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Analysis of WDM Network using NGPON

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Abstract: In present day communication has become an important aspect for everyone. In our digital age, it is almost impossible to imagine our lives without the internet. The biggest advantage of the internet is its accessibility and it is easy to use, everything is just a click away. Thus optical fibres are an essential technology for data demand in this generation. All the application requires the internet for its availability, these applications range from mission-critical to the social media. Hence it is certain that the services level should be at its best. PON networks which use WDM technology are now used to fulfill the demand. The latest PON network is the NGPON2, which has proven to provide better service among all the others. Hence, we have implemented the same. The parameters which we consider are throughput, congestion and packet drop. These parameters of the network should be analysed thoroughly in the network so as to increase the efficiency of the packet delivery in the network. The results are shown in the simulation tool.
Keywords: NGPON2, WDM, PON, Throughput, Congestion, Packet drop

I. INTRODUCTION

Since the beginning of the digital era, the internet has been blooming since then. The Internet has become a need. The data consumption has increased drastically, which requires a system which has the capacity to deliver the services with demand. This can be achieved with the help of optical fibre. Optical fiber access systems are one of the driving forces behind the success of the Internet. Passive optical networks (PONs) are the key technology for providing low-cost access services [13].

The architecture of PON networks has two main components, namely optical line terminal (OLT) and optical network units (ONUs). The OLT is placed in the central office and the ONU near the users. Optical Distribution Network (ODN) is the one which connects both of these through optical fibres and power splitters.

There has been a lot of development in this area. Many PON standards are given by the International Telecommunication Union (ITU). Some of them are Gigabit-capable PON (G-PON) [7], Ethernet passive optical network (EPON), 10-Gigabit-capable PON (XG-PON) [8]. The latest recommendation by ITU is the next generation-PON2 (NG-PON2) [9]. NGPON2 includes time- and wavelength division multiplexing PON (TWDM-PON), Opportunistic and dynamic spectrum management PON (ODSM-PON), etc.

In this paper we analyse the WDM network using the NGPON2 through simulation by considering packet drop, congestion and throughput as the parameters. Section 2 gives a brief survey of the papers required for the analysis. In Section III we can see the network architecture and how the implementation is carried out explained pictorially by a flow chart. In section IV the results obtained from the simulations considering the selected parameters are shown and explained with section V explaining why NGPON2 is selected and why it is better than the other PON. This all in together will result in the NGPON to show the packet transfer efficiency in the WDM network.

II. LITERATURE SURVEY

Wavelength division multiplexing is now one of the conventionally used technologies for high capacity optical communication. It raises bandwidth by permitting discrete data packets to be sent at the same time over an optical fiber. The WDM base exists in the capacity to send various kinds of information over fiber networks as light. By permitting distinctive light channels, each with its own remarkable force, to be sent at the same time over a fiber optical network of a solitary network is made. Instead of using multiple strands per service, a single fiber can be assigned to specific services [1].

The information which is transmitted through downstream in the Wavelength division multiplexing - passive optical network (WDM-PON) framework is carried out through an optical line terminal to the optical node unit as to cut through the outer source module thus it gets the seed light to do so. There are two attributes which can be looked into in this framework. One of them is that the optical transmitters of the WDM-PON nodes are working, paying little need for optical frequency. Another one which we can say is that the EPON or GPON ONU can be obliged without making any change [2].

The WDM base exists in the capacity to send various kinds of information over fiber networks as light. By permitting distinctive light channels, each with its own remarkable force, to be sent at the same time over a fiber optical network of a solitary network is made [3].

WDM-PON system as per an encapsulation of the current innovation, including: an optical line end situated at the focal office, and for transmit chime an optical sign to a Subscriber side and accepting an optical sign from the Subscriber side, a seed light module situated at the central office, and for Supplying a range cut seed light including a majority of wavelengths to corresponding optical transmitters of the optical line termination, an optical network unit situated at the Subscriber side, and for accepting an optical sign from the optical line termination, changing over the equivalent into an electric sign to get downstream data and transmitting an optical sign containing upstream information to the optical line end and an optical wavelength change gadget situated at the Subscriber side, and for wavelength-changing over upstream and downstream signals into signs of various groups [4].

Theodoros has compared three PON architectures namely GPON, XGPON, and NG-PON2. He has calculated Net Present Value (NPV), Internal Rate of Return (IRR) and payback period for each network. Also population density is also taken into account. As NG-PON2 offers better bandwidth and speed, it is considered to be a future proof solution especially in high population areas [22].

A regular WDM PON engineering that consists of a CO (central office), two cyclic AWGs (array waveguide gratings), a trunk or feeder fiber, a progression of conveyances strands, and ONUs toward the clients. The primary periodic AWG that situates at CO multiplexes downstream frequencies to the ONUs and demultiplexes upstream frequencies from the ONUs. The storage compartment fiber conveys the multiplexed downstream frequencies to a second periodic AWG that situates at RN. The second AWG demultiplexes the downstream frequencies and aids each into a circulation fiber for transmission to the ONUs. The downstream and upstream wavelengths dispensed to each ONU are isolated by a several of the free spectral range (FSR) of the AWG, permitting the two wavelengths to be coordinated all through the equivalent AWG port that is associated with the goal ONU. The advantages of WDM PON incorporate convention and bitrate straightforwardness, security and protection, and simplicity of upgradeability and system the executives [5]. As the demand for higher bandwidth increases, many research is happening. One important technology is Time and wavelength division multiplexed Passive Optical Network (TWDM-PON), is it considered to be a primary solution for NGPON2. The authors in [21] have reviewed different TWDM technologies. They have also analysed hybrid architecture. They have shown that TWDM-PON solution is best for optical-wireless networks [21].

Jerome and et al, have analysed the TCP performance over XGPON architecture. They have taken efficiency, fairness, responsiveness, and convergence as parameters. They have implemented three TCP variants namely Reno, CUBIC and H-TCP [23].

WDM conveys limits and arrives at that empowers administrators to think administration creation motors and information preparing in less locales that sit farther, harking back to the system. A definitive objective is to serve up to 1,000 endpoints within any event 1,000Mbit/s over a separation of up to 100km. This is just possible when WDM is remembered for the entrance and backhaul systems. This WDM-PON-based model prompts an extreme redesign of existing operational models and, eventually, to reasonable broadband conveyance [6].

Horath and et al, has using OPNET modeler to implement NGPON2 network. The simulation of static and dynamic grant allocation are shown. The simulation has 8 ONUs, Max-Min fair algorithm was used. They used simplified NGPON2 for their implementation [20].

III. METHODOLOGY

NG-PON, also called as the next generation passive optical network are used in Wavelength Division Multiplexing that is, WDM or Time Division Multiplexing this is, TDM or also in networks which use both the multiplexing. Here in this paper we are analysing the WDM network using NG-PON.

Let us consider an example of the network as shown below and analyse the network.

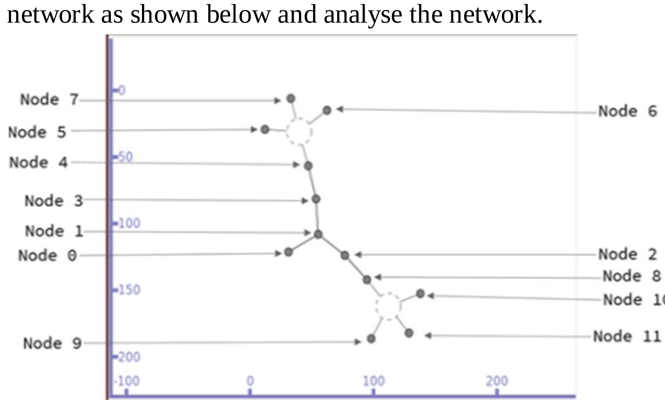

Figure 1: Network Architecture

The figure 1 shows the network architecture, the node 0 is the base station. The node 1 is called Optical Line Terminal (OLT). It is generally located in a central office. The node 2 and node 3 are Optical network Units (ONU). Many ONU is located near the user's premises. They are connected through the optical distribution network (ODN), which consists of optical fibre and power splitters located in the outside plant. All these nodes are connected using point-to-point links. All nodes together form the next generation passive optical network (NGPON). The nodes 4 and 8 are the user nodes. These nodes mainly connect the end nodes to the base station. The nodes 5, 6, 7, 9, 10 and 11 as CSMA nodes are connected in ring topology. These nodes are connected through CSMA channel.

The functionalities of the nodes present in the NGPON network that is the OLT node, ONU nodes and the ODN are explained. As we all know that NGPON2 is the world's earliest multiple wavelength passive optical network ODN is used for selecting the wavelength in the optical distributed network. OLT Node being bidirectional floats in both upstream and downstream directions. It helps in accessing the information of the ODN. In Upstream functionality, OLT is used for distributing the traffic of the data and voices to ODN collected from the users by OLT. In downstream functionality, the OLT node gets the information from the metro network about the traffic of vice data and the video. The other type of node present in the NGPON2 network is the ONU node. The ONU node can be considered as the end of the ngon2 network from where we connect to as many numbers of users connecting through Wi-Fi or copper wire or optical fibre. It transmits the optical signals in the NGPON2 network to the electrical signals to transmit to the users and also vice versa.

Here the user nodes are considered to be the CSMA nodes. Here the CSMA network is considered because of its advantages. In this network to prevent the collision of the data being transmitted only one node is allowed to transmit at once. This is made sure by checking the channel whether any data is being transferred prior to that particular node to start the transmission.

In this the packet is delivered from CSMA nodes and is delivered to the base station through the user node and the NGPON2. The transmission can be carried out by any number of nodes from the CSMA network. The analysis of the network is shown by simulation in the NS3 Network. We have considered NS3 Simulator as it is best suitable for network research which is free and open source simulation software. It also is best for optical simulations.

In the built routing function used, the function first calculates the shortest path using Dijkstra SPF routing algorithm. And populates the same in the forwarding table.

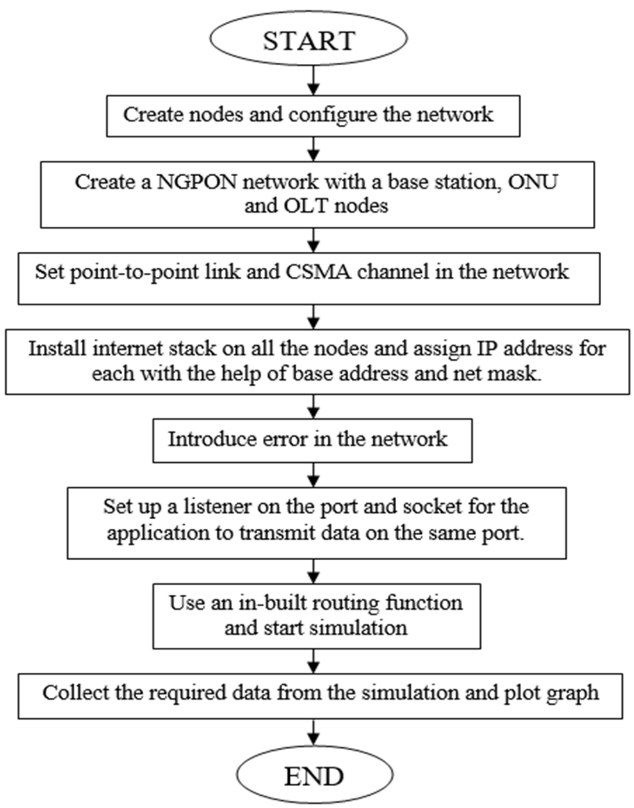

Figure 2: Control Flow Diagram

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A. First the network is configured. The parameters like number of nodes, simulation time, interval time between packets, start delay for beacon jitter, size of packet etc., are set.
B. Then the nodes are created. The NGPON network is configured. The base station, OLT node and the ONU nodes attribute like netmask length are set. Then we set up a point-to-point channel between all nodes in the NGPON network. We also define the channel attributes. The CSMA channel attribute is set between the CSMA nodes.
C. The next step is to install protocol stack on all the nodes. Then the network id and the subnet mask are obtained to assign the IP address of each node. Error is added to the network in order to run the simulation, since it depicts the real-life scenario.
D. To capture the packet transmission, we set up a listener on port. Therefore, it requires a socket on that port which captures all the activities. This listener listens for the provided clock time. Then we put some traffic over these ports, from CSMA nodes to the base station.
E. The packets are routed to the destination using an inbuilt routing function.
F. During the transmission, the parameters like congestion changes and packet drop information are collected. Also, the throughput is calculated. Then graph is plotted for analysis.

IV. SIMULATION RESULTS

We show the simulation results for the NGPON network using a simulation tool, which is NS3. We measure the system based on the following parameters: Throughput, Congestion, and Packet drop.

Throughput is the number of data packets transferred per second. It is calculated as the ratio of overall number of packets transmitted to the total time taken to transmit them. Congestion takes place when a network nodule is carrying supplementary data or packets than it can handle, it affects the performance degradation. Packet drop happens when the packet is not delivered since there are more packets in the network that cannot be delivered.

In the simulation we have implemented a NGPON network with one node, two node, four node and six node transmissions.

A. One Node Transmission

In figure 3, the packet transfer is occurred from one node from the CSMA network, in here from the mesh topology to the base station. Here the ONU node transfers the packets to the OLT node of the NGPON network from there though the point to point network, packet is transferred to the base station.

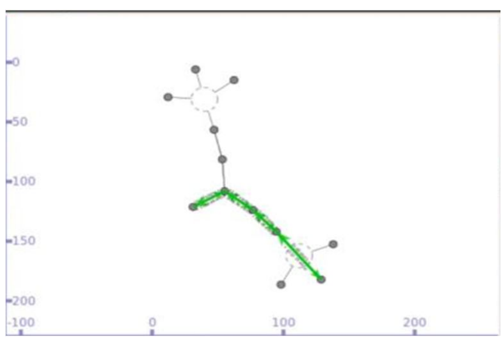

Figure 3: One Node Transmission

B. Two Node Transmission

In this two node transmission as shown in figure 4, the transfer of packets is carried out to the base station from the two nodes from two different mesh topologies.

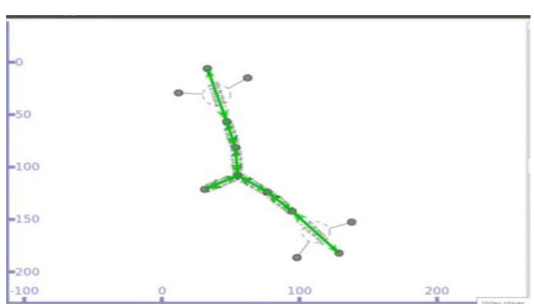

Figure 4: Two Node Transmission

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C. Four Node Transmission

As shown in figure 5, the transmission is carried out from four nodes. Here the packets are transferred to the user nodes from the CSMA network nodes and then to the base station. Two nodes of the same CSMA network use a single point-to-point channel to reach the base station.

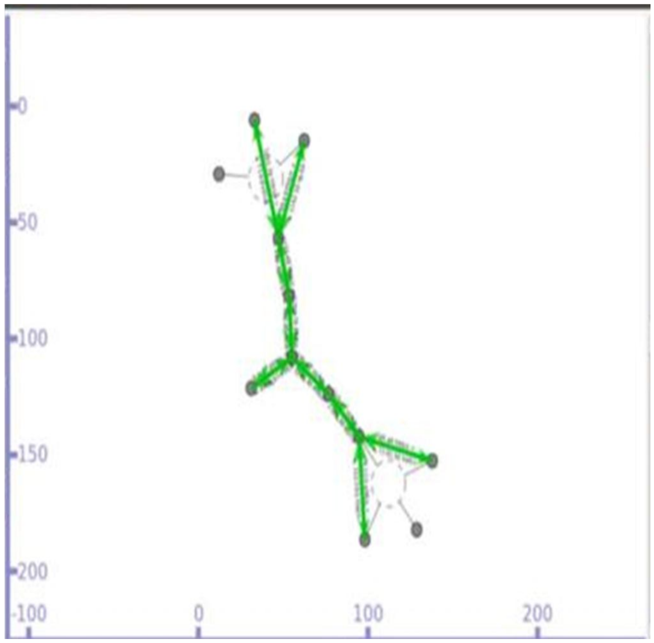

Figure 5: Four Node Transmission

D. Six Node Transmission

In figure 6, the transmission is carried out between six nodes. Here the packets are transferred from two nodes of each CSMA network to the respective user nodes, which passes the packets to the base station through the optical fibers.

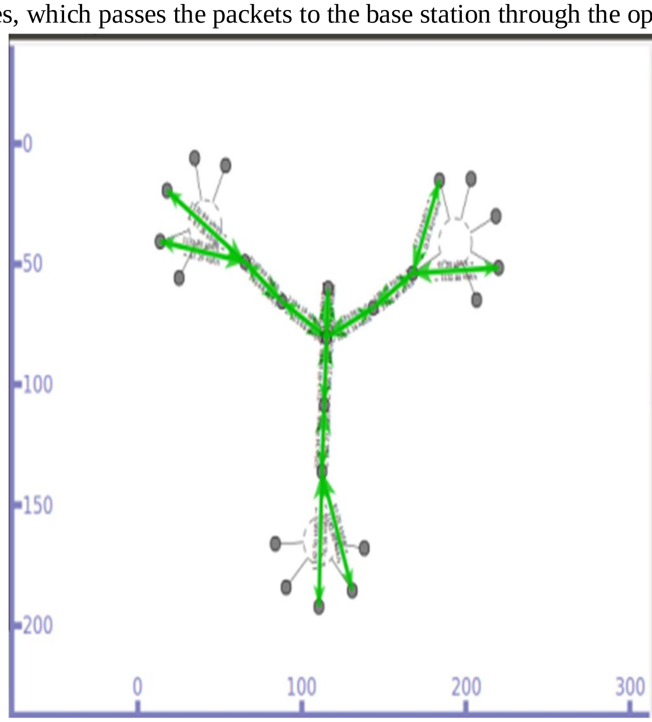

Figure 6: Six Node Transmission

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V. RESULTS

A. Throughput

The figure 7 shows the trace of transmission. It displays the sender address and destination address along with transmitted and received packets. It also shows the throughput at that transmission and the final throughput of the whole transmission.

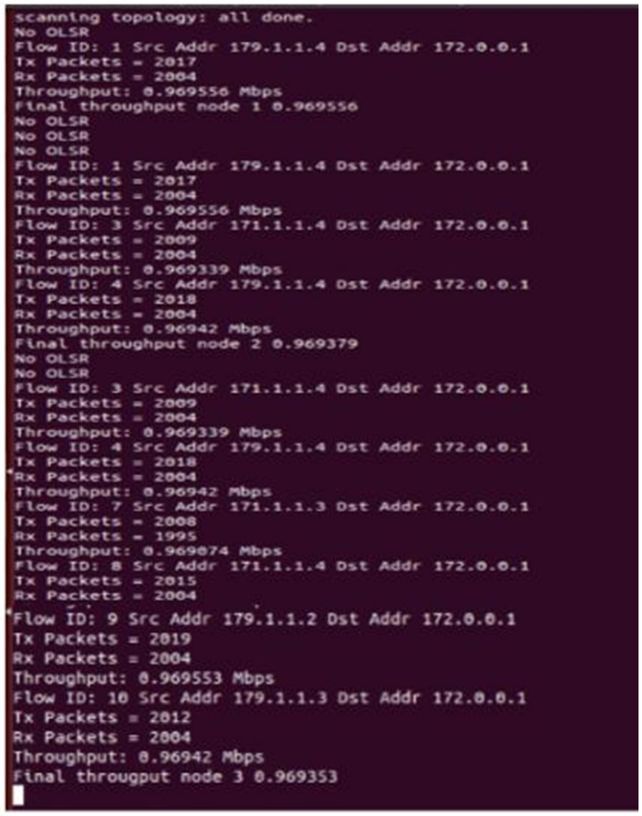
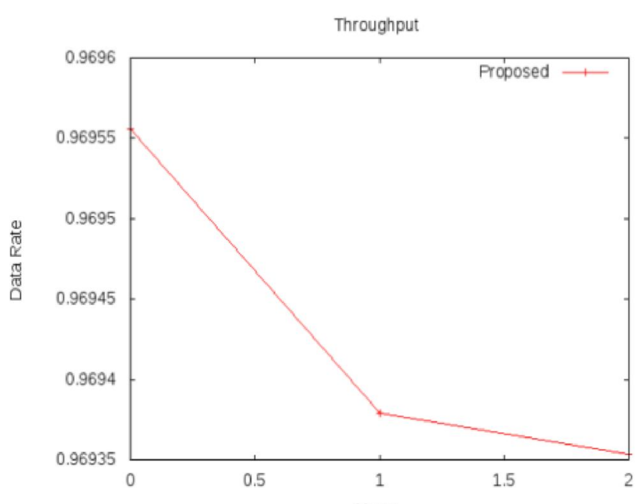


Figure 7: Throughput of different node transmission

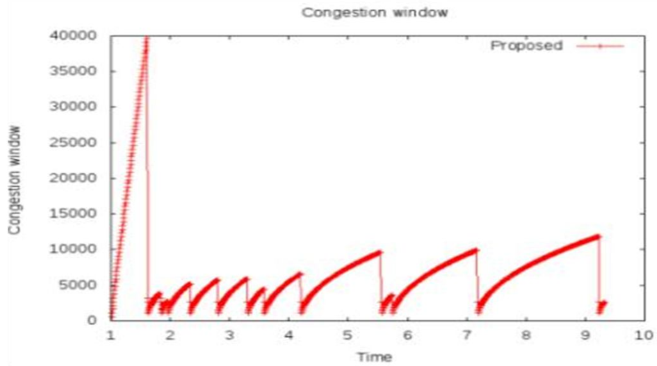
We have plotted a graph of data rate versus no of users, as shown in graph 1, there is a negligent decrease in the throughput. The values for one user are the same as two users. And as the users increase the NGPON2 network is capable of delivering higher throughput.



Graph 1: Graph of calculated Throughput of NGPON2 network

B. Congestion

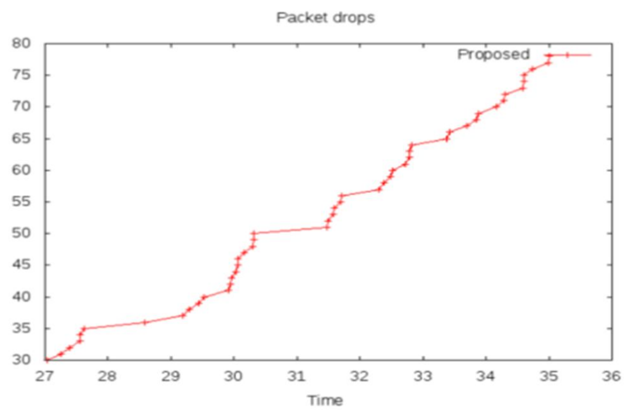
The congestion graph in Graph 2 is similar to TCP Tahoe. TCP Tahoe is a congestion control algorithm which has three mechanisms: Slow Start, Congestion Avoidance and Fast Retransmit. It works on the packet conservation policy [16].



Graph 2: Congestion graph of the transmission in NGPON2 network

C. Packet Drop

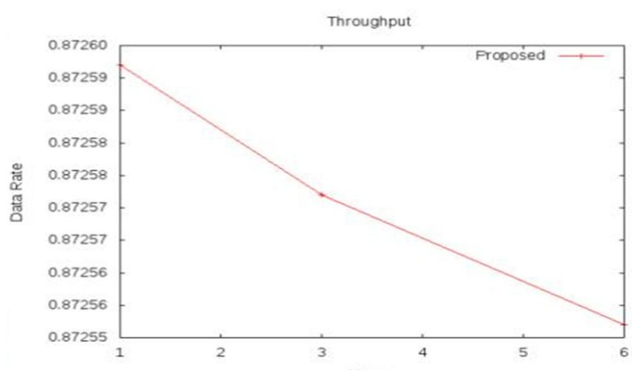
Packet drop in case NGPON network is shown in Graph 3. Packet drop is an important parameter defining performance.



Graph 3: Packet drop during the transmission in NGPON2 network

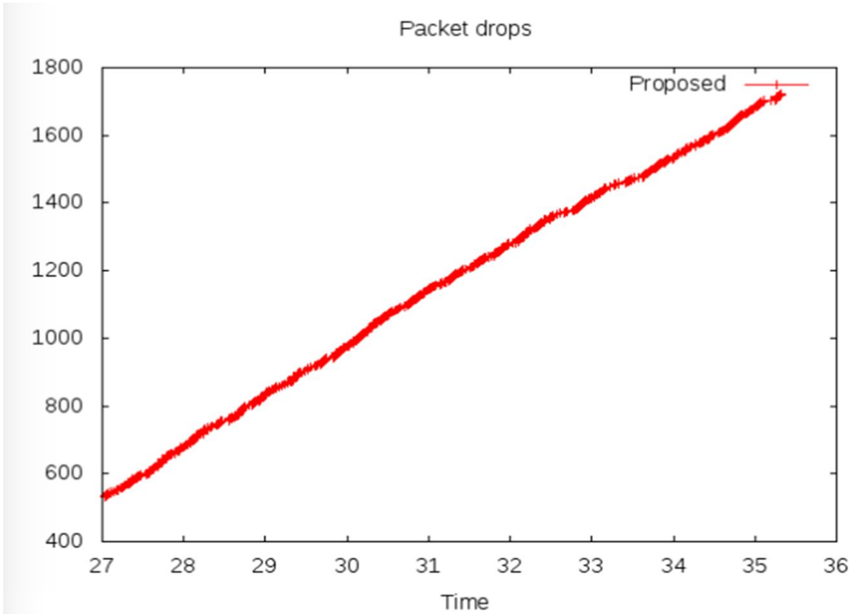
VI. COMPARISON

We have compared the NGPON2 network with the Wi-Fi network. If we compare the corresponding graph of both the networks, we see that NGPON2 has better performance.

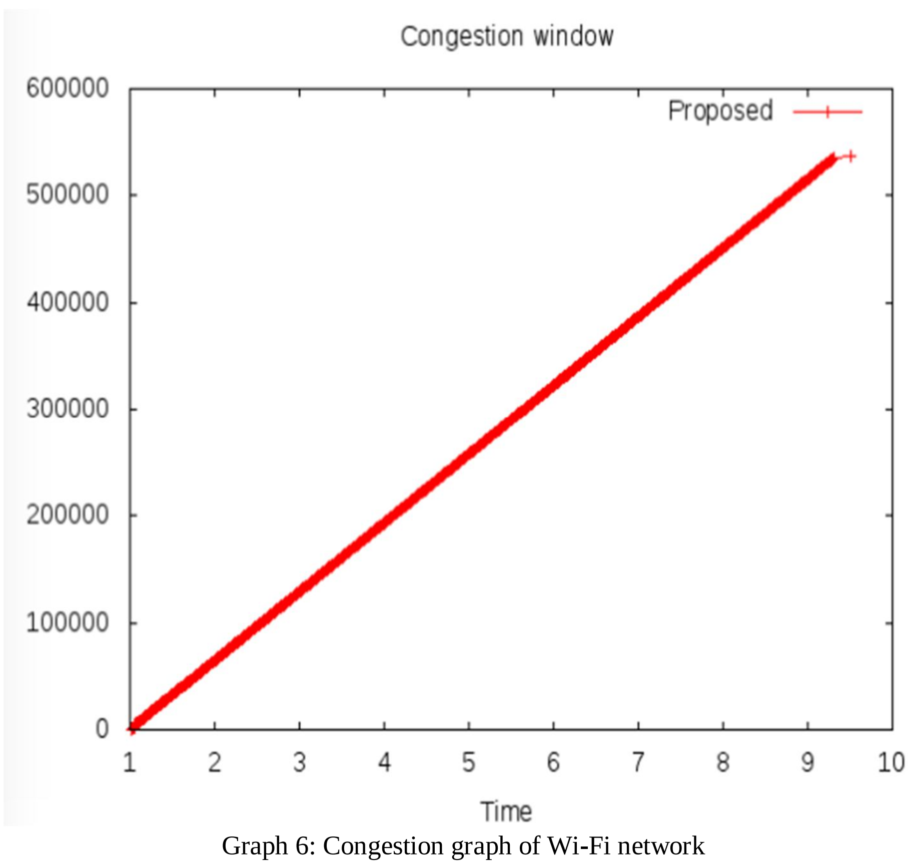


Graph 4: Throughput for Wi-Fi network

If we compare graph 4 and graph 1, we see that Wi-Fi networks have lower throughput compared to the NGPON2 network. Also packet loss is much lower compared to the Wi-Fi network, as shown in graph 5.



Graph 5: Packet drop of Wi-Fi network



Graph 6: Congestion graph of Wi-Fi network

Comparing graph 2 and graph 6, that is the congestion graphs of both networks. It can be observed that Wi-Fi networks have no congestion control mechanism. Therefore the congestion rate is higher than the NGPON2 network.

Due to many drawbacks in the copper based system, we have adopted optical fibres as a mode of transfer. We started with PON network.

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NGPON2 has been proven to provide best service such as higher bandwidth, higher speed and so on. The table 1 shows the comparison with the GPON network.

Parameters	Gigabit-capable PON (GPON)	Next Generation PON (NGPON2)
Speed	Supports a minimum of 1.2Gbit/s in upstream and 2.4Gbit/s downstream. And maximum of 2.4Gbit/s up and down stream both.	Supports a minimum of 40Gbit/s in the downstream and 10Gbit/s in the upstream direction. Maximum of 160Gbit/s in the downstream and 80 Gbit/s in the upstream.
Split ratio	Generally supports up to 1:64	Range of 1:16 to 1:128.
Distance	Maximum of 60 km.	As a minimum of 40 km without reach extenders. Longer reach : 60-100 km.
Compatibility	Since this a new architecture, all the infrastructure has to be built from scratch.	Compatible with legacy power splitting ODNs. Also with all legacy PON like GPON, XGPON, etc
Bandwidth	Less bandwidth	Higher bandwidth than these legacy PON systems
Spectrum	GPON as minimal spectrum	If the NG-PON2 system does not co-exist with legacy PON, then it could use the spectrum allocated to those PON systems.
Video delivery	Many legacy PON deployments use RF-video overlay for video delivery	NG-PON2 systems can deliver videos and also support the RF-video overlay used by the legacy PONs.
Performance	Achieves better performance than copper based systems.	Achieves improving delay and jitter performance.
Services	Supports legacy services like Ethernet, POTS, T1, E1, E3, DS3, digital video	Supports legacy services, such as POTS and T1/E1 using emulation and/or simulation, high speed private line (framed and unframed), and emerging packet-based services. Optical business services such as wavelength services and OTN are supported.
Operation, Administration and Maintenance (OAM)	Protection switching requires less than ten codes to be used for both upstream and downstream, which will be realized by the field of the OAM frame.	The NG-PON2 system provides full FCAPS (Fault, Configuration, Accounting, Performance, and Security) management capability for the ONU.The TWDM channels in the NG-PON2 system supports DBA for efficient sharing of bandwidth.

Table 1: Comparison of NGPON2 with GPON

VII. CONCLUSION

In this paper we have implemented Next-generation passive optical network (NGPON) whose architecture is able to achieve a total of 40 Gbit/s of network throughput that is at each user, up to 10 Gbit/s symmetric upstream/downstream speeds can be achieved. We have used the NGPON module in NS3. NGPON is compatible with existing legacy PON which gives it more advantages.

Here in our project we have considered parameters like throughput, packet drop and congestion. We have analysed the results and have plotted graphs on these parameters. We have also compared the results with the Wi-Fi network. And found that the NGPON2 network is better. As demand for high data rates increased during this digital era, NGPON provides the necessary architecture to meet this demand. The fact that it can be co-existed with the already installed PON, this solution also becomes cost effective. Therefore, NGPON is considered to be an important technology for high speed Internet.

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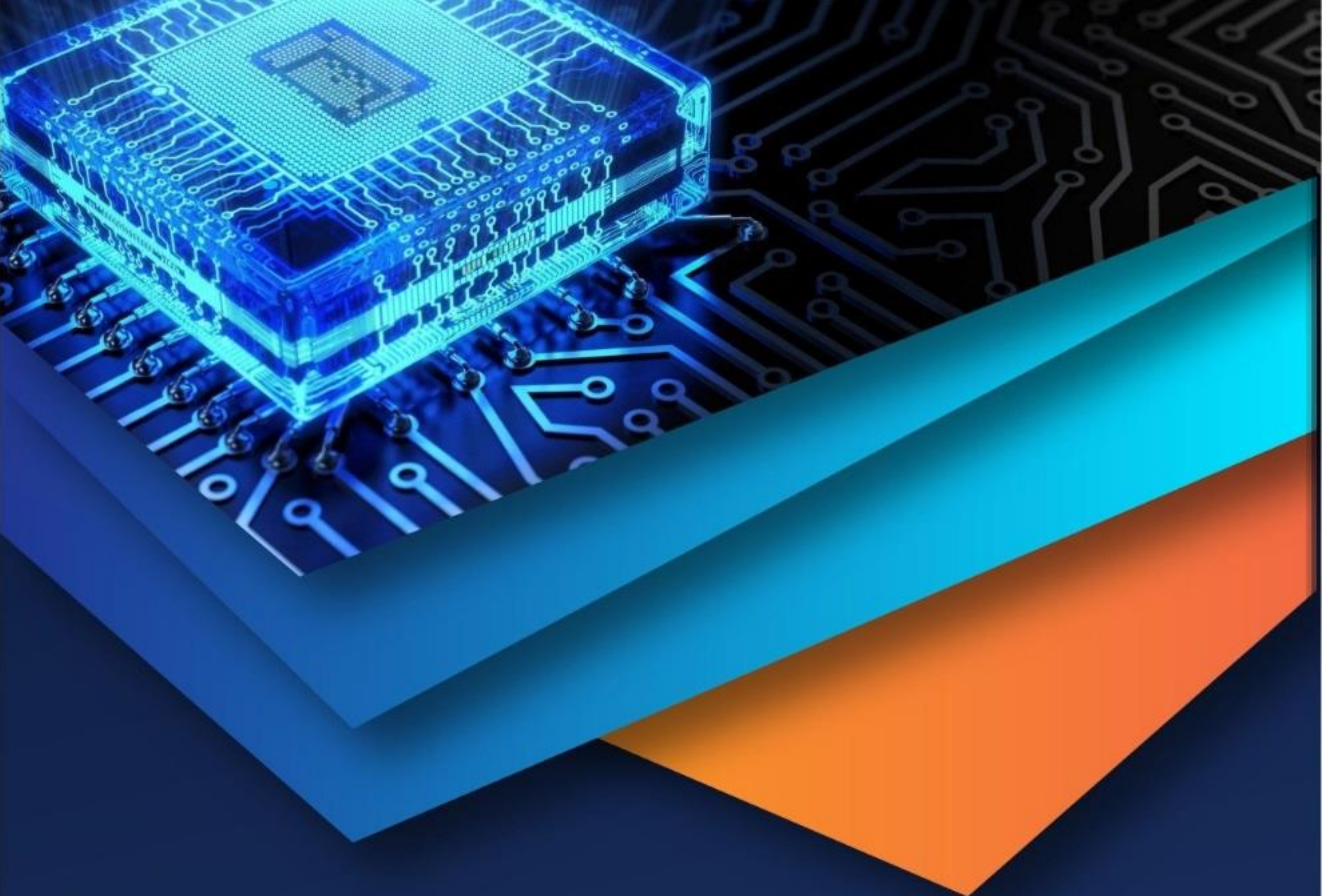

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