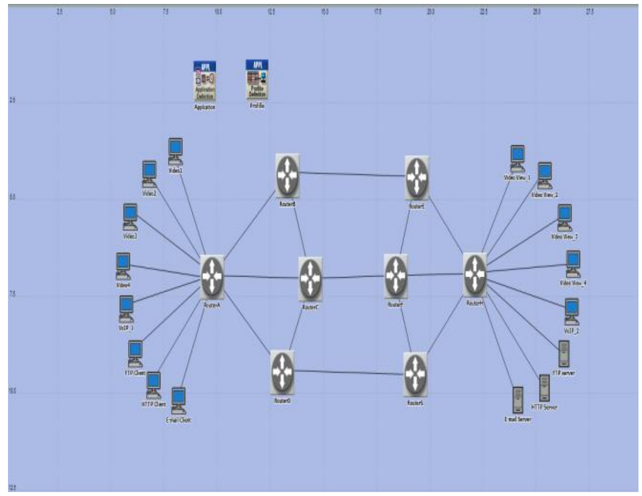

Fig.1. Network topology used for simulation.

In network topology shown in Fig. 1, 8 routers are used. In the router on the left side, 4 video cameras are connected, a VoIP client, a FTP client, a HTTP client and an e-mail client. In the router on the right side, 4 PCs that are used to monitor four cameras on the left side are connected, a VoIP client, a FTP server, a HTTP server and an e-mail server. Connection side equipment and routers with each other, is realized through a duplex link SONET_OC48. The main goal of this paper, as we noted at the beginning is to analyze the delays caused during end-to-end transmission. It should be noted that for FTP, HTTP and e-mail applications, network delays aren't critical, but the same does not apply for video and VoIP applications because delays during the network for the case of video and VoIP, directly affects the picture and voice quality. According to ITU-T G.114 standard it is recommended that when designing a network, delays along network should not be higher than 400ms [8], because delays directly affect the performance of VoIP, interactive applications and video conferencing.

V. The Selection of Applications and Statistics for the Purposes of Analysis

For the case shown in Fig. 1, we have selected 5 applications for analysis. These applications are:

1) Video application – enables the flow of videos from video cameras on the left side to the right side;
2) VoIP application – enables communications of two mutually users, when using VoIP terminal for communication;
3) FTP application – is used for uploading and download of documents from a FTP server.
4) HTTP application – is used for browsing of the different contents from a HTTP server.
5) E-mail application – is used for sending and receiving messages via e-mail server.

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Now for selected applications we will choose statistics that will be used for the purposes of analysis. Selected statistics for analysis are [9]:

1) **Packet Delay Variation** - Variance among end to end delays for video and voice packets. End to end delay for a video and voice packet is measured from the time it is created to the time it is received.
2) **Packet end to end delay** - The time taken to send a video and voice application packet to a destination node application layer. This statistic records data from all the nodes in the network.
3) **Object response Time (seconds)** - Specifies response time for each in lined object from the HTML page.
4) **Page response Time (seconds)** - Specifies time required to retrieve the entire page with all the contained inline objects.
5) **Download response Time (sec) for FTP file** - Time elapsed between sending a request and receiving the response packet. Measured from the time a client application sends a request to the server to the time it receives a response packet. Every response packet sent from a server to an FTP application is included in this statistic.
6) **Upload response Time (sec) for FTP file** - Time elapsed between sending a file and receiving the response. The response time for responses sent from any server to an FTP application is included in this statistic.
7) **Download response Time (sec) for e-mail** - Time elapsed between sending request for emails and receiving emails from email server in the network. This time includes signaling delay for the connection setup.
8) **Upload response Time (sec) for E-mail** - Time elapsed between sending emails to the email server and receiving acknowledgments from the email server. This time includes signaling delay for the connection setup.
9) **Queuing delay** - This statistic represents instantaneous measurements of packet waiting times in the transmitter channel's queue. Measurements are taken from the time a packet enters the transmitter channel queue to the time the last bit of the packet is transmitted.

Let us now consider what can happen to a packet as it travels from its source to its destination. A packet starts in a host (the source), passes through a series of routers, and ends its journey in another host (the destination). As a packet travels from one node (host or router) to the subsequent node (host or router) along this path, the packet suffers from several different types of delays at *each* node along the path. The most important of these delays are the **nodal processing delay (**The time required to examine the packet's header and determine where to direct the packet), **queuing delay (**The time for which the package is waits to be transmitted onto the link. The queuing delay of a specific packet will depend on the number of other, earlier-arriving packets that are queued and waiting for transmission across the link), **transmission dela**y (The time required to transmit all bits of the packet in link) and **propagation delay** (The time required to propagate packet from a router to another along link)**;** together, these delays accumulate to give a **total nodal delay** [10].

$$d_{end-to-end} = d_{processing} + d_{queueing} + d_{transmission} + d_{ditribution} \quad (1)$$

VI. Summary of Configuration Used for Simulation

Below is presented a summary of all the parameters and values used for applications, which are used for simulation in this model. This summary is shown in Table 1 [11].

Table1. Configurations used for simulations.

Nr.	Description	Value	Unit
1	Speed link	2.378	Gbps
	Configurations for Video application		
2	Video frame rate	30	Fps
3	Video frame size	320x240	Pixeles
4	Start Time Offset	Constant(3)	Seconds
5	Inter-repletion Time	Exponential (300)	Seconds
6	Start time	Constant (100)	Seconds
	Configurations for voice application		
7	Encoder Scheme	G729A	
8	Frame size	0.010	Seconds
9	Voice frames per Packet	1	
10	Coding Rate	8	Kbps
11	Compression delay	0.02	Seconds
12	Compression delay	0.02	Seconds
	Configurations for FTP application		
13	FTP file size	Constant (5000000)	Bytes
14	Inter-Request Time	Exponential (720)	Seconds
	Configurations for HTTP application		
15	HTTP Specification	HTTP 1.1	
16	Object size	Constant (1000)	Bytes
17	Page Interarrival Time	Exponential (60)	Seconds
	Configurations for e-mail application		
18	E-mail Size	Constant (1000)	Bytes
19	Send Interarrival Time	Exponential (720)	Seconds
20	Receive Interarrival Time	Exponential (720)	Seconds

Numbers 4, 5, 6 presented in Table 1 are the same also for voice, FTP, HTTP, and e-mail applications. Besides configurations presented in Table 1 were used also some additional configurations, which are not included in Table 1. For video, we get High Resolution Video, while Type of Service (TOS) is taken Streaming Multimedia. For VoIP, FTP, E-mail and HTTP type of service is taken Best Effort. For FTP and E-mail traffic is taken Medium Load, while for HTTP we have taken Heavy Browsing. It should be noted that in this case all applications must operate simultaneously.

VII. Discussion and Analysis of Simulation Results

By exploiting configurations presented above the following will be discussed and analyzed of the obtained results through the OPNET Modeler 14.5 software. These results are gained for the case of topology shown in Fig. 1. Simulation time is limited to 10 minutes.

As mentioned above for FTP, HTTP, e-mail applications, delays that occur along the network are not so critical. However the same does not apply for Video and VoIP applications. Video and Voice applications are enough critical against delays that occur in the network, compared with FTP, HTTP and e-mail applications.

In this case analyses are realized for three routing protocols, respectively: RIP, OSPF and EIGRP protocols. For three routing protocols, for simulation the same configurations are used, respectively parameters shown in Table 1. By exploiting configurations in Table 1, below are graphics presentations of the results obtained from simulations.

In Fig. 2 are shown the results in relation with packets delays variations for video applications, for the three routing protocols.

A. *Analysis of results for video application*

The results obtained will be analysed and discussed, starting from average delay variations of packets. These results in relation with packets delays variations for Video applications, for the three routing protocols are graphically presented in Fig. 2.

From the results shown in Fig. 2, we can see that delays variations for RIP protocol are higher than for OSPF and EIGRP protocols. As seen for the case of OSPF protocol these variations are slightly higher than when along the configuration is used EIGRP protocol [11].

In Fig. 3, are shown the obtained results for the video applications of packages end-to-end delays, for the three types of routing protocols.

From fig. 3 we can see that when EIGRP routing protocol is used, the delay that is caused during network for video is 9 ms, for OSPF routing protocol delay is 11 ms, while for RIP routing protocols delay is 19 ms. From this we can see that the use of EIGRP protocol, has achieved an improvement of 2 ms regarding delays, compared with OSPF protocol, while in comparison to RIP protocol we have an improvement of 10 ms [11].

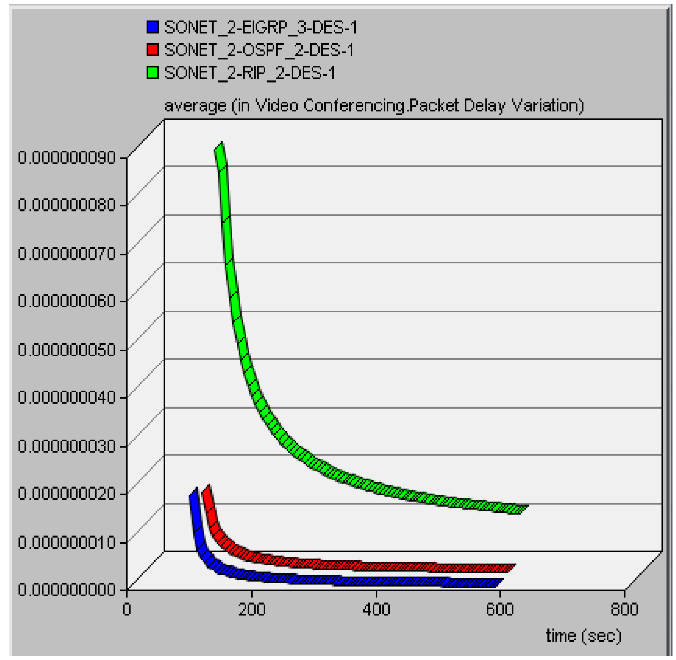

Fig.2. Average packets delays variations for case of video applications.

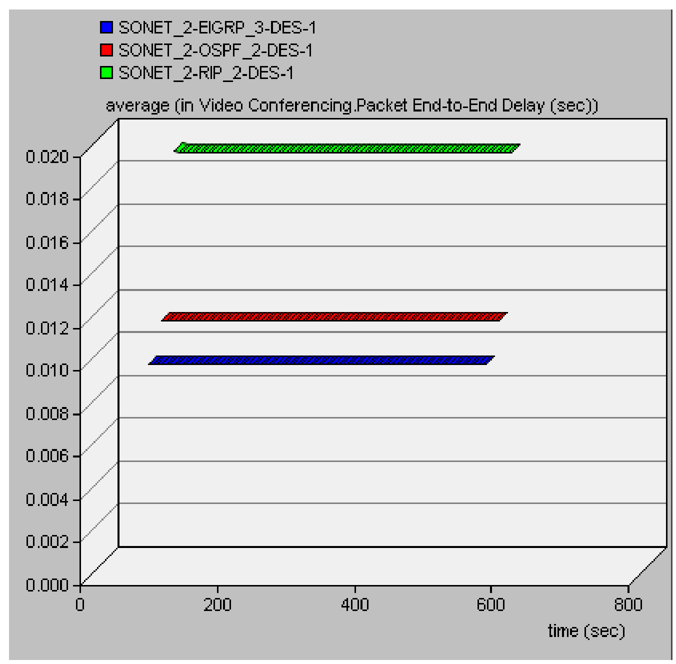

Fig.3. Average packets end-to-end delays for case of Video applications.

B. *Analysis of results for voice application*

In this sub section will be analysed and discussed the results obtained in relation to variations and delays that appear in the network for VoIP application.

In Fig. 4 are shown packets delays variations for the case VoIP for the three routing protocols.

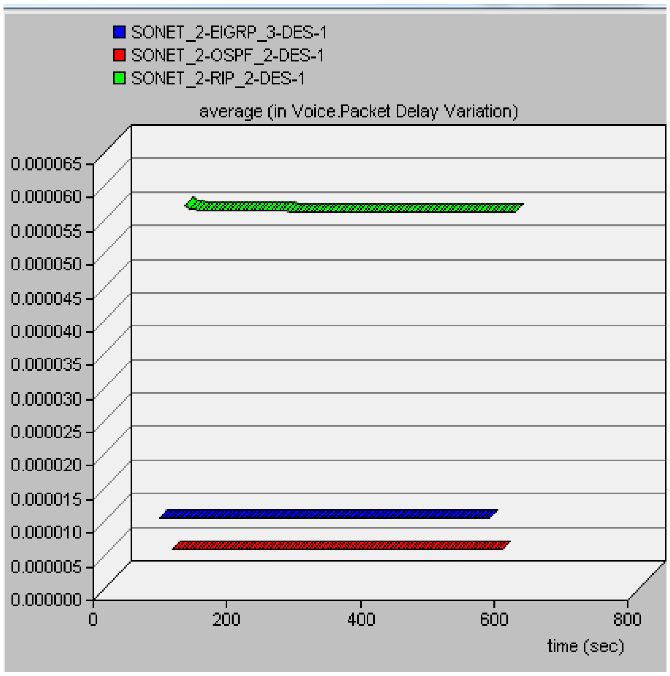

Fig. 4**.** Average packets delays variations for case of VoIP applications.

From Fig. 4 we can see that the variations for VoIP are lower when OSPF protocol is used for communication compared to the case when EIGRP and RIP protocols are used. But this difference regarding of packets delays variations is very small between OSPF and EIGRP protocols, while with RIP protocol this variation is higher.

In Fig. 5 we have presented end-to-end delays that are caused during network for the case of VoIP for the three routing protocols.

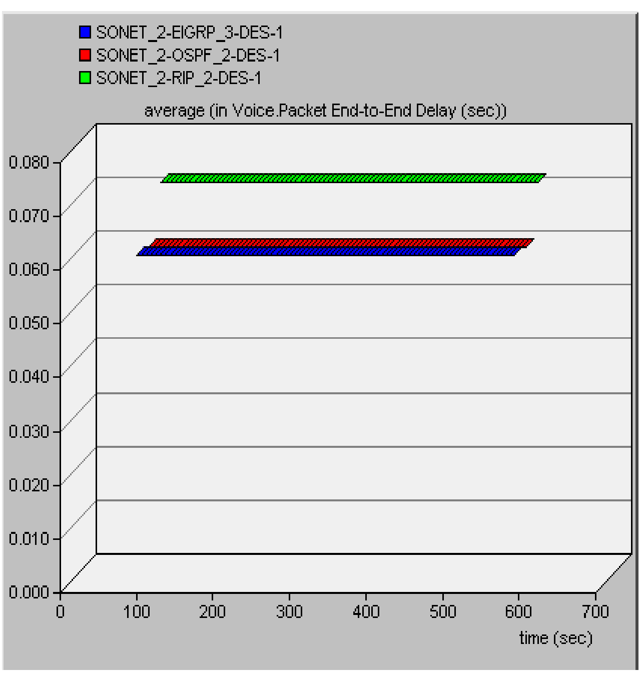

Fig. 5. Average packets end-to-end delays for case of VoIP communication.

From Fig. 5, it be seen that the delays that are caused during network for VoIP when EIGRP protocol is used for configuration is 57ms, for OSPF protocol is 58ms, while for RIP protocol this delay reaches up to 70ms. Thus as seen, the difference between the delays that occur in the case when for routing information during network EIGRP and OSPF protocols are used is very small, but in the case of RIP protocol this difference is for 13ms, respectively 12ms.

C. Analysis of results for HTTP application

In Fig. 6 are shown graphically the results obtained in relation to average object response time from HTTP page for the three routing protocols.

From the results shown in Fig. 6, we can see that average object response time from HTTP page, when for routing information along the network we have used RIP protocol, is starting from 7 ms and reaches 12ms, for OSPF protocol it starts at 4 ms and then drops to about 2.2 ms, while for EIGRP protocol this response time is about 1.9 ms to 1 ms.

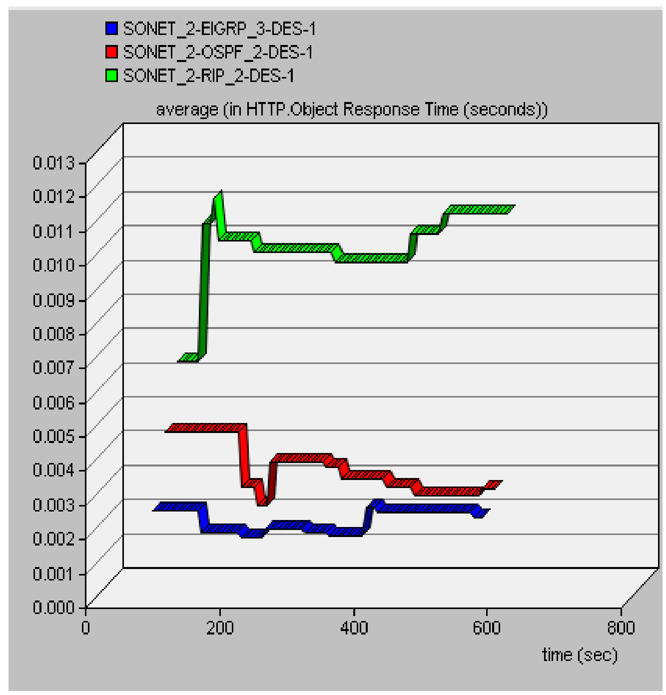

Fig. 6. Average object response time from HTTP page.

From the results obtained we can see that the response time for the case when EIGRP protocol is used for configuration is less compared to OSPF and RIP protocols. This difference is obviously higher compared to RIP protocol than with OSPF protocol.

While in Fig. 7 results obtained are graphically presented in relation to average response time the HTTP page with all its objects, for the three routing protocols.

From the results shown in Fig. 7, it can be seen that average object response time for the HTTP page, when RIP protocol is used for configuration, its starting from 32 ms and reaches up to 47 ms, while for OSPF and EIGRP protocols, this response time is approximately 7 ms. As we can conclude from this case, response time when OSPF and EIGRP protocols are used is significantly lower than when RIP protocol is used.

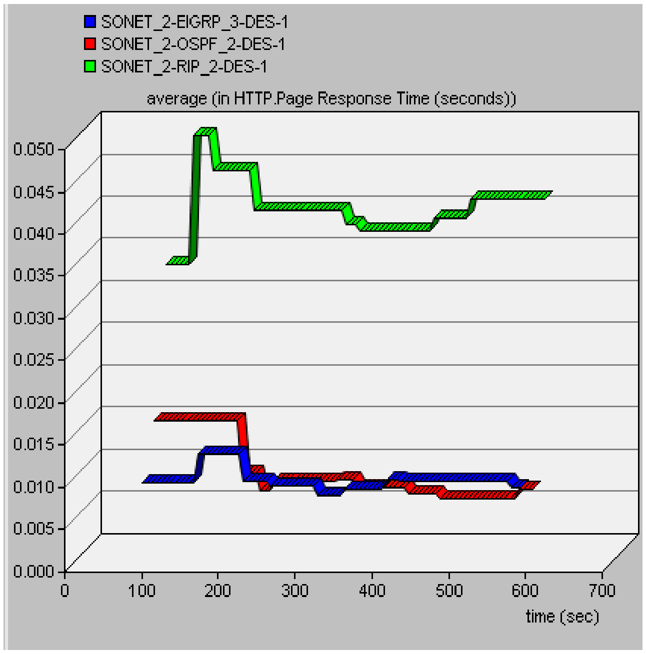

Fig. 7. Average object response time the HTTP page with all its objects.

D. Analysis of results for FTP application

Results obtained from simulations for FTP application are graphically presented in Fig. 8. Respectively, results obtained in relation with average time spent by sending a request for download to receiving the package as a response.

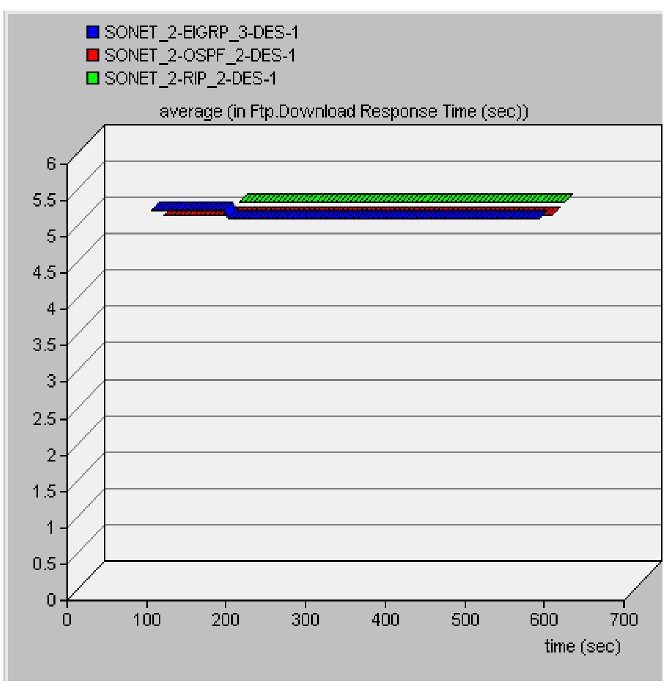

Fig. 8. Average response time for downloading FTP files.

From the results shown in Fig. 8, it can be seen that average response time for downloading FTP files, when during network RIP protocol is used for routing information is 5s, while for OSPF and EIGRP protocols, this time is approximately 4.8 s. From the results obtained we can see that for this case, there is no significant difference for the three routing information protocols regarding the response time. While the results obtained in relation with average upload response time for the FTP files, respectively response time from sending a request for uploading to receiving the package as a response for three routing protocols are presented in Fig. 9.

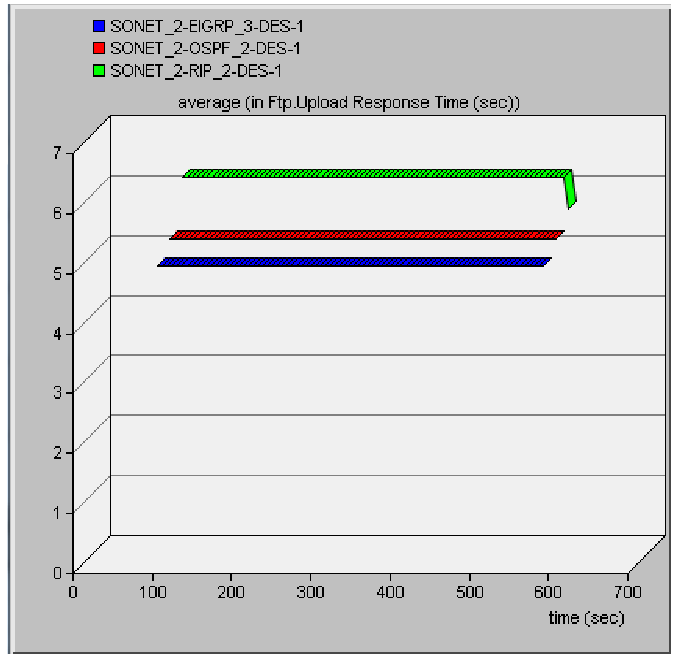

Fig. 9. Average response time for uploading FTP files.

From the results shown in Fig. 9, it can be seen that average response time for uploading FTP files, when RIP protocol is used for routing information is 6 s, for OSPF protocol is 5 s, while for EIGRP protocol 4.7 s. As seen in this case, response time for the case when EIGRP protocol is used for configuration is lower for 0.3 s compared to OSPF, while compared RIP protocol is for 1.3 s less.

Unlike the case shown in Fig. 8, where the difference regarding the response time was not so big, for the case shown in Fig. 9 this difference is more visible.

E. Analysis of results for HTTP application

Whereas the results obtained in relation to the average response time when downloading and uploading e-mails from the server will be graphically presented in Fig. 10 and 11. In Fig. 10 are shown the results in relation to download response time from the server.

From the results shown in Fig. 10, we can see that the average response time for downloading e-mails from the server, when RIP protocol is used during configuration of network devices is higher than for OSPF and EIGRP protocols. For the RIP protocol, this response time is approximately 31 ms. For OSPF protocol is approximately 18 ms, while for EIGRP protocol this response time varies approximately from 13 ms to 8 ms.

In Fig. 11 are shown the results obtained for the average response time in relation to the uploading of e-mails from the server.

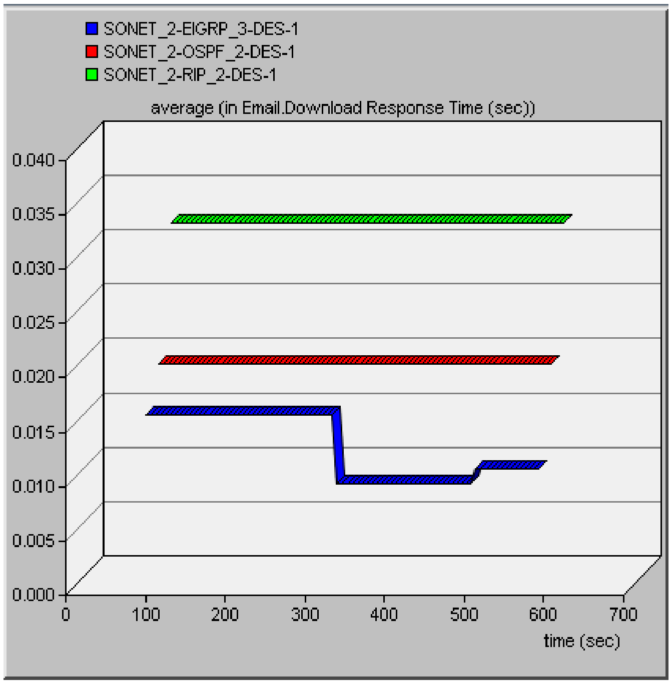

Fig. 10. Average response time for downloading e-mails from the server.

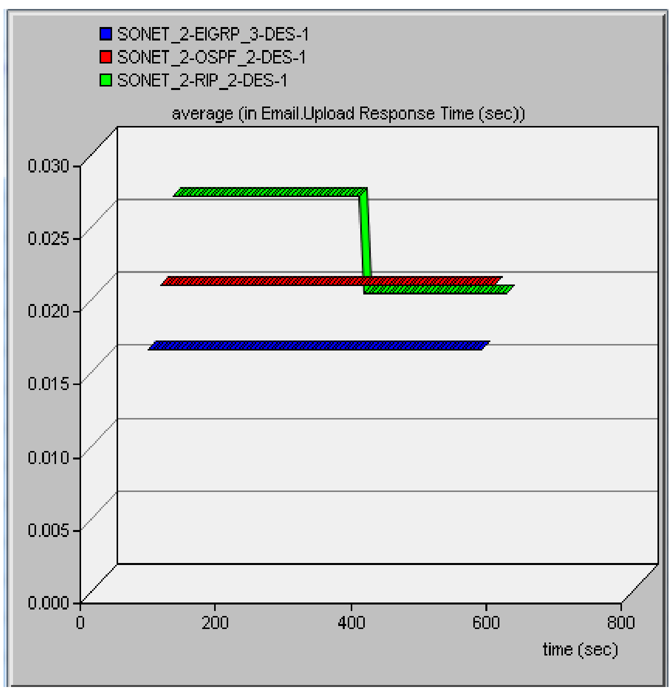

Fig. 11. Average response time for uploading e-mails from the server.

From the results presented in Fig. 11, it can be seen that average response time for uploading e-mails from the server, when RIP protocol is used during configuration of routers in the network for routing information is 26 ms.

This response time continues until the 420th second of the simulation, and after 420 seconds the response time reduces from 26 ms to approximately 18.5 ms, that is similar to the response time, when OSPF protocol is used for configuration. When EIGRP protocol is used for configuration we can see that the required time is approximately 15ms, which is for approximately 3.5 ms less time than in the two other protocol cases.

As can be seen, in both cases for e-mail application, response time is smaller when EIGRP protocols is used for routing information, than when RIP and OSPF protocols are used.

F. Analysis of results for queuing delay

In this sub section we will analyze the queuing delays caused as a result of the queuing between two points. Here we have taken for analysis the delays caused for Video 3 in Router A, during flow from the left side to the right side. Analyses in this case are conducted for three routing protocols. The results obtained are shown in Fig. 12.

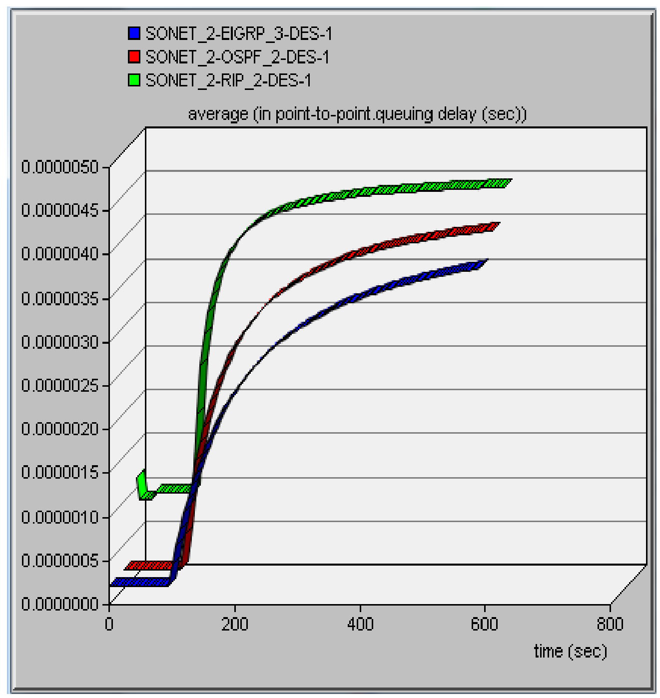

Fig. 12. Average queuing delay.

From the results obtained we can see that for EIGRP routing protocol queuing delay starting at 0.2 seconds and after 600 seconds of simulation reaches up to 3.5 μs. For OSPF routing protocol delay starting at 0.2 μs and after same time of the simulation reaches about 3.9 μs, while for RIP protocol starting from approximately 0.9 μs and after 600 seconds of the simulation reaches up to 4.4 μs. Based on the results presented in Fig. 12 we can conclude that when EIGRP routing protocol is used, queuing delays are smaller than when OSPF and RIP protocols are used.

VIII. Conclusion

In this paper OPNET Modeler 14.5 software is used for delays analysis that are caused during the network for FTP, HTTP, e-mail, VoIP and Video applications, depending from routing protocols that are used for communication. For analysis are used three routing protocols, respectively, RIP, OSPF and EIGRP protocols. Configurations used in this case, as mentioned, were taken the same for all three routing protocols.

From the results obtained it can be seen that the delays and variations are smaller when EIGRP protocol is used for routing traffic. A slight difference compared to EIGRP protocol, related to delays caused by the network, was seen when for routing OSPF routing protocol is used. While the most significant delays were caused in the case when for routing RIP routing protocol was used.

Moreover, from results presented above for FTP, HTTP, e-mail applications for which caused delays during network are not so critical, it can be seen that response time in relation to upload and download files, e-mail from the server, and object from HTTP page were shorter when EIGRP protocol is used for routing traffic than when OSPF and RIP protocols are used.

Based on results obtained we can conclude that the use of EIGRP routing protocol affects significantly in reducing the delay caused by network and response time compared to OSPF and RIP routing protocols. Although difference between EIGRP and OSPF protocols is not very significant in relation to delays that are caused during network. Therefore we can emphasize that using EIGRP and OSPF protocols for information routing will have a significant advantage compared to RIP protocol in order to reduce delays in the network.

In the future it remains to be verified if these conclusions are also valid for other cases of configurations, different network topology, other technologies and standards, because in this case study we have used the technology, respectively standard for optical networks, SONET.

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