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Frame Relay versus Asynchronous Transfer Mode: A Comparative Study and Simulation

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Abstract—Frame Relay and Asynchronous Transfer Mode (ATM) are two famous technologies in wide-area networks that use the virtual circuits for connecting and multiplexing many branches and networks. Those technologies can be used to carry different types of information such as real-time information which needs high data rate, low delay and an efficient throughput of the network's data communication devices. This paper is a study based on simulation for comparative performance evaluation between the Frame Relay and ATM to understand the overview and the nature of these technologies focusing on real-time applications using the OPNET simulation tool for analyzing the performance of voice application. The evaluation parameters are traffic sent, traffic received, delay, Jitter and the end-to-end delay which have been used to compare the performance of the ATM and Frame Relay in high-speed networks. The simulation results demonstrate that the ATM has high traffic sent, high traffic received, and less delay compared to the Frame Relay. In addition, this paper may be considered as an insight for the new researchers to guide them to an overview, essentials, and understanding of the virtual connections for Frame Relay and ATM.

Index Terms—Frame Relay, Asynchronous Transfer Mode, Traffic, OPNET, Voice, Real-time Applications.

I. INTRODUCTION

There are many techniques and protocols of the wide area communication for transferring data between remotely networks and devices. But, to carry out the real-time data with high accuracy and with minimum delay in high-speed network needs high-speed technologies. The Frame Relay and ATM are two well-known technologies that are used in these days.

They are considered as the variations of the legacy X.25 protocol to eliminate the data transmitted overhead and to provide best controlling of signals by carrying the signals on different channels and paths using the virtual connections[1].

Both Frame Relay and ATM are connection oriented protocols, support switching and multiplexing of multiple logical connections on the single physical link and they provide dynamic bandwidth allocation for efficient traffic management, but there is no processing of an error correction**.**

In addition, Frame Relay has the characteristics of packet switching network, variable packet size, more cheap cost than the ATM and other network's types like leased lines. It appeared in the early 1990s as the successful technique for X.25 by overcoming physical errors (e.g. noise lines) that were found in X.25. Hence it is taken as better controlled congestion, high performance, throughput and high speed compared to X.25 for the lowest two layers of OSI model (Link-layer and the physical layer)[1][2].

Whereas, ATM is known as cell relay, it was designed in the 1980s, and fit to standardize in ITU-T at 1987. ATM combines the circuit switching and packet switching of small size. It is designed for low latency in real-time applications like video and voice and high throughput like file transfer. But in this method there is minimum flow control and error control capabilities. The ATM’s virtual circuits are established for both the source and the destination devices [1][2].The data is transferred as fixed cell of 53 bytes long of both header (5 bytes) and data payload (48 bytes) [3].

Moreover, in the ATM a virtual channel is a logical connection similar to virtual circuit. The virtual channels which have the same end points can be grouped into virtual paths. Hence, all the circuits in virtual paths are switched together. This offers increased efficiency, architectural simplicity, and the ability to offer enhanced network services.

In general, the real-time applications such as voice over IP and video on demands need high data rate and throughput for data transmission from source to destination. The Frame Relay has less data rate than the ATM and it provides low quality for communication of those applications. Hence, this paper provides and analyses the comparative study between the Frame Relay and ATM to understand the overview and the nature of these technologies in Wide Area Network (WAN) for real-time applications. The analysis of voice application was done using the OPNET simulation tool based on the various parameters(traffic sent, traffic received, delay, Jitter and the end-to-end delay) to compare the performance of the ATM and Frame Relay in high-speed networks.

The rest of this paper is organized as follows. Sections II & III provide an overview of Frame Relay& ATM technologies respectively. Section IV presents the theoretical comparative study between Frame Relay and ATM. The OPNET simulator tool is defined in section V. Section VI performs simulation modeling & scenarios of voice applications for both Frame Relay & ATM using different parameters. Section VII describes the simulation results and discussion. Finally, the conclusion and future work is given in Section VIII.

II. Frame Relay

Frame Relay appeared in early 1990s. it is the backbone of a communication network for more companies and it is also provided by Internet Service Provider (ISP) for the remote intranet branches on different remote cities.

Moreover, it is an enhanced network of X.25 for reducing the End-to-end delay, equipment cost, and overhead of X.25. At the beginning, Frame Relay is developed to work on ISDN and now it is expanded to other public and private non-ISDN network interfaces. It is also considered as the backbone to provide services to upper layer protocols that have the network layer like IP. Furthermore, it has typical data rate from 64Kbps reach to 45Mbps (or T3).There are three types of frames show in table 1.

Table 1. The Frames Type

SN	Type	Description
1	Information Frames	Carry data as well as Next Send (NS) and Next Receive (NR) counts
2	Supervisory Frames	Controls flow of data with Receiver Ready (RR), Receiver Not Ready (RNR), and Reject (REJ) frames
3	Unnumbered Frames	Establish and maintain communications with Set Asynchronous Balanced Mode (SABM), Unnumbered Acknowledgment (UA), Disconnect (DISC), Disconnect Mode (DM) and Frame Reject (FRMR)

The data transfer in Frame Relay, which works typically on the data link layer, occurs in packets that are named frames. The virtual connections are recognized by the unique identifier that is called Data link connection identifier (DLCI)**.** The DLCI connections in Frame Relay devices are called 'ports'. All Data Terminal Equipment's (DTEs) devices that connected to frame relay network need a port that is unique for every remote device. However, there are 10 bits for DLCI's field value in the Frame Relay header that provides 1,024 different virtual connections or DLCIs.

Furthermore, the data terminal equipment (DTE) that connected to Frame Relay network needs a port that is unique for every remote device. There are two types of connections in Frame Relay such as the Switched Virtual Circuit (SVC) and the Permanent Virtual Circuit (PVC) which are defined by ANSI and ITU-T. The PVC has two stages of operational states as data transfer and idle. Whereas, the SVC has four operational states as call setup, data transfer, idle, and call-termination. The DTE's devices establish the virtual connections via call setup and then they transfer the data between DTE's devices. The idle stage means that the connection is active, but there is no data transferring. The call-termination, as the last stage, is tearing the virtual connection off [1][2][3][4].

There are two types of establishing connection between devices in frame relay which are the point to point and point to multipoint sub-interfaces connection. It is considered as the Non-Broadcast Multi-Access (NBMA) network that does not provide broadcast between its virtual channels by default and it provides multi access across PVC or SVC channels [4].

However, there are some limitations such as the function of Frame Relay is just to detect errors at the data link layer and there is neither error control nor hop to hop flow control of data. Furthermore, the Frame Relay is weak in control and administration of the congestion for the data traffic (e.g. drop packets when congestion occurs).Whereas, the upper layers are responsible for the error correction and flow control of an entire payload [1].

The author of paper[5] showed such limitations by comparing the Frame Relay with other networks like MPLS which has low latency and a labeling feature of packets instead of the huge process of routing that is based on IP addresses. He used OPNET simulator tool according to certain parameters as latency, Ethernet delay and traffic received.

III. ATM

ATM is a node or a switching device which routes cells. The cell is a basic transmission unit that is always fix length. Therefore, an ATM is also known as a cell relay.

The ATM has features of both circuit switching and packet switching techniques. Such ATM is implemented as controlled hardware and it is designed for using real-time applications with low latency, and also for using high throughput in case of file transfer. The same ATM uses an external or isochronous clocking for transferring data faster[3], and it can be deployed in private, public or hybrid networks either Local Area Network (LAN), Campus Area Network (CAN) or WAN.

The ATM header has two types of formats such as: User-Network Interface (UNI) and Network-Network

Interface (NNI) formats. Each type has two fields in each ATM cell header as Virtual Path Identifier (VPI) and Virtual Channel Identifier (VCI) that are reserved for the virtual connections.

The VPI field works as routing and it uses the virtual values for switching the cells between ATM's networks. In UNI interface the VPI field has 8-bits value to permit up to 256 virtual path identifiers (i.e. from 0 to 255 values). While, in NNI interface format the VPI field has 12-bits value to allow for 4,096 virtual path identifiers (from 0 up to 4,095).

Whereas, the VCI field is used as switching for the end users. This field has 16-bits value for both UNI and NNI interface formats which can allow to get 65,536 virtual channels. The actual values of such range from 32 to 65,535 are used for virtual circuit connections in ATM network, whereas the other VCIs values are reserved by ATM Forum and ITU-T. The combining of both VPI and VCI is referred to as virtual channel connection (VCC).The VCC is defined as allocating connection of VPI and VCI known as the connection identifier (CI) [1][6][7].

There are some previous studies in the area of the Frame Relay and ATM networks that are summarized and conducted as follows:

Reference [8], the authors analyzed and simulated the traffic of ATM and Frame Relay compared with the TCP/IP protocol for applications such as Email, voice, DB, FTP, and HTTP. The analysis depends on the end-to-end delay, throughput, and the response time. They concluded that ATM has better performance, low CPU processing time and the management is easily compared with the Frame Relay and TCP/IP.

Ref. "unpublished" [9], the authors have designed and discussed the ATM network topologies and then simulated and compared them to other networks such as Ethernet connects to the ATM backbone in order to obtain the performance of the ATM network using the OPNET simulation tool and some parameters such as delay and bit-throughput.

Ref. [10], the author gave some comparisons between the Frame Relay and the ATM in which they have the fidelity and reliability of digital facilities in order to provide fast packet switching. The most difference between them is that the ATM has a fixed size of packets called cells, while the Frame Relay has a variable length of packet size called frames. Also, the author provided the performance of comparative study of high-speed network like FDDI for broadband-ISDN (Integrated Services Digital Network) that is considered as a basic network for Frame Relay and ATM which can carry the multimedia applications like voice, video (animation) and images.

Ref. [11] authors discussed the asynchronous networks like ATM that provides high level service for supporting the voice communication type on the real time services such as voice and video sensitive to the traffic parameters.

They mentioned that the main reasons for ATM development were:

- Increasing demand for telecommunication and information technologies and services.
- Convergence of data and voice communication.

They used some traffic parameters that are delay, error rate and data loss. The ATM is low delay and faster for real time data.

IV. Comparison between the Frame Relay and ATM

This section provides the theoretical comparative study by summarizing the differences between the Frame Relay and ATM technologies using different criteria.

Frame relay is a telecommunication service designed for cost-efficient data transmission for different traffic between LANs and between end-points in a WAN. It puts data in a variable-size unit called a frame and leaves any necessary error correction (retransmission of data) up to the end-points, which speeds up overall data transmission. Frame relay complements and provides a mid-range service between ISDN, which offers bandwidth at 128 Kbps [2].

Whereas, the ATM has features of both circuit switching and packet switching techniques. it is a dedicated-connection switching technology that organizes digital data into 53-byte cell units and transmits them over a physical medium using digital signal technology. Individually, a cell is processed asynchronously relative to other related cells and is queued before being multiplexed over the transmission path. Because ATM is designed to be easily implemented by hardware (rather than software), faster processing and switch speeds are possible. The ATM, which operates in somewhat similar fashion to frame relay but at speeds from 155.520 Mbps or 622.080 Mbps [3]. The optimal length of cell relay depends on the data type. Long cell usually implies better throughput. The error checking is only done on the header in ATM rather than on the whole cell or frame. In addition, a virtual channel of ATM that follow the same route through the network are bundled into Paths. A similar mechanism is not in frame relay.

Table 2. Summarizes some differences between Frame Relay and ATM in their nature, definition, architecture, speed, data rate, coverage area and platform [1][2].

V. OPNET Simulator Tool

An OPNET is an abbreviation for Optimized Network Engineering Tools. It is visual environment and object-oriented model that uses the Discrete Event Simulations (DES) for wide measures of the network worldwide such as traffic data rate, throughput, end-to-end delay, receiving/sending packets, etc. It can be used for simulating the traffic, communication, protocols, guided and unguided networks[12][13].

Table 2. The comparison study between Frame Relay and ATM

Criteria	Frame Relay	ATM
Other Name	Frame Relay	Cell Relay
Frame Size	Variable & depends on the information sends.	Fixed & each cell is 53 bytes (header and data).
Platform	Software Controlled	Hardware implementation convenience.
Cost	Low	High
Overhead	Medium	Less
Throughpu t	Medium	High
Reliability	High	Low
Speed	Low	High
Data Rate	64 Kbps up to 45 Mbps (T3).	155.520 Mbps or 622.080 Mbps.
Coverage Area	Suitable for WAN and MAN only.	Suitable for WAN, MAN, LAN and CAN
Error Control	It does not support error and flow control, it let these function for upper layers.	It provides minimal error and flows control via 8 bits in ATM cell header called HEC (Header Error Control) that used at UNI interface format only.
Congestion control	Capability which are ideal for computer communications.	It does not support Congestion control
QoS	It does not support quantifiable Quality of Service (QoS).	It provides quantifiable Quality of Service (QoS).
Type of Traffic	Carry traffic in the form of data only.	Carry voice, video, image and busty nature of traffic.

VI. SIMULATION MODELING & SCENARIOS OF FRAME RELAY AND ATM

In this section the modeling topology and scenarios used in comparing the Frame Relay and ATM to recognize which of them can provide higher data rate and less delay than the other for the real-time applications in high speed network. The evaluation metrics are based on the various parameters (traffic sent, traffic received, delay, and the end-to-end delay) measuring in the units of packets per second or bytes per second. The OPNET simulator tool (14.5) with the similar scenarios for both Frame Relay and ATM topologies are used with 15 minutes' simulation run time.

Voice conferencing is set using Pulse Code Modulation (PCM) quality speech so that a high quality of voice traffic can be generated and easily viewed by the receiver. An encoding type called G.711is operated at bit rate 64 kbps for transferring Voice over Internet Protocol (VoIP)[14] [15]. The next subsections show and discuss the topologies used in both technologies.

A. *Frame Relay*

This section shows and describes the topology that is used in this simulation for the Frame Relay. Fig. 1, shows the Frame Relay Topology.

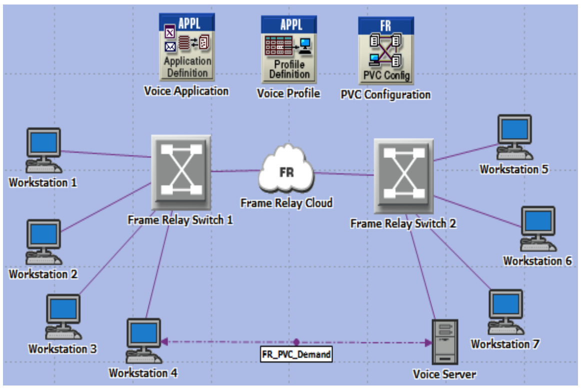

Fig.1. The Frame Relay Topology

The Frame Relay devices and applications are easily chosen from the Frame_Relay_Advanced menu. In the network model, the given network topology has been composed of following network devices and configurations which includes network devices name, types and how many devices needs to each type that is used in simulation. Table 3, shows configurations of the Frame Relay.

Table 3. The Frame Relay Devices, Types, and Number of Chosen Devices

SN	Device Name	Device Type	Number of chosen devices
1	Application Config.	Application (Voice)	1
2	Profile Config	Application (Voice)	1
3	FR PVC Config	Frame Relay Application	1
4	Fr32_cloud	Frame Relay Cloud	1
5	Fr8_atm8_switch_adv	Frame Relay Switch	2
6	Fr_wkstn_adv	Workstation	7
7	Fr_server_adv	Server	1
8	FR_E1_int (Duplex Link)	Link Models	10
9	FR_PVC_Demand	Demand Models	1

B. *ATM*

This section shows the topology used in this simulation for the ATM with the same scenario condition that is used in the Frame Relay. Fig. 2, shows the ATM Topology.

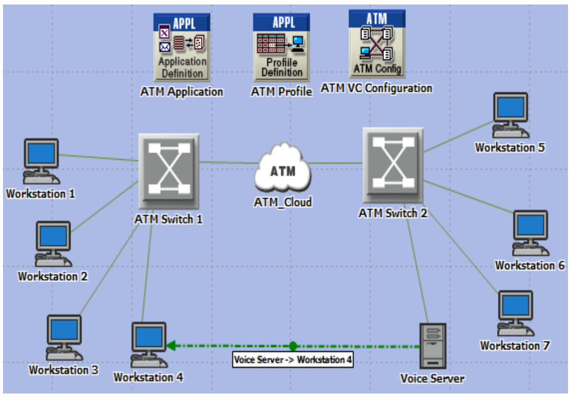

Fig.2. The ATM Topology

The ATM devices and applications are chosen from the ATM_Advanced menu. In the network model, the given network topology has been composed the network devices and configurations which includes network devices name, types and how many devices need to each type that is used in simulation as shown in Table 4.

Table 4. The ATM Devices, Types, and Number of Chosen Devices

SN	Device Name	Device Type	Number of chosen devices
1	Application Config	Application (Voice)	1
2	Profile Config	Application (Voice)	1
3	ATM PVC Config.	ATM Application	1
4	ATM32_cloud_adv	ATM Cloud	1
5	ATM16_crossconn_adv	ATM Switch	2
6	ATM_wkstn_adv	Workstation	8
7	ATM_server_adv	Server	1
8	ATM_adv (Duplex Link)	Link Models	10
9	AAL5_G711 Voice	Demand Models	1

VII. Result and Discussion

This section describes and assesses the obtained results conducted from the simulation scenarios mentioned in the previous section as follows.

A. Traffic Sent

The traffic sent is the parameter that influences an overall performance of the network which can measure the amounts of data sent from the source to the destination.

Fig. 3, depicts the traffic sent for both ATM and Frame Relay. It indicates that the ATM network provides the best and high data rate of traffic sent (indicates the blue line) better than the data rate of Frame Relay network (shown in the red color line) for the voice application. It shows that the traffic sent in ATM network is 1,400 Packets per second, whereas 800 Packets per second for Frame Relay. Then, it can be said that the ATM is suitable for carrying the real-time applications such as the voice which needs high data rate of traffic sent. In another way, Fig. 4 shows the results for the same parameter in bytes per second for the voice application.

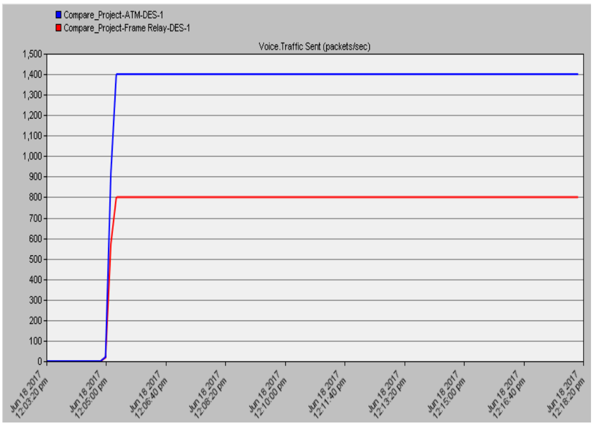

Fig.3. Traffic sent (packets/second) of Frame Relay and ATM

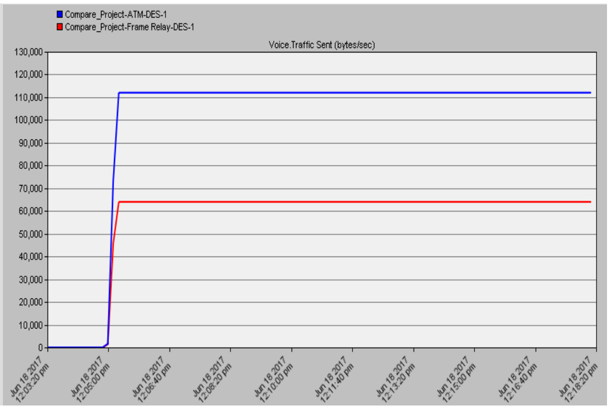

Fig.4. Traffic sent (Bytes/Second) of Frame Relay and ATM

It is observed that the ATM network has the data rate of traffic sent (indicates the blue line) approximately 112,000 bytes per second, whereas the Frame Relay has traffic sent approximately 63,000 bytes per second (shown in the red color line). Therefore, it is concluded that the ATM provides higher data traffic sent than the Frame Relay for the real-time voice application. Hence, the ATM is a suitable network which needs high data rate and low delay through the communication between the source and destination.

B. Traffic Received

The traffic received is another important parameter that influences an overall performance of the network which can measure the amounts of received data at the destination.

Fig. 5, depicts the traffic received for both ATM and Frame Relay. It indicates that the traffic received in ATM can reach to 1,200 packets (or cells) per second whereas it can reach to approximately to 200 packets (or cells) per second for Frame Relay. Therefore, it demonstrates that the ATM has faster data flow than Frame Relay. Thus, the ATM is more suitable for voice communication.

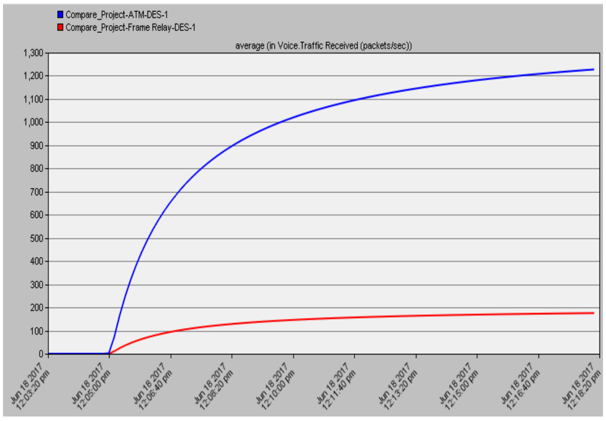

Fig.5. Traffic Received of Frame Relay and ATM in Packets/s

In addition, the Fig.6., shows the traffic received of ATM network approximately reaches to 100,000 bytes per second (shown in the blue color line) and the traffic received in Frame Relay approximately reaches to 13,000 bytes per second (shown in the red color line). Hence, the data received in ATM are greater than in Frame Relay, so the ATM network works better than the Frame relay for voice transmission type.

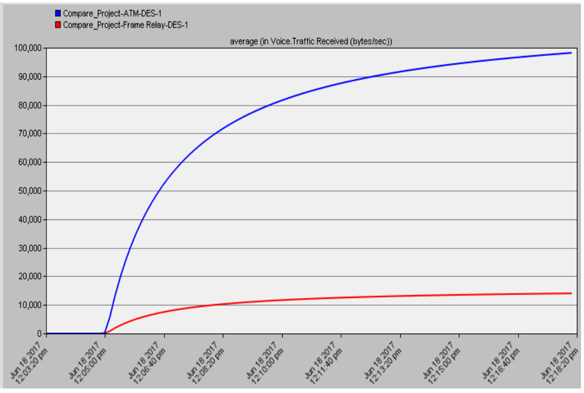

Fig.6. Traffic Received of Frame Relay and ATM in bytes/s

Moreover, fig. 4, and fig. 6 analyzed the relation between the traffic sent and traffic received. It observed that in ATM, the traffic send is 112,000 bytes per second and the traffic received of 100,000 at the destination with losing only approximately 12,000 bytes per second. While the Frame relay traffic sent is approximately 63,000 bytes per second and the traffic received at 13,000 bytes per second with the loss of approximately 50,000 bytes per seconds. This proves that the ATM is approximately four times faster than the Frame Relay. Also, the delay in ATM network between traffic sent and traffic received is less compared to Frame Relay network.

C. Delay

Delay is an important parameter that can be used to measure the overall performance of the network. Fig. 7, illustrates the difference between the voice packet delay in both methods.

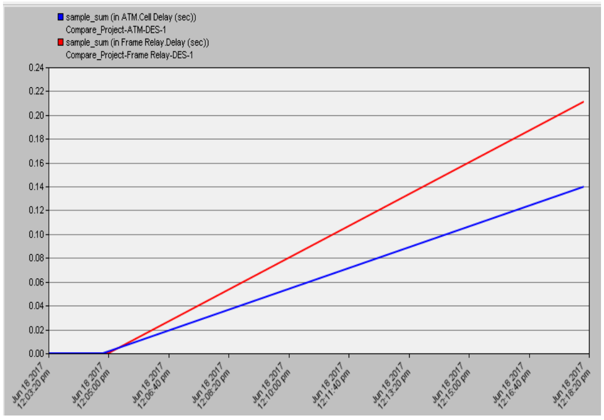

Fig.7. The Frame Relay and ATM Delay

According to the Fig. 7it is seen that the ATM network has the delay about 0.14 time units whereas the Frame Relay has the delay about 0.21 time units. As a conclusion it is observed that the ATM is more efficient than Frame Relay in voice transmission because the ATM has a small fixed size of cells and an external clocking which can increase the speed and decrease the delay.

D. Jitter

The jitter is defined as the delay variation of data communication between two end systems.

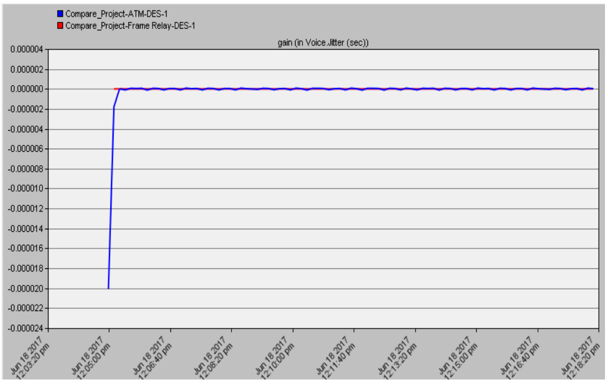

Fig.8. Jitter for Frame Relay and ATM

The Fig. 8, observing the ATM cells begin from negative values, this assure that the difference of time at the destination device is less than at the source device, after that stable at the same line 0 value like the Frame Relay jitter.

E. End to End Delay

The last parameter used in this simulation is the end-to-end delay. It is defined as the time taken to transmit the packet through the network from source to destination. In the end-to-end delay, there is some slight difference between the ATM and the Frame Relay as shown in the Fig.9.That is to say the ATM has relatively less end-to-end delay than the Frame Relay for the permanent virtual connection between the server and the workstation at the other side of the network.

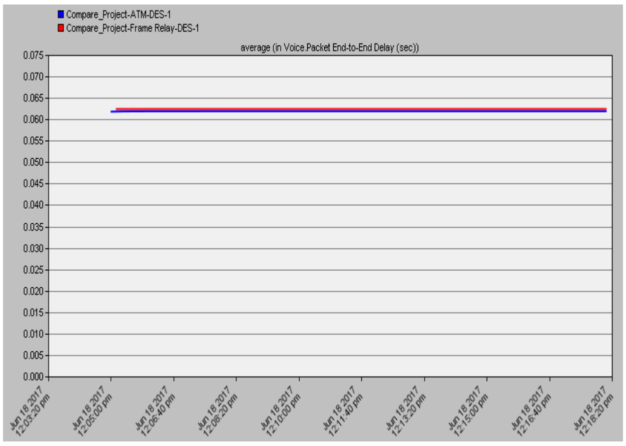

Fig.9. End-to-end delay of Frame Relay and ATM

VIII. CONCLUSION

Frame Relay and ATM are two famous wide area communication technologies used for transferring data between remotely networks and devices. Therefore, this paper presents the comparative study between the Frame Relay and ATM for voice real-time applications using the OPNET simulation tool according to some parameters (traffic sent, traffic received, delay, Jitterand the end-to-end delay). The theoretical comparative study and simulation results show that the data rate of ATM is better than that of Frame Relay. The obtained results from the simulation show that both parameters traffic sent and traffic received are higher in ATM and the delay is less than what is in the Frame Relay. Hence, this comparative study can assess that the ATM has better transmission performance than the Frame Relay for the real-time applications such as Voice over IP. In Future work, we will compare the ATM and Frame Relay with other communication networks technologies.

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