PERFORMANCE ANALYSIS OF SOFTWARE DEFINED NETWORKS

A DISSERTATION

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IN
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CANDIDATE'S DECLARATION

I, Anjali (2K20/MOC/01) student of M. Tech (Microwave and Optical Communication Engineering), hereby declare that the Major Project-II dissertation titled "Performance Analysis of Software Defined Optical Networks" which is submitted by me to the Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in the partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Major Project-II dissertation titled "Performance Analysis of Software Defined Optical Networks" which is submitted by Anjali (2K20/MOC/01) in Department of Electronics and Communication Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the award of Master of Technology, is a record of project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Prof. Dr. Gurjit Kaur
(SUPERVISOR)

ACKNOWLEDGEMENT

The success and final outcome of this project require a lot of guidance and assistance from many people and I am extremely fortunate to get this all along the completion of my project work. Whatever I have done is only due to such guidance and assistance and I would not forget to thank them.

I owe my profound gratitude to my project guide Prof. Dr Gurjit Kaur for giving an opportunity to do this work. Dr. Gurjit Kaur took keen interest on my project work and guided me throughout, till the completion of my project work by providing all the necessary information, constant encouragement, sincere criticism and sympathetic attitude.

Anjali

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ABSTRACT

There has been many changes in the network service providers that engages the routers, switches and many other complex protocols, but the current computing trends don't want to change the network as a whole as of optical networks. In the market of current network trends, data eccentric nodes has been a part of them and these nodes requires high speed as of now, to meet the high speed demands the circuit switching part has been merged with the packet switching part which can modify the network as a whole. The high speed of the network is managed by the circuit switching while error free delivery of packets from the transmitter section to the receiver section has been managed by the Packet Switching. Circuit switching is being used in the Optical Networks because nothing can overpower the speed of the light and they travel by the speed of light.

Only Packet Switched network won't make any difference there is a need to make the system programmable, adaptable and flexible according to the current computing trends since there is a need of the networks to adjust according to the heavy traffic demands since in different networks there is a different traffic demand in the data eccentric nodes. The nodes should travel by itself to forward and route the packet according to the path when it is idle and should move through the conventional path when it's congested. This routing of packets could be done through OpenFlow Switches following the OpenFlow Protocols.

The communication system which are used conventionally consists of large number of switches, middle boxes and routers for the communication part, they basically lack in the programmability of the network. SDN is different from these conventional communication systems as it separates the forwarding plane with the control plane. Switches used here are also different from the conventional as they follow a significant protocol which is basically an Open Flow Protocol.

In the project, the Optical part of Software Defined Networks (SDN) has been designed through the Optisystem Software version 19.0. Optical switch using Reconfigurable Optical Add Drop Multiplexer (ROADM) have been designed in the software. The data is provided to the user through Optical switches present in the ROADM, the data could be a binary bit or a binary sequence depending upon the needs and requirements of the user.

The system consists of the CW Array which consists of total 8 numbers of users at different frequencies that are 193.1Thz, 193.2Thz, 193.3Thz, 193.4Thz, 193.5Thz, 193.6Thz, 193.7Thz and 193.8Thz. Another set of CW Array and multiplexer is also present where the data is sent through the fork to the subsystem designed of ROADM. It consists of WDM Drop, Control, Optical Switches and WDM Add. The signals of different frequencies are provided to the subsystem. The results are recorded in both time and frequency domain at different signals provided and from the obtained results it can be concluded that the received data is same as that of transmitted data.

SDN provides provision to the users to be independent of the network operators as the users don't have to change the network as a whole with the changing trends of computing demands just have to reprogram the network.

Table of Contents

LIST OF FIGURES

CHAPTER 1- INTRODUCTION

1.1: NEED FOR SDON

Nowadays a lot of issues have been facing up be the network providers that are concerning the management system of the current networks. The networks which are basically consisting the routers, switches and some other blocks with the complex protocols.

There are some nodes which are currently trending in the current networks that demands for high speed, in order to fulfill the demands of the high speed in the network merge the circuit switching circuits with the packet switching circuits. Since the packet switching has came into the picture to ensure the high speed then it must also ensure the error free delivery of packets, like the packets which are sending from the transmitter side should get a replica or at least the packet with the minimal error practically.

So concluding the part of the switching networks, the error free delivery of packets can be assured by the packet switching networks while the high speed of optical networks can be assured by the circuit switched networks. So having talked about the parameters such as speed and error free delivery of the packets but there are some other parameters also such as flexibility and programmability which the system should adapt because there is a change in the nodes, the eccentric nodes are used so our system to adapt these network demands and accomplish them. But the optical networks won't allow the networks to change as a whole, so there is a need in system to make its own conventional path when the traffic is there it shouldn't be idle, so that's where the SDN and its programmability come into the picture.

SDN leads to improving the performance of any significant Optical or Ethernet Network. The flexibility of any network tend to account more since the packet which is travelling to a particular address can be easily accessed by the user and it can match the packet with the header according to the instructions in the OpenFlow table and can also reroute the packet if there is any miss entry is present. As a whole SDN has a global view of network and can lead to better optimization of the resources available.

1.2 SDN

In optical networks, the packet switching which is being managed by SDN controller. SDN stands for Software Defined Networks. SDN is a network that separates the control plane and forwarding plane, the switches are being forwarded by the forwarding plane only.

So it can lead to the evolution of the networks only if it is combined with the high speed assured by the optical networks, the error free delivery of packets, the programmability and flexibility in the current networks due the traffic networks can then lead to the evolution in the domain of network trends. This will result to cost efficient, effective, flexible and innovative idea towards the history of the networks.

In SDN there is a better centralized control over the networks which can be focused on. SDN also has the feature of better optimization of the resources. So if it can combine the Optical Networks with the software Defined Networks our networks can be made programmable and flexible according to the current network demands demanding in the traffic control since now the networks are using the eccentric nodes in the networks and the path of the network can be decided only by the SDN it will decide that whether the particular packet can be forwarded or not if there is a conventional path available then it can directly forward the packet through the forwarding plane and if the path is busy or if the packet cannot be forwarded it can be ensured by the miss entry of the packet.

SDN is basically a revolutionary change in the trends of the networks with the better optimization of the resources and enhancing the various factors of the networks making it flexible and adaptable. The communication system which are used conventionally consists of large number of switches, middle boxes and routers for the communication part, they basically lack in the programmability of the network. SDN is different from these conventional communication systems as it separates the forwarding plane with the control plane. Switches used here are also different from the conventional as they follow a significant protocol which is basically an Open Flow Protocol. SDN has the centralized control plane and involving Software Defined Networking in the existing network has for sure makes optical network system programmable, flexible and adaptable.

1.3 SDN ARCHITECTURE

The architecture of the Software Defined Network has been given below in Fig 1.1; the SDN along with the optical network will make the current network programmable, adaptable and flexible in the current networking trends and will make any network reliable, effective and cost effective.

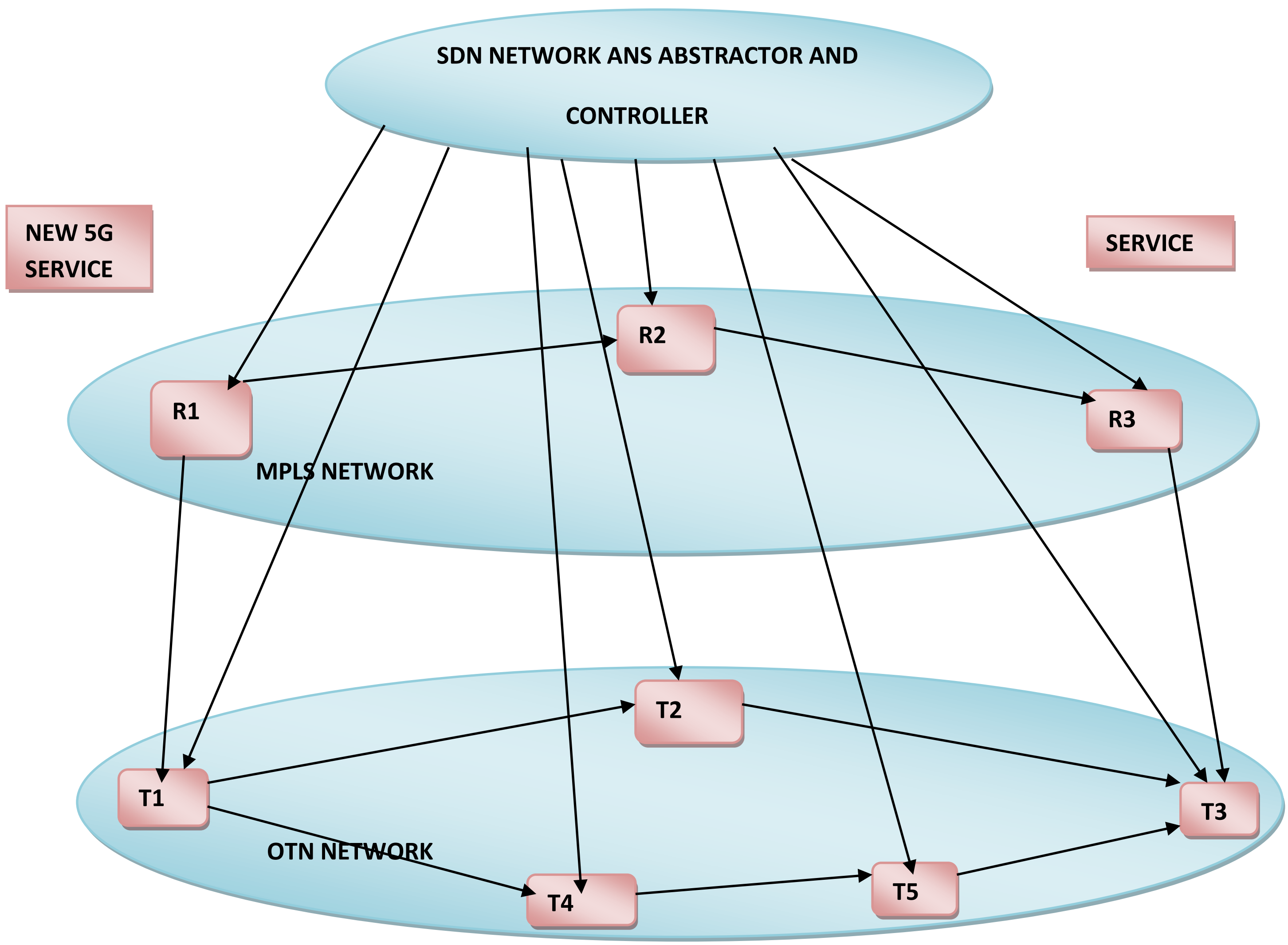

Fig 1.1 SDN Architecture

1.4 THREE LAYER SDN ARCHITECTURE

There is a three layer Software Defined Network Architecture in Fig 1.2 and those three layers are namely Control Layer, Application Layer and Infrastructure Layer, these layers are present but except for these two layers two interfaces are also present which are physically present in between the layers of the architecture namely, Southbound Interface and Northbound Interface.

The Southbound Interface is present in between the Control Layer and Infrastructure Layer while the Northbound Interface is present in between the Control Layer and the Application Layer and the communication takes place in between the layers and the protocol which is responsible for the communication to take place is called OpenFlow Protocol.

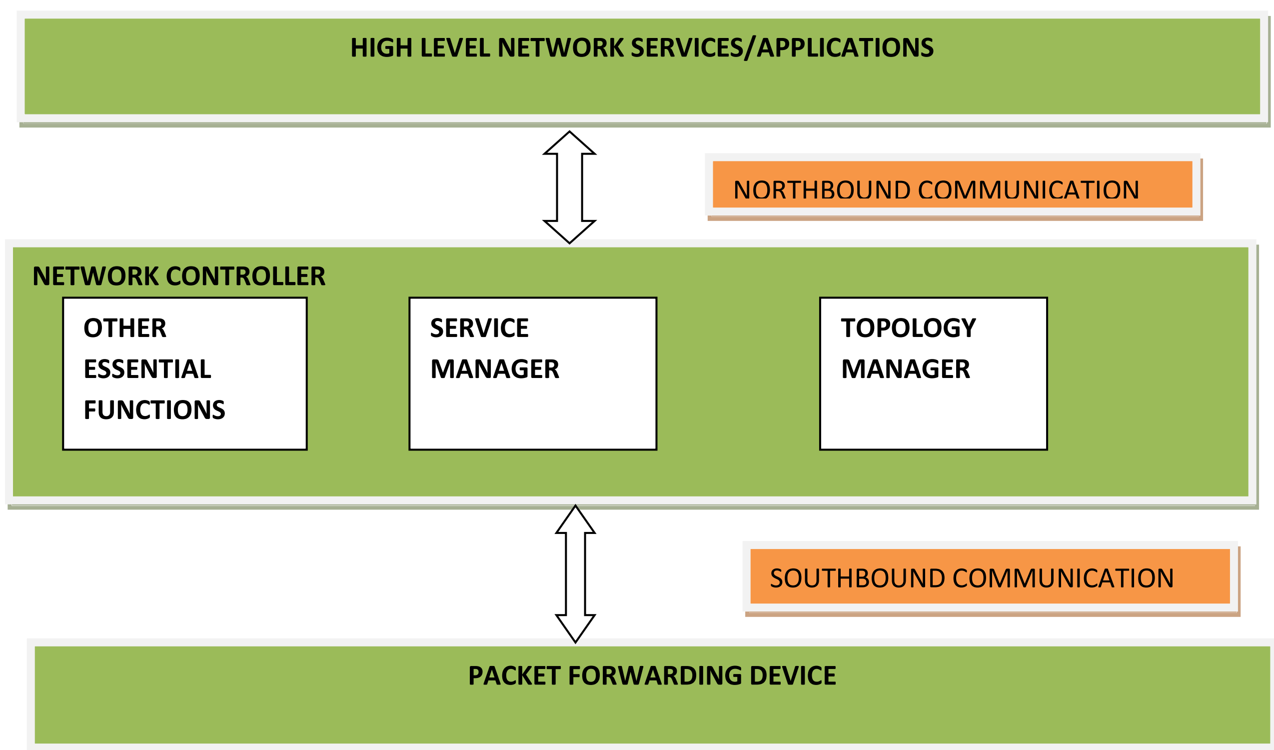

Fig 1.2 Three Layer SDN Architecture

1.5 OPENFLOW PROTOCOL

OpenFlow Protocol is basically the communication protocol which is responsible for the communication in between the data plane and the control plane of the Software Defined Architecture. And among all the protocols which have been listed or used in the history of Software Defined Networks, OpenFlow Protocol has proved to be the dominant ones among all the other protocols. Even though the work is currently being done over these protocols this one is still in its developing and evolving stage and has released several versions of the protocol like OF1, OF1.2, OF1.2 and OF1.3.

Every version of the protocol is unique in its own way the newer released version of any particular version of protocol is powerful than the previous version of its own. Some features which are given by this protocol are like IPv6, MPLS i.e., Multi Protocol Label Switching, metering, rerouting, policing and scalable control.

In any network the behavior of forwarding the packet to the destination relies basically on the forwarding rules which are present inside any networking element. The networking element will consists of switches and routers present in any conventional networking system. And the switches are present in both of the traditional network circuits as well as on Software Defined Circuits. And the forwarding plane is also separated from the control plane. The forwarding rules are present in the OpenFlow tables which can vary for every network based on their size and structure. Matching the packet header, rerouting the packet if the channel is congested all these of the behavior are present in the packet forwarding pipeline.

The OpenFlow Control works basically on the three basic concepts:

a) OpenFlow Switches comprises of the forwarding plane or data plane and the network is comprised of OpenFlow Switches.
b) A secure channel must be there that will connect the OpenFlow Switches with the controller.
c) One or more OpenFlow controllers must be present in the control plane such as NOX, POX etc.

1.6 OpenFlow Switches

To physically implement the OpenFlow protocol there is a need that OpenFlow switches will basically acts as a forwarding device for the packets, it will basically forward the packets to next level according to its flow table. The table will be present in the switch only and will contain the flow entries such as Match Fields, Counters and the Instructions which are given in the Flow table only.

So basically the OpenFlow switch has to route the incoming packet according to the instruction which is given in a particular Flow table. So initially the incoming packet will search for its entry and if the entry is present in the plane then the switch will easily forward the packet according to its Flow table. So here the matching field is done. Now let us consider another case that what if the entry of the particular packet is not present that is matching field is not matched with the packet header then either the packet is being forwarded to the next flow table or it can be dropped if all the flow tables has been checked or simply could be passed on to the controller.

The components of the OpenFlow switch consists of a group table and one or few flow tables. The instructions to move the packet forward in the packet switching is controlled here and in the flow tables the instructions will be mentioned such as packet matching could be a case where the packet will match the address of the header if it is present in the flow table and if it is there it is forwarded to the location specified in the table, here the packet will automatically move according to the data fed instructions and if on other hand the address of the packet is not present then the packet will be dropped and will be forwarded to another location specifically which is specified in the flow table. Flow Table basically maintains the flow of packet automatically and according to the data instruction fed in the table.

These decisions are basically taken on the basis of the instructions which are present in the flow table, now if the packet is directly passed on to the controller then that needs to be updated the flow table and has to set up the new path for that case. So basically when the flow entry is updated the counter has been set which will calculate in how much time the new entry has been created and after few time that flow entry of the particular entry will get discarded automatically. So this was the whole process of the forwarding of the packet using OpenFlow Switch based on the instructions which are present in the respective flow table.

1.7 SDN AND OPTICAL NETWORKS

Optical network is basically used for the communication in between the two points or more. Previously, the network used for any communication uses the electrical signals but the Optical Networks unlike those uses the light signal for the communication purpose.

So in order to perform the circuit switching which basically enables faster delivery of the packets to the Destination Port, the Optical Network uses switches with some Optical Interfaces and these are confined only to the optical layer that is the Wavelength Division Multiplexing which further confines and add on to Dense Wavelength Division Multiplexing where the more number of wavelengths could be used and high speed operations could be performed, further it also confines to Reconfigurable Optical Add Drop Multiplexer(ROADM) which acts as a Optical Switch and a supporting connection between the Optical layers. So in order to meet the current computing trends in the networks it includes SDN with the Optical Networks that will make the network programmable, adaptable and Flexible.

ROADM Based Network has been implemented further using Optisystem version 19.0. ROADM layout constitutes for the OpenFlow switch which is basically used to move the packets from one destination to another through an underlying protocol of OpenFlow Protocol. It basically consists of 8 number of users which are being transmitted by the transmitter. Another set of users are also present which are also transmitted to the subsystem of ROADM which consists of the WDM Drop which has the specification to drop at signal of any frequency at any particular period and WDM Add which can add any particular frequency to the existing set of signals. The data which is sent to the Optical Switches is controlled by the Control which are basically user defined bit sequence from which the data can be changed according to the requirement.

Some of the examples of optical network in which the SDN could be included are:

a) Sub-Wavelength Switched Network(tunable transmitter)
b) Sub-Wavelength Switched Network(tunable receiver)
c) ROADM Based Network
d) Generic Packet or Fiber Switching or TDM

CHAPTER 2 LITERATURE SURVEY

[1] To meet the current networking trends the test bed has been simulated along with the optisystem in [1]. Incorporating both Circuit switching and Packet switching a network can be created in order to make the system programmable, adaptable and flexible so that the high speed and error free delivery of packets can be maintained through. The basics of SDN have been implemented along with the basics of Optisystem. A simulated design of SDON has been reflected and comparative analysis has been done in terms of BER and Q-Factor.

[2] A comparative analysis has been carried out of a simple DWDM Layout and a SDN which consists of packet switching and optical part of the network. The input is taken from the Optical Switch and the detailed study of effect of optical part on the SDN has been carried out and the co-simulation has also been studied.

[3] In paper [2], the holographic ROADM (Reconfigurable Optical Add drop Multiplexer) has been implemented in the Optisystem. Holographic ROADM has been an application for CWDM Optical Networks. Here the combination of several input wavelengths has been performed and the output has been sent to receiver as a collective mix of wavelengths to the output. Internal switching has been performed using Banyan tree structure and the Bessel approach has been used to get the similarity of the actual response which is obtained from the holographic devices.

[4] In paper[3], the evolution of Software Defined Networks has been studied and has discussed on how it has played the role for the development of NGN. NGN stands for Next Generation. In this paper the comparative analysis of SDN has been performed and been compared with conventional method. The functional architecture of SDN has been studied in this paper, its function and methodology along with the OpenFlow switches and the protocols.

Current researches and projects has been carried out to normalize the Conventional SDN with NGN. It basically helps in handling of huge data traffic networks and service providers to allow the error free delivery of packets and make it more functionable, programmable, adaptable and flexible.

[5] In paper[4] Interfacing of Software Defined Networks has been done with the optical networks in order to meet the current 5G operation market demands and to handle the huge data

traffic network demands. Here the current switching part is being handled by any particular Optical network while the packet switching has been taken care by the Software Defined Networks. Comparative analysis being made showing that the SDN meets the current needs of optical market demands an make the system more adaptable.

[6] From [5] various simulations and many other Framework has been developed such as INET, OMNeT in order to view or analyze the performance of software Defined Networks. A major challenge has been faced as how to analyze the results of performance analysis of Software Defined Networks using the above listed tools. Several features have to be tested out such as scaling factor, scaling the network to large networks, a difficulty was faced for the migration of the abstract to real time by doing the minimal changes only that will be acceptable for the deployment. The methods which are basically used currently for the testing of SDN and analyzing the performance of the network mainly includes new programming languages, capability to debug using static analysis and various other framework of the innovative tool required for measuring and analyzing the performance of SDN.

The implementation model of OpenFlow system for the OMNeT has been implemented in the INET Framework. The implementation includes the simulation of the various approaches for designing various prototypes and exploring new SDN based application and implementing them at a low cost.

As SDN allows the data network to be programmable, flexible and adaptable and can be accessible to a large number of users at a particular span of time. The design and the use of simulation models for OMNeT modules has been experimented out and the OpenFlow Functions for various simulator with OMNeT simulator has been done. The simulations are performed in order to make the complete application of SDN using various simulators. Both the simulators have been compared and the measurement has been taken for both individually which can be used and could be a part of SDN Application. The measurement has been taken from various other tools and as a result the measurement arrived from both the simulator tool is correct and accurate and can be used further for future references according to the functionalities, their capability and performance.

[7] In [6] describes the requirement of OpenFlow Logical Switch. The components which are basically used in the OpenFlow Switch is described in this section and then the OpenFlow Protocol which is basically responsible for controlling the OpenFlow switch from a remote OpenFlow Controller has been specified.

The components of the OpenFlow switch consists of a group table and one or few flow tables. The instructions to move the packet forward in the packet switching is controlled here and in the flow tables the instructions will be mentioned such as packet matching could be a case where the packet will match the address of the header if it is present in the flow table and if it is there it is forwarded to the location specified in the table, here the packet will automatically move according to the data fed instructions and if on other hand the address of the packet is not present then the packet will be dropped and will be forwarded to another location specifically which is specified in the flow table. Flow Table basically maintains the flow of packet automatically and according to the data instruction fed in the table.

[8] A Glossary has been provided which basically describes all the key specification terms used in OpenFlow switch such as Action, it is basically an operation which is being performed on the packet. List of Actions, it includes the list of actions which has to be performed over the packet it could be packet matching, miss table entry etc. The network interfaces are present in between the Open Flow processing which is used to pass the packet from one interface to another, these are called OpenFlow Ports. These all the related key terms describing the operation of OpenFlow protocol have been described.

[9] From [7], in current optical networks capacity requirement has been an ultrahigh challenge in the current optical switching nodes, there has been a fast development of nodes such as eccentric nodes which requires high speed and there is a high complexity of this node is present in the architecture. To fuse the node requirement with the future network could be a real challenge. To overcome this challenge enhanced Software Defined Network eSDN has been implemented here with the involvement of P-NOX and N-NOX the nature of the network can be made flexible according to the future needs and to meet the architecture of multi dimensional switching structure all the implementations have been done for the proposed cause.

[10] From [8], the packet forwarding behavior of an optical network has been studied by the implementation of taxonomy for packet forwarding pipeline. The conventional methods using switches and routers and the trending one of SDN has been compared based on the survey. This taxonomy uses the representation the forwarding pipeline based in Software Defined Networks and to develop a cohesive attributes based on the interaction of FTE for an end to end path in SDN.

[11] In [9], the functions and how the management of the Software Defined Networks is basically done and how the packet flow takes place in between the layers such as application layer, data layer and control layer is done is discussed through OpenFlow Protocol using OpenFlow Switch is discussed here. There are number of applications coming forward of SDN of managing the control of network resources across different technology domains such as Ethernet, Wireless and Optical. Here a control plane architecture is discussed based on the function of OpenFlow to use SDN for cloud use. And for the same the architecture has been implemented and the results and the performance are evaluated on the basis of cloud case.

[12] In the last decade cloud computing has been emerged as to enable the utility based computing resource management without even the requirements of the hardware equipment. Multiple data centers at various different locations is run through cloud services. From the introduction of the Software Defined Networks and Network Function Virtualization a lot more of opportunities has been opened up in the clouds through the proper provisioning of the resource, dynamically handling the data through the clouds and proper optimizations of cloud services has been achieved. In [10], for geographically hosting the distributed Multi-scheduling some architecture has been proposed including the principles for Programmable Network Clouds.

The operating cost has been minimized without the violation of any provisions and a resource planning for SLA aware provisioning has been done. The techniques for SLA has been investigated and discussed for VNF deployment and composition. Performance analysis of VNF using analytics and monitoring techniques has been done along with the Open challenges has been discussed and the algorithms for SDN Controller has been implemented and are presented with the valid evaluation results.

The networks can be programmed also according to the user needs; this idea of programmable networks has gained consideration and momentum by the introduction o Software Defined Networks only. SDN possesses a feature to dynamically simplify the network management and through programmability of the network the innovation can be enabled in the field of Optical Networks. Therefore, SDN is termed as radical new idea in networking. In [11], with the emphasis of SDN the state of the art in programmable networks has been implemented. The SDN architecture has been implemented and the OpenFlow standards have been discussed in particular. Research has been explored based on the SDN paradigm.

[13] Current technology is based on 4G, there are some prime objectives and demands which need to be addressed such as increase in capacity, to improve the data rate, to decrease the latency and to provide better quality of service to users in near future. Drastic improvements need to be done in order to meet these requirements. In [12] a detailed survey of results has been discussed based on fifth generation (5G), some key emerging technology and cellular network architecture is helpful to improve the architecture and need the above listed demands. The prime focus in[12] is on 5G network architecture, device to device communication and multiple input multiple output technology.

[14] Interference management, sharing of spectrum with cognitive radio, cloud technologies for 5G, full duplex radio and software defined network technologies has been discussed. A detailed survey is conducted in different countries and associations that are working on 5G technologies.

[15] To transmit high speed optical signals using low speed sub carriers and multiple spectral overlapped signals, a multiplexing technique is there which is Optical Orthogonal Frequency Division Multiplexing is there which is used for designing elastic optical network. In [13] detection optical OFDM is designed as a transport technique. Here, DDO-OFDM is designed which basically leads to hardware and software recognition which potentially offers a low cost solution to elastic optical networks which have specialization in metro networks and short to medium distance core networks in [13] SDN control plane has been enabled though the extension of open flow and its performance is measured with DDO-OFDM which is basically being used in elastic optical networks.

Based on the decomposition of control and data planes, Software Defined Networks has been considered as a promising network in order to fulfill a requirement for simplified network and enabling the research innovations. From [14], SDN related technologies have been reviewed and the main parts of the SDN such as Control plane, Data plane has been covered in order to help the researchers to set the meaningful direction for future SDN research.

[16] In [15], an overview of Software Defined Optical Networks has been discussed and the general concepts of Software Defined Networks have been explained. The relationship of the SDN with the network function visualization has been observed and also explained the OpenFlow Protocol which is the protocol responsible for the communication in between the Software Defined Networks. The benefits and challenges of SDN has been discussed if the SDN has been extended to multiple layer optical networks which also includes elastic optical networks as well as flexible grid for the unified implementation of control plane. In [15], benefits achieved by the SDON has been discussed and some of the research problems has also been addressed.

[17] The networks which are able to allocate the correct modulation format and correct optical spectrum range to the existing networks according to the client are EON- Elastic Optical Networks. For intelligent and dynamic end to end path provisioning and a provision to recover such networks, the control plane is the enabling key for the communication within these networks. In[16], two different control planes have been deployed for EON, the first one is GMPLS that is, Generalized Multi Protocol Label switching or PCE that is, Path Computation Element and the other one is the extension model for OpenFlow. Both the control planes have been experimentally validated in [16] and have been compared on the basis of the provision of path latency.

[18] In [17], it specifies the Forwarding and Control Element Separation protocol which is used for the communication between forwarding element and control element. It is specified to meet the ForCES protocol requirement and also defines the requirement for the Transport Mapping Layer.

When the Software Defined Network merges with the Optical Transport Techniques then this enables the network operators and data centre operators to provide the data to user dynamically and also their resources be the minimizing the operation and capital expenditure according to the user's needs and requirements. The multi domain networking abilities rely mainly on path computational element while working with SDN has made a provision for the inevitable issue. In [18], multi domain software defined transport network (SDTN) has been studied in this paper.

[19] SDTN has been demonstrated through field networks and also the design of OpenFlow has been extended through the design of Java script programming interface in order to maintain and support this framework. For the proposed above schemes the blocking performances are estimated.

[20] To achieve utilization of resources and better efficiency the problems caused by the heterogeneous network needs to be solved. In [19], a proposed architecture of packet and optical network convergence is demonstrated under various network requirement testbed. DWDM Layout and SDON have been compared in [20] and the packet matching is done through programming simulations by stating various advantages of SDON over existing optical networks.

PROBLEM IDENTIFICATION

1. Conventional Optical network uses the large number of routers, switches and the bit sequence for every switch was fixed.
2. The data cannot be varied according to the user requirements while in the thesis Software Defined Optical Network has been implemented where the data is not fixed it as it is there in the earlier papers, the bit sequence, frequency and wavelength could be varied through the control which is provided to the Optical Switch underlying the OpenFlow Protocol.

RESEARCH OBECTIVES

1. To design and implement the optical part of Software Defined Network on Optisystem Software version 19.0
2. To design Optical switch whose data can be varied according to the user requirements
3. To design ROADM Layout which consists of 8 numbers of users of different frequencies such as 193.1Thz, 193.2Thz, 193.3Thz, 193.4Thz, 193.5Thz, 193.6Thz, 193.7Thz and 193.8Thz.
4. To perform the comparative analysis of the Software Defined Networks with the conventional Optical networks

CHAPTER 3 – SIMULATION MODEL

3.1 ROADM LAYOUT

ROADM stands for Reconfigurable Optical Add Drop Multiplexer. ROADM is a kind of Wavelength Division Multiplexing device as shown in Fig 3.1 that has access to all the wavelengths which are present on the fiber and also have the ability to add or drop some of the wavelengths at a particular location and also allowing some of the wavelengths to optically pass them without any required termination.

In ROADM the optical direction is fixed. ROADM works on the two fundamentals first one is wavelength splitter and the second one is Wavelength Selecting Switch (WSS), it is an active component that performs then actual wavelength switching. ROADM is basically the programmable version of OADM. ROADM has the special ability to switch the traffic remotely from Wavelength Division Multiplexing at a particular wavelength layer. The Wavelength Select Switch helps to achieve the above property of ROADM.

With the help of ROADM the user is able the send the commands to the hardware stating which wavelength has to be dropped or added. ROADM is very flexible as it can be connected any where very easily and also has the provision to be modified as there is a change in the requirement of the network. ROADM has various advantages over OADM such as:

a) Simple Transport Network Design

b) Responds quickly to the new Bandwidth Demands

c) Remote Configuration

d) Extended Wavelength Transport

e) Better in service network upgradability

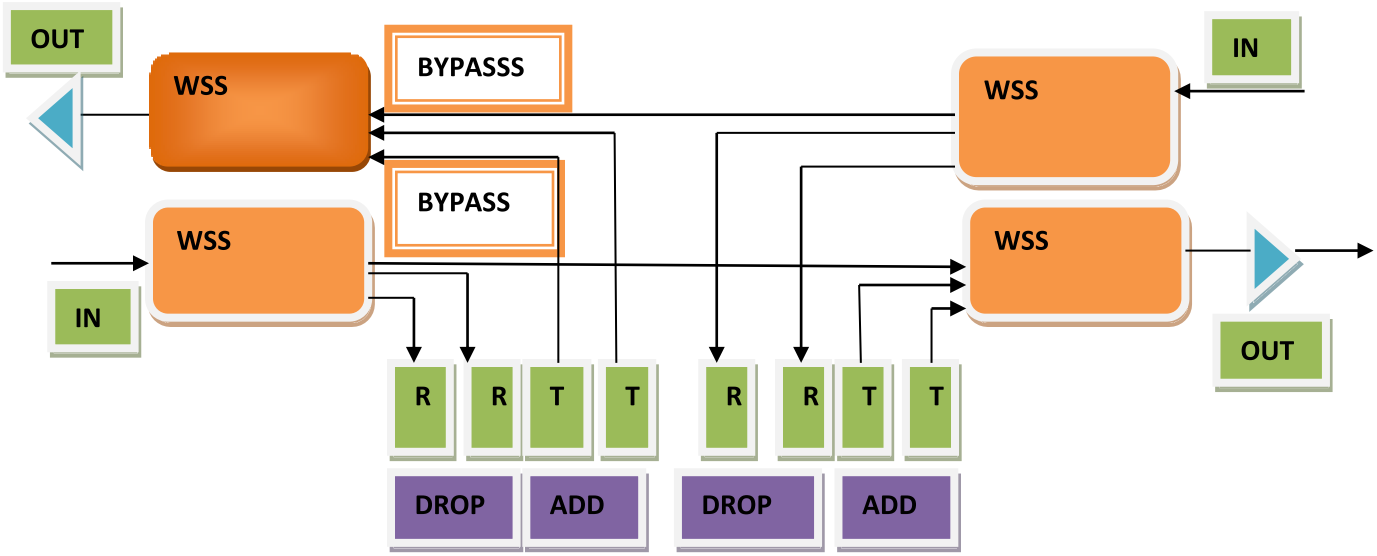

Fig 3.1 ROADM Layout

Fig 3.1 shows the block diagram of ROADM which is showing the fundamental process of WSS that is, Wavelength Selecting Switch. Reconfigurable Optical Add Drop Multiplexer(ROADM) which acts as a Optical Switch and a supporting connection between the Optical layers. So in order to meet the current computing trends in the networks it includes SDN with the Optical Networks that will make the network programmable, adaptable and Flexible.

ROADM Based Network has been implemented further using Optisystem version 19.0. ROADM layout constitutes for the OpenFlow switch which is basically used to move the packets from one destination to another through an underlying protocol of OpenFlow Protocol. It basically consists of 8 number of users which are being transmitted by the transmitter. Another set of users are also present which are also transmitted to the subsystem of ROADM which consists of the WDM Drop which has the specification to drop at signal of any frequency at any particular period and WDM Add which can add any particular frequency to the existing set of signals. The data which is sent to the Optical Switches is controlled by the Control which are basically user defined bit sequence from which the data can be changed according to user's requirement.

3.2: ROADM LAYOUT IN OPTISYSTEM

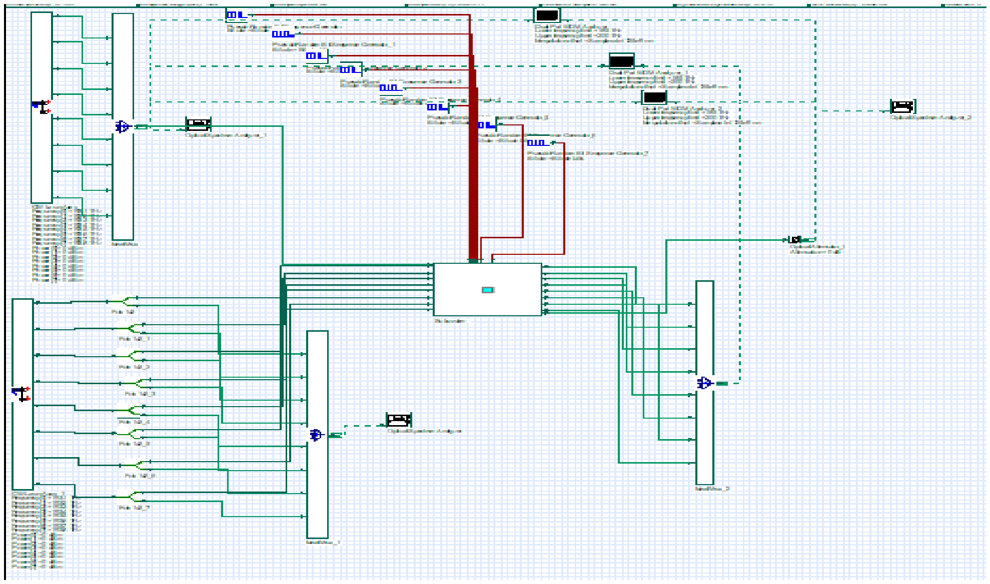

Fig 3.2 ROADM Layout in Optisystem

In the ROADM Layout Fig 3.2, CW array is present in the transmitter side of the layout which consists of 8 channels of different frequencies that is, 193.1THz, 193.2THz, 193.3THz, 193.4THz, 193.5THz, 193.6THz, 193.7THz, 193.8Hz with the line width of 10MHz and then the signals are send to the Ideal Multiplexer. In the Multiplexer both the input and output signals are optical. After the ideal MUX, the optical spectrum analyzer is present in order to view the output from the MUX. Since 8 number of channels are present so 8 PRBS that is, Pseudo Random Bit Sequence Generator is present in which the input to the subsystem is going.

The Dual Port WDM analyzer is present which will provide the values of input and output power at different frequencies in order to view the reduction or increment in the powers, noise figures and such type of parameters. Similarly the other set of frequencies is also given from the transmitter side from CW Laser Array such as 193.1THz, 193.2THz, 193.3THz, 193.4THz, 193.5THz, 193.6THz, 193.7THz and 193.8Hz. These outputs from the array are given to the fork. Fork basically copies the same input signal into two output signals.

3.3 SUBSYTEM PRESENT IN THE OPTISYSTEM

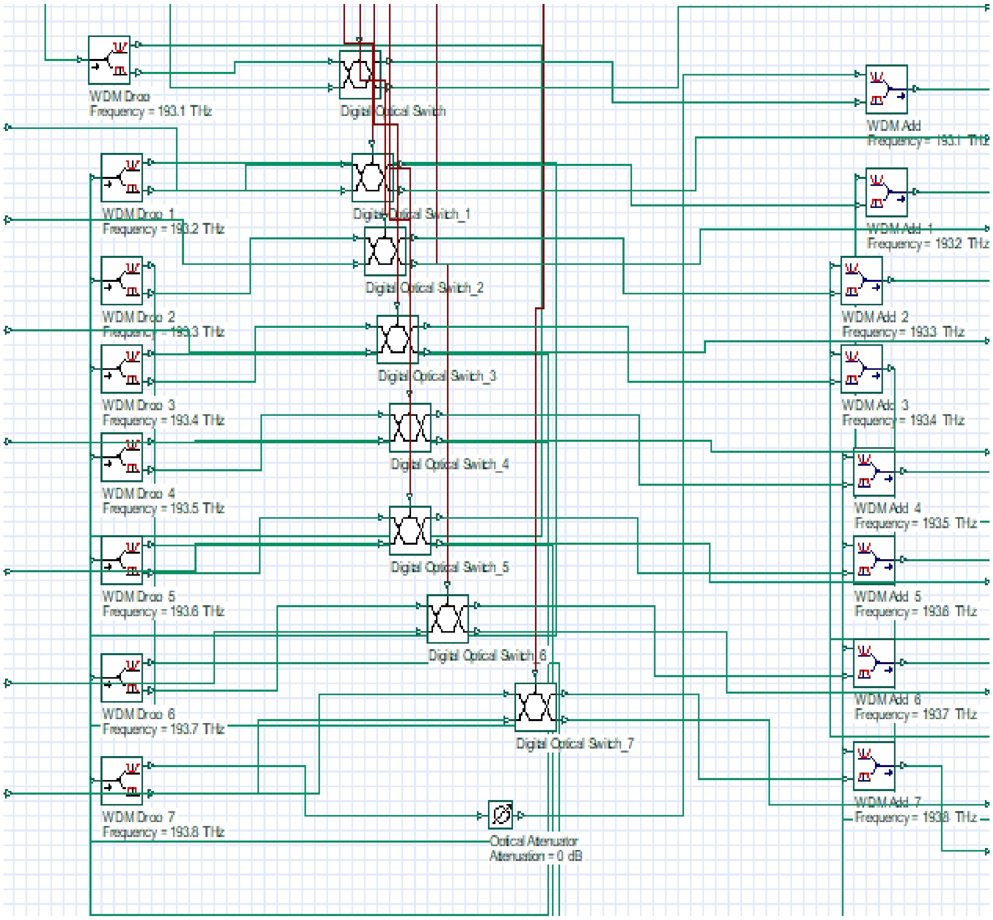

Fig 3.3 Subsystem of ROADM

From Fig 3.3, 8 WDM drops are present here of different frequencies and the output of the WDM drop are going to the Digital Optical Switch. WDM drop basically drops the WDM channel from the WDM signal. Digital Optical Switch is basically a 2*2 non ideal switch where the 3 inputs and 2 outputs are present; a control signal has to be binary which is coming from PRBS Generator while the inputs and outputs are of optical nature. The outputs of the switch are the input to the WDM Add. WDM add adds the WDM channel to the WDM signal.

The main controlling happening in the layout of ROADM is through Switches only. The switch used here is n Optical switch which has been discussed in the introduction portion of SDN.

CHAPTER 4 – RESULTS AND DISCUSSION

ROADM has been simulated through the Optisystem version 19.0

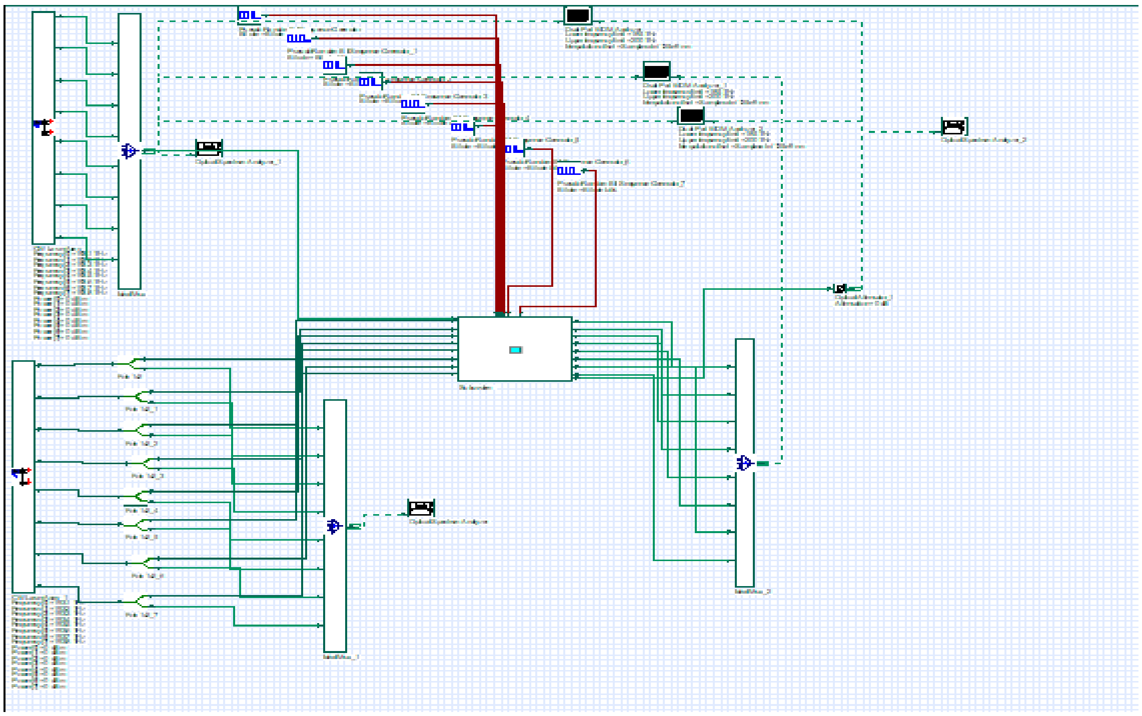

Fig 4.1 ROADM Layout Simulation

Fig 4.1 represents the ROADM Layout simulated in the optisystem, the transmitter side of the ROADM consists of the transmitter side where the 8 channels are transmitted viz different frequencies through WDM Mux and the WDM Transmitter, forks of 1*2 are present equal to the number of users present at the transmitter side that is, 8. The subsystem is present in the ROADM layout where WDM Add and WDM Drop systems are present equal to the number of users that is, 8.

Control has been provided to the Optical Switch which is an OpenFlow Switch of SDN and through which the bits are transmitted to the Switch following OpenFlow Protocol. All the control and simulation has been done on bits given from control to Optical Switch.

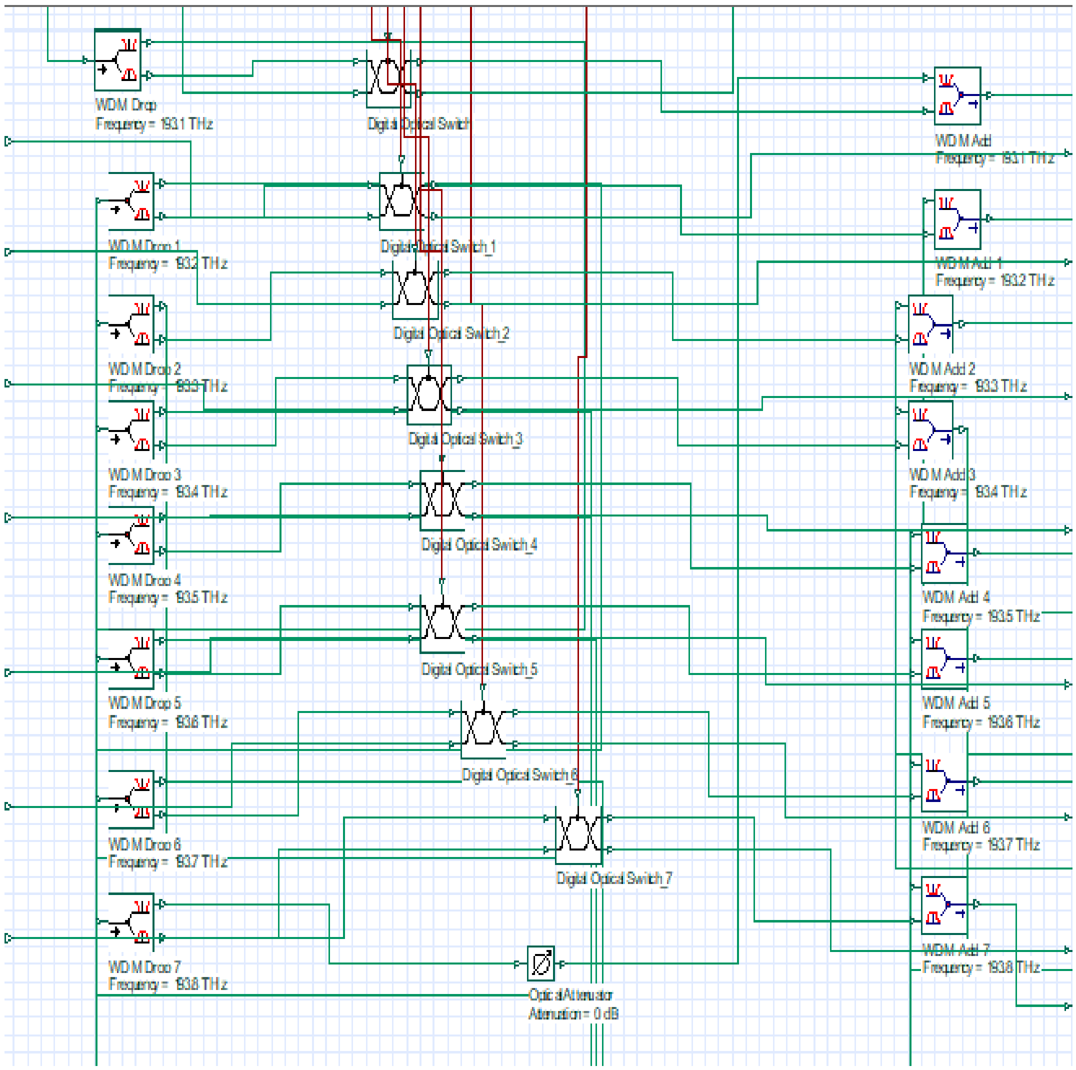

Fig 4.2 Subsystem Simulation

Fig 4.2 represents the subsystem which is present in the ROADM System. Subsystem is the feature of the Optisystem which is used to make the system of the layout look simplified; it is of the box type. The Subsystem of the ROADM consists of 8 WDM Drop which is equal to the number of users, Drop is basically used to drop one of the frequencies while it also consists of 8 WDM Add which is also equal to 8 basically equal to the number of users. Add is basically used to add frequency component to the existing frequency components.

4.2 PARAMTERS REQUIRED FOR THE TRANSMISSION

Table 1 Parameters required for the transmission

PARAMETERS	VALUES
Number of output ports	8
Frequency	193.1Thz
Frequency Spacing	100Ghz
Line Width	10Mhz
Noise Bandwidth	0dbm
Bit Rate	10e+009
Initial Phase	0 deg
Transmitter side	CW Array
Amplifier	EDFA
Subsystem	ROADM
MUX	Ideal MUX
Switch	Digital Optical Switch
Control	User Defined Bit Sequence

The various factors are listed in Table 1 which are required for the process of the transmission of various components over the different channels and the parameters includes like the number of ports required in the MUX, the frequency of the components which are required for different number of users, Frequency spacing that is after how much interval of time, the second frequency is passed on to the channel, the linewidth required in the process of the transmission, the noise bandwidth, the initial phase and the bit rate which was required by the frequency components to be passed on the channels and the output of each frequency component can be visualized through the optical spectrum analyzer which is present at the end of every signal source of transmission.

The transmitter side consists of the CW array which is generating 8 numbers of users. Multiplexer used here is an Ideal Mux from which the output is accelerated to the subsystem which consists of WDM Drop and WDM Add along with Digital Optical Switch.

4.3: SPECTRUM RECORDED FROM THE TRANSMITTER SIDE FOR DIFFERENT FREQUENCIES

a) For Frequency 193.1Thz

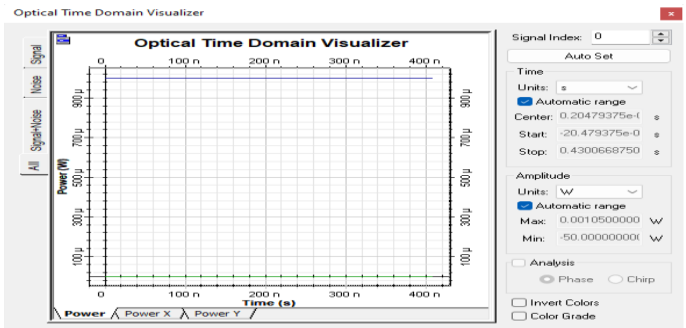

Fig 4.3 Transmitted Spectrum at 193.1 Thz

Fig 4.3 represents the spectrum which is recorded in the Optical Time Domain Analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.1 Thz is passed.

b) For Frequency 193.2Thz

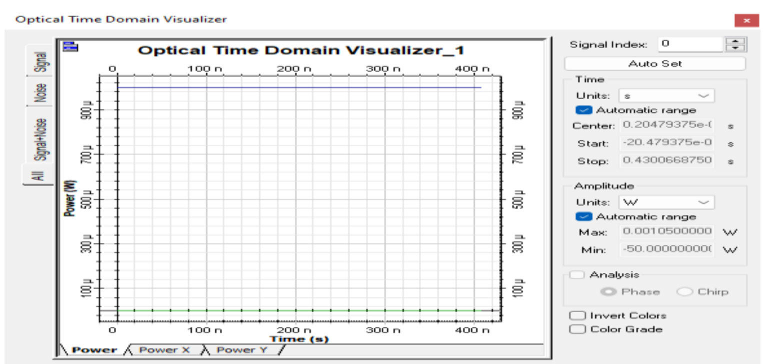

Fig 4.4 Transmitted Spectrum at 193.2 Thz

Fig 4.4 represents the spectrum which is recorded in the Optical Time Domain Spectrum Analyezr from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.2 Thz is passed.

c) For Frequency 193.3THz

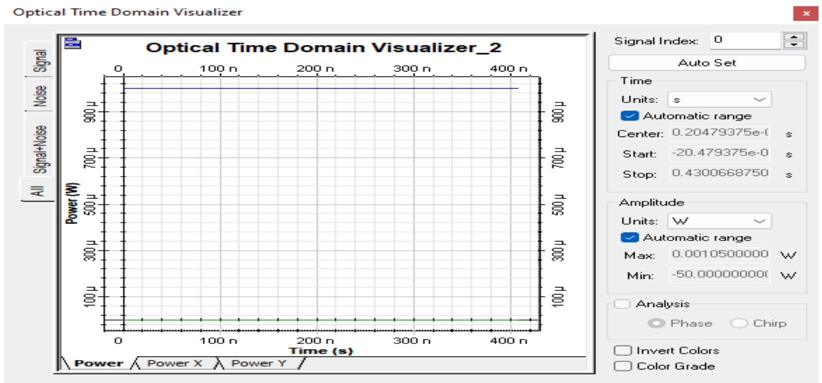

Fig 4.5 Transmitted Spectrum at 193.3 Thz

Fig 4.5 represents the spectrum which is recorded in the Optical Time Domain Spectrum from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.3 Thz is passed.

d) For Frequency 193.4THz

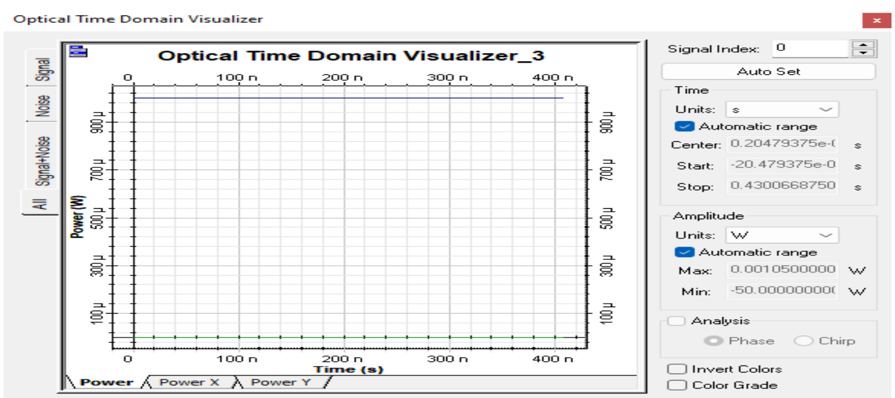

Fig 4.6 Transmitted Spectrum at 193.4 Thz

Fig 4.6 represents the spectrum which is recorded in the Optical Time Domain Spectrum analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.4 Thz is passed.

e) For Frequency 193.5THz

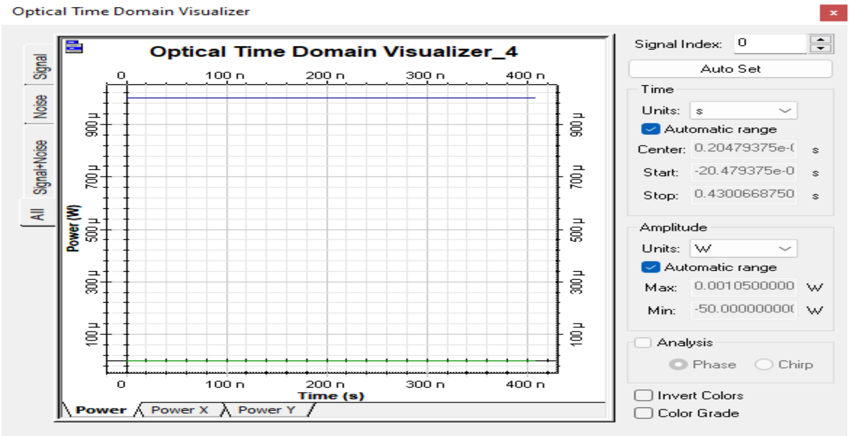

Fig 4.7 Transmitted Spectrum at 193.5 Thz

Fig 4.7 represents the spectrum which is recorded in the Optical Time Domain Spectrum analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.5 Thz is passed.

f) For Frequency 193.6THz

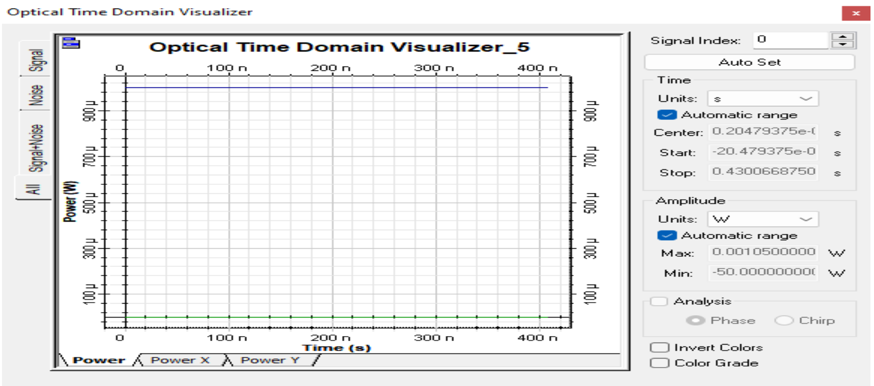

Fig 4.8 Transmitted Spectrum at 193.6 Thz

Fig 4.8 represents the spectrum which is recorded in the Optical Time Domain Spectrum analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.6 Thz is passed.

g) For Frequency 193.7THz

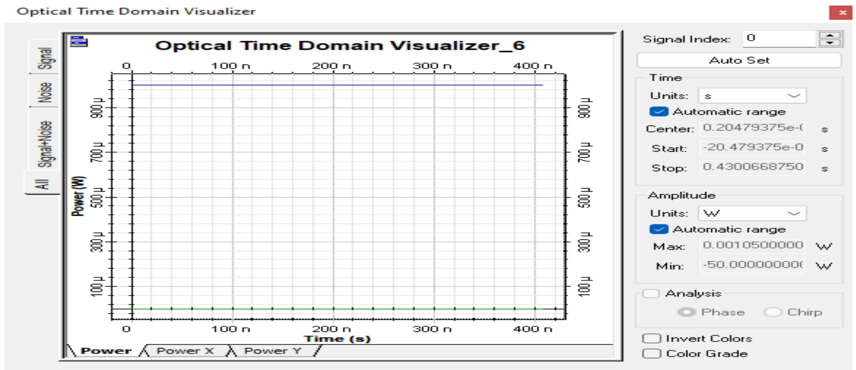

Fig 4.9 Transmitted Spectrum at 193.7 Thz

Fig 4.9 represents the spectrum which is recorded in the Optical time domain Spectrum analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.7 Thz is passed.

h) For Frequency 193.8 THz

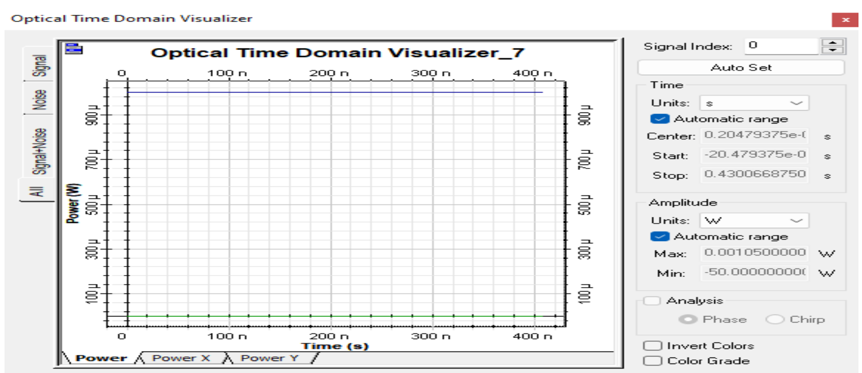

Fig 4.10 Transmitted Spectrum at 193.8 Thz

Fig 4.10 represents the spectrum which is recorded in the Optical Time Domain Spectrum analyzer from the transmitter side of the ROADM, this reading of the output is taken when the frequency component of 193.8 Thz is passed.

4.4 OUTPUT FROM THE TRANSMITTER SIDE

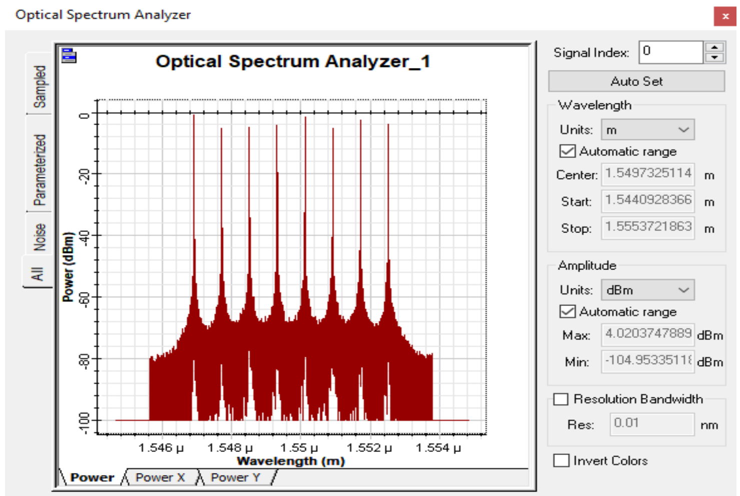

Fig 4.11 Transmitted Spectrum at all frequencies

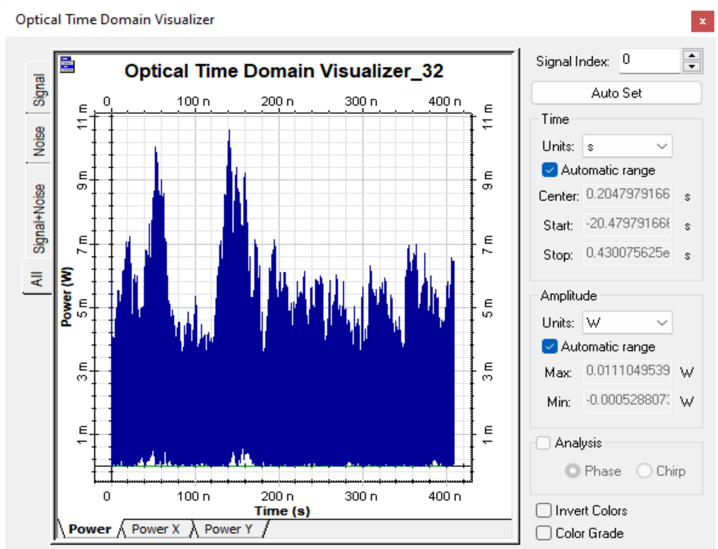

Fig 4.12 Transmitted Spectrum at all frequencies

Fig 4.11 and 4.12 represents the output which is recorded from the transmitter side of the ROADM combining both the 8 number of users from the output of the both transmitter sections of all the frequencies used in the layout of the ROADM sections consisting the ideal mux and then the fork which is then passed on to the channel of the ROADM Layout.

4.4: OUTPUTS RECORDED FROM WDM DROP AT DIFFERENT FREQUENCIES:

a) For Frequency 193.1THz

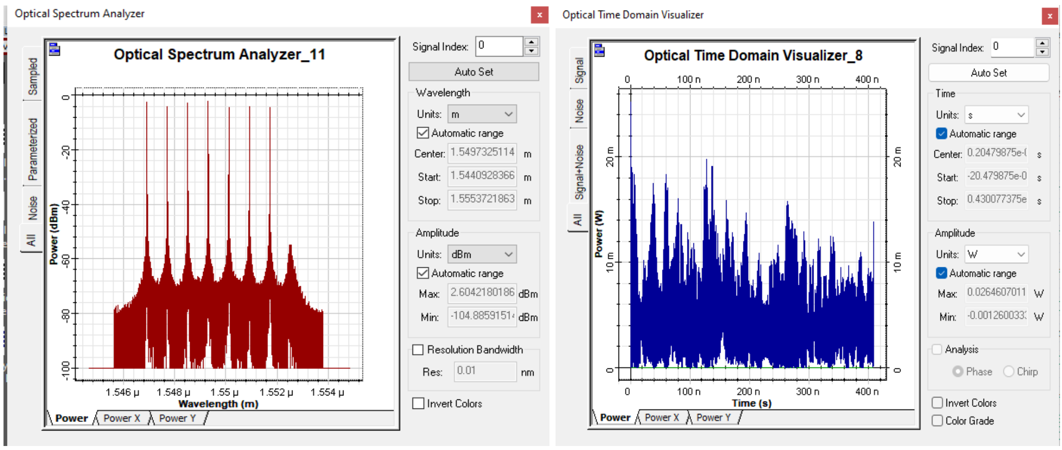

Fig 4.13 WDM Drop Spectrum at 193.1Thz

Fig 4.13 consists of the output received from the transmitter side of channel at the frequency of 193.1 Thz, both the outputs identifies the frequency component which is being dropped.

b) For Frequency 193.2Thz

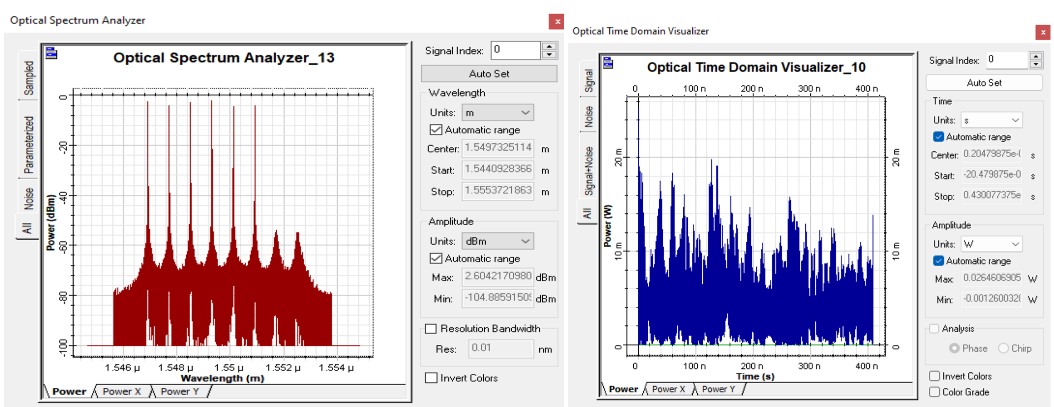

Fig 4.14 WDM Drop Spectrum at 193.2Thz

Fig 4.14 consists of the output received from the transmitter side of channel at the frequency of 193.2 Thz, both the outputs identifies the frequency component which is being dropped.

c)For Frequency 193.3Thz

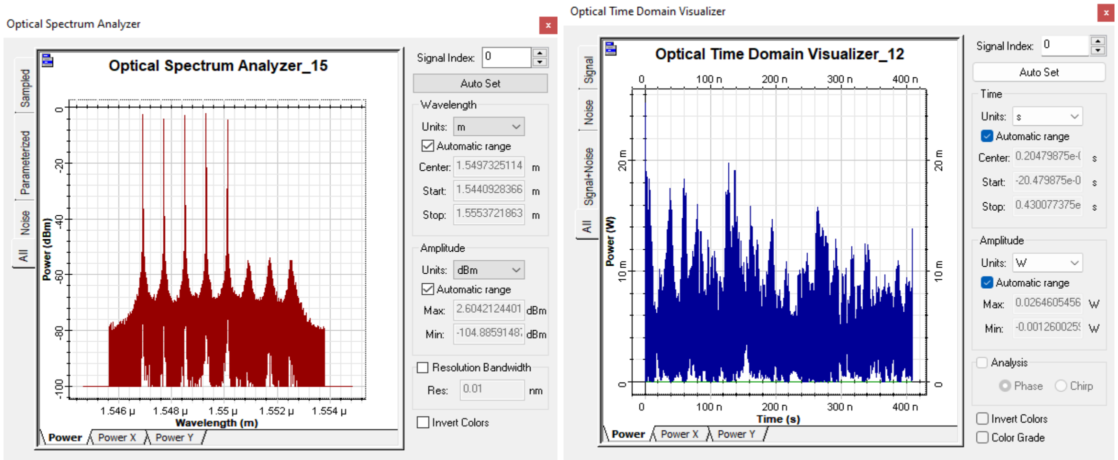

Fig 4.15 WDM Drop Spectrum at 193.3Thz

Fig 4.15 consists of the output received from the transmitter side of channel at the frequency of 193.3 Thz, both the outputs identifies the frequency component which is being dropped.

d) For Frequency 193.4Thz

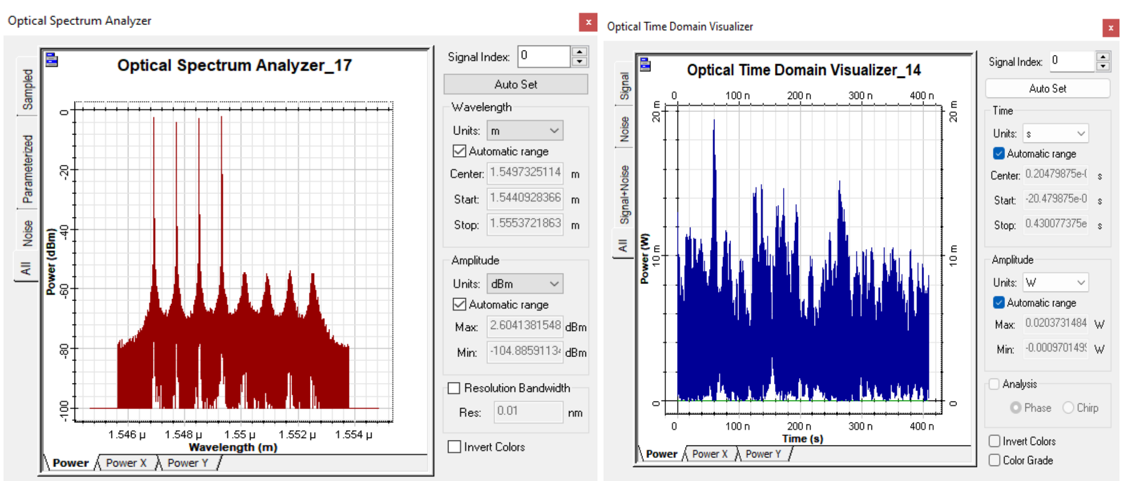

Fig 4.16 WDM Drop Spectrum at 193.4Thz

Fig 4.16 consists of the output received from the transmitter side of channel at the frequency of 193.4 Thz, both the outputs identifies the frequency component which is being dropped

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e)For Frequency 193.5Thz

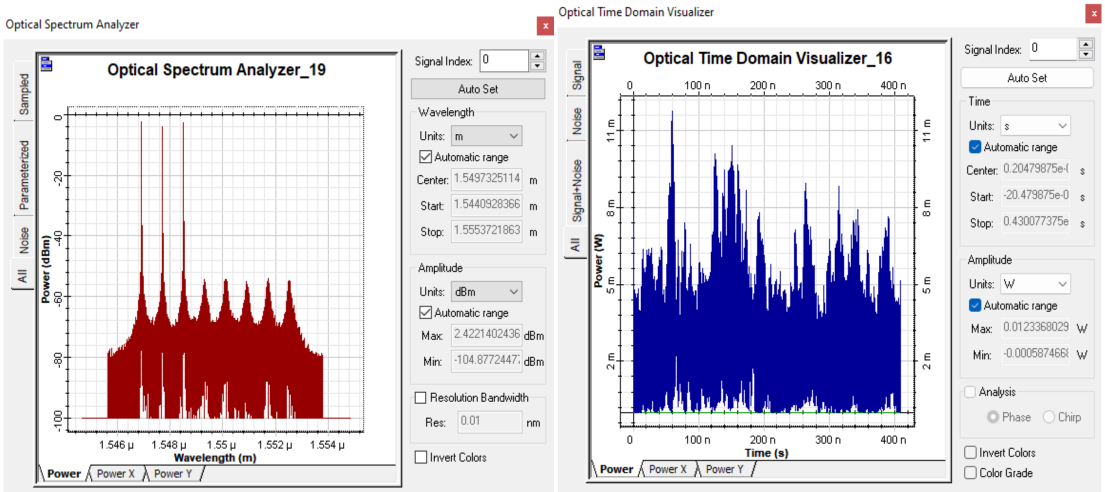


Fig 4.17 WDM Drop Spectrum at 193.5 Thz

Fig 4.17 consists of the output received from the transmitter side of channel at the frequency of 193.5 Thz, both the outputs identifies the frequency component which is being dropped.

f) For Frequency 193.6Thz

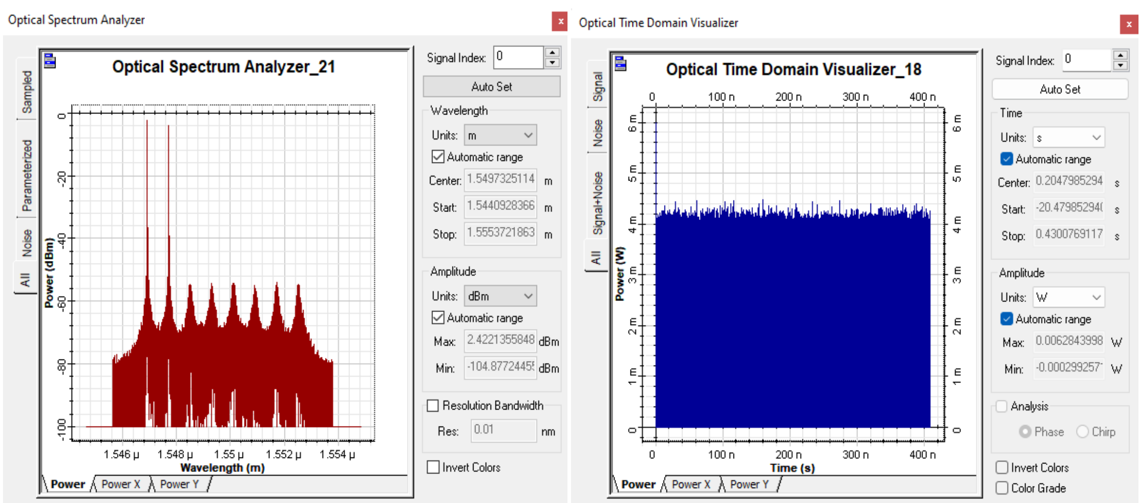


Fig 4.18 WDM Drop Spectrum at 193.6 Thz

Fig 4.18 consists of the output received from the transmitter side of channel at the frequency of 193.6 Thz, both the outputs identifies the frequency component which is being dropped.

g)For Frequency 193.7Thz

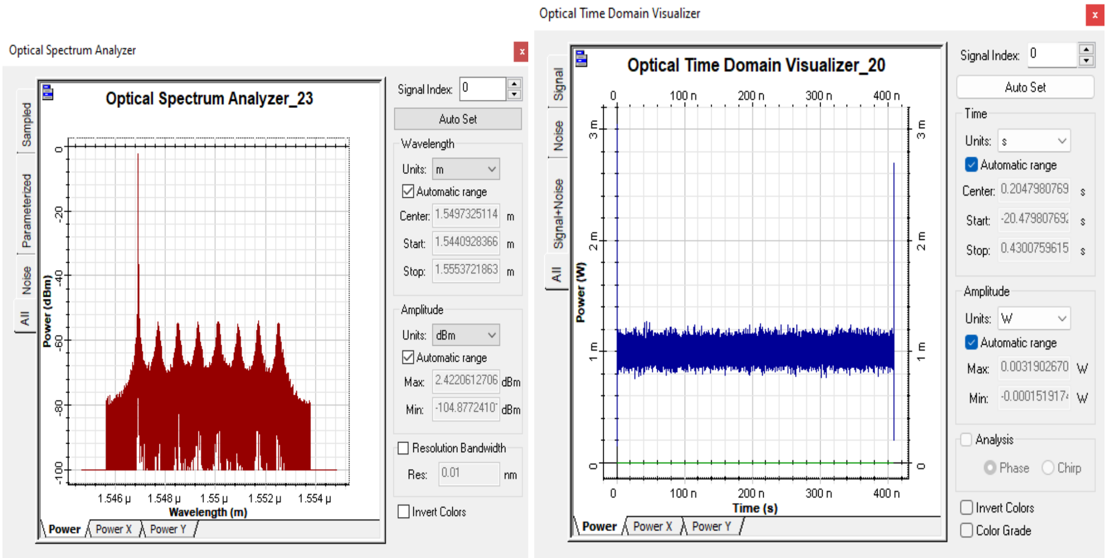


Fig 4.19 WDM Drop Spectrum at 193.7 Thz

Fig 4.19 consists of the output received from the transmitter side of channel at the frequency of 193.7 Thz, both the outputs identifies the frequency component which is being dropped.

h)For Frequency 193.8Thz

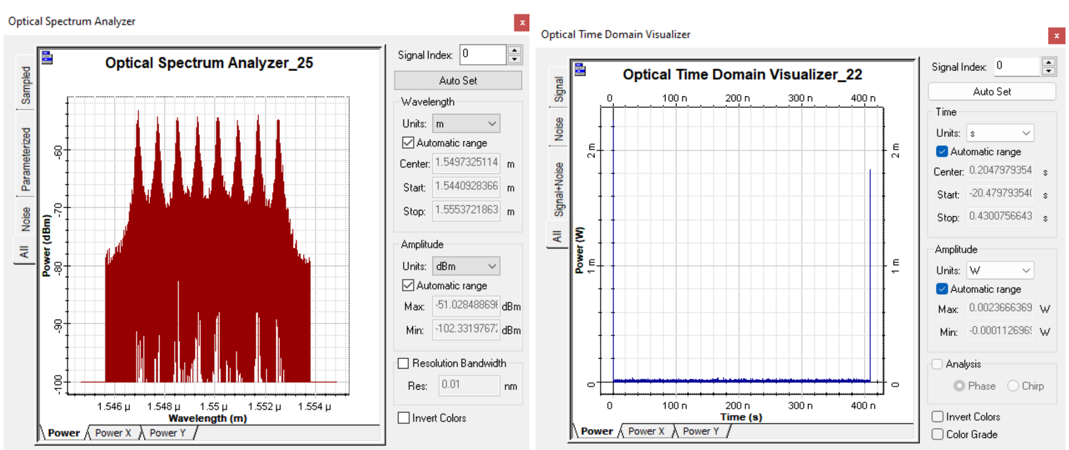


Fig 4.20 WDM Drop Spectrum at 193.8 Thz

Fig 4.20 consists of the output received from the transmitter side of channel at the frequency of 193.8 Thz, both the outputs identifies the frequency component which is being dropped.

4.5 : Outputs recorded from the output of optical switch at different Frequencies:

a) For Frequency 193.1Thz

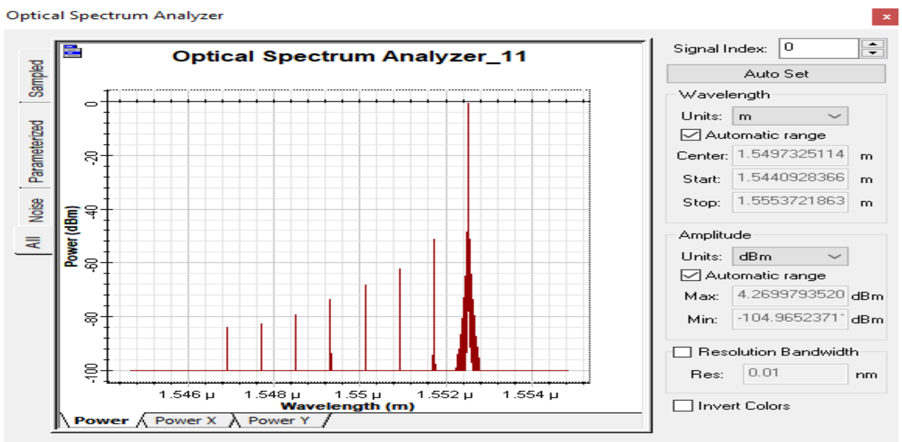


Fig 4.21 Output of Optical Switch at 193.1Thz

Fig 4.21 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.1Thz of frequency.

b) For Frequency 193.2Thz

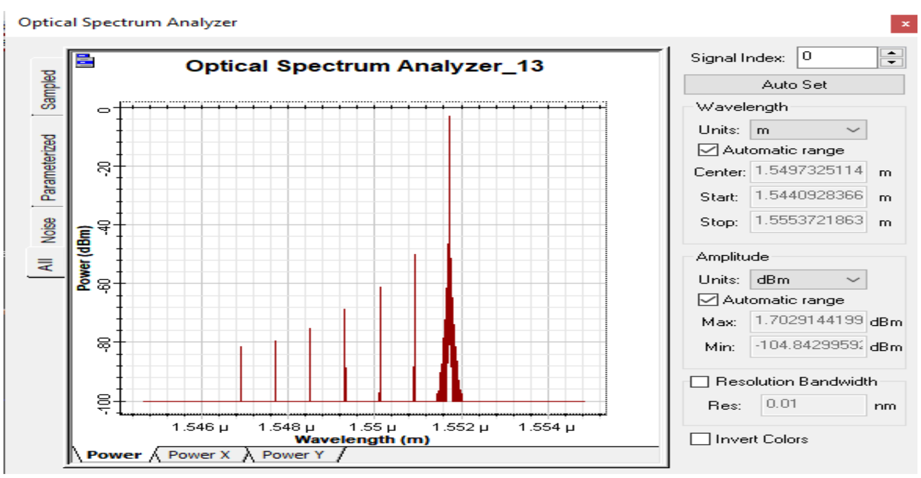


Fig 4.22 Output of Optical Switch at 193.2Thz

Fig 4.22 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.2Thz of frequency.

c)For Frequency 193.3Thz

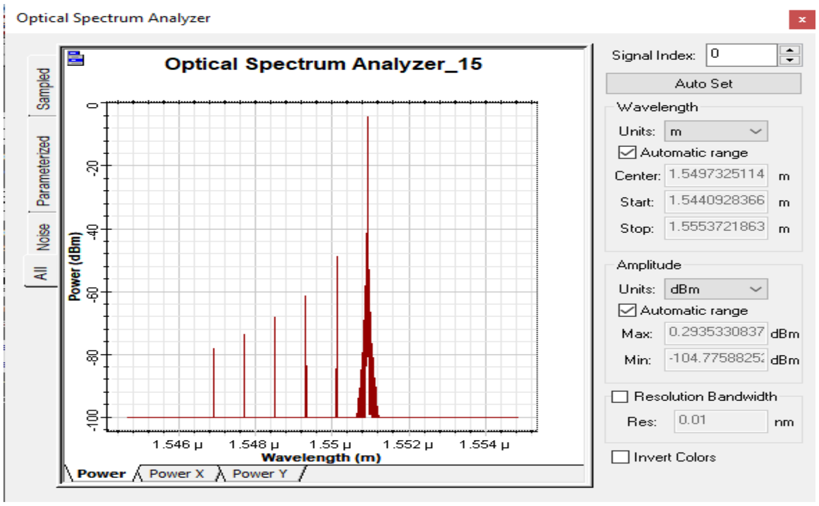


Fig 4.23 Output of Optical Switch at 193.3Thz

Fig 4.23 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.3Thz of frequency.

d) For Frequency 193.4Thz

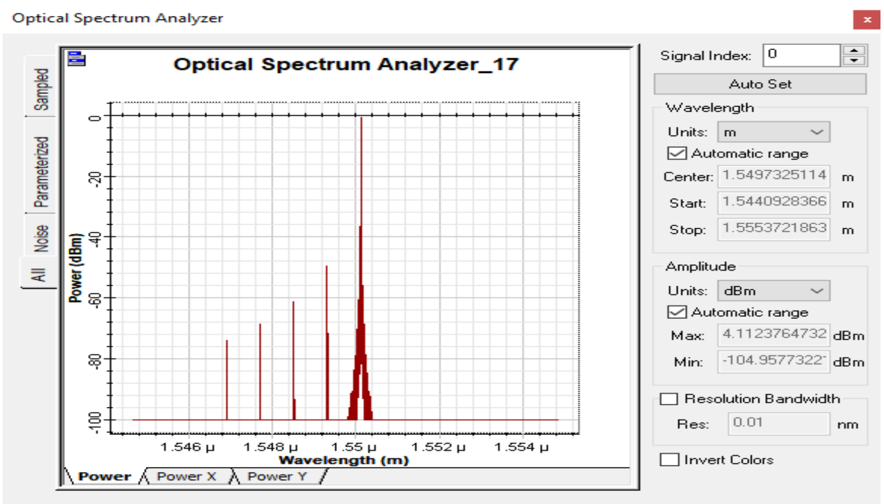


Fig 4.24 Output of Optical Switch at 193.4Thz

Fig 4.24 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.4Thz of frequency.

e) For Frequency 193.5Thz

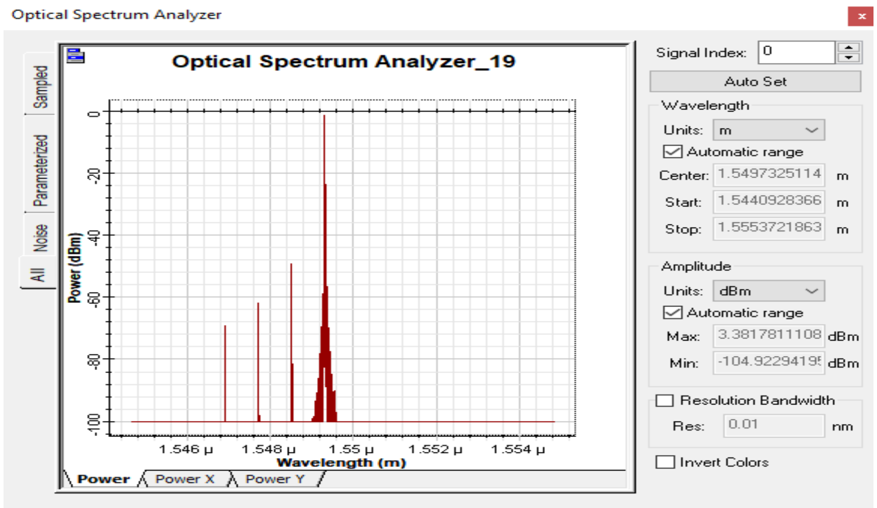


Fig 4.25 Output of Optical Switch at 193.5Thz

Fig 4.25 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.5Thz of frequency.

f) For Frequency 193.6Thz

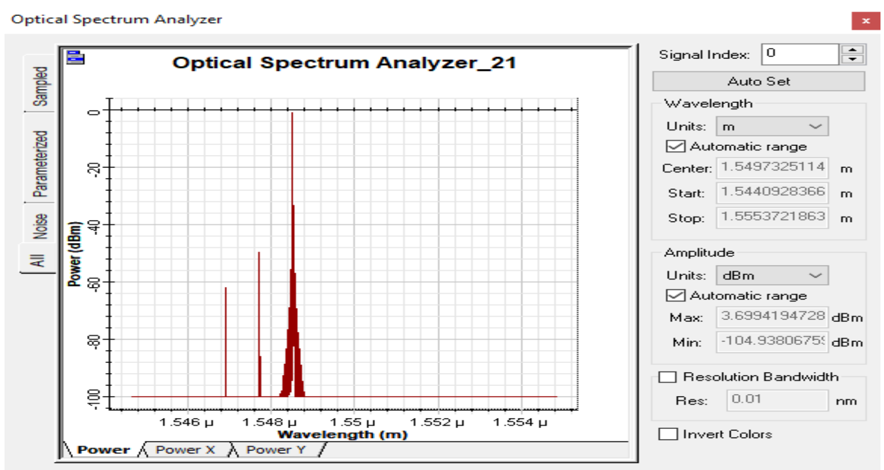


Fig 4.26 Output of Optical Switch at 193.6Thz

Fig 4.26 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.6 Thz of frequency.

g) For Frequency 193.7Thz

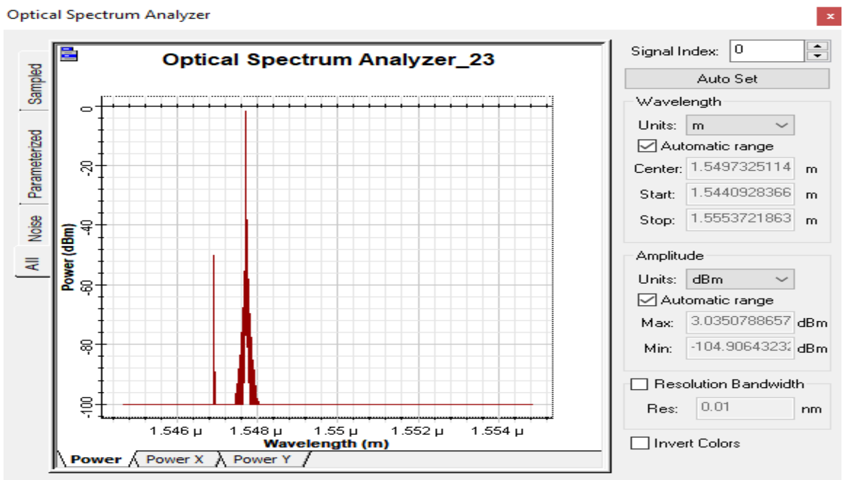


Fig 4.27 Output of Optical Switch at 193.7Thz

Fig 4.27 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.7 Thz of frequency.

h) For Frequency 193.8Thz

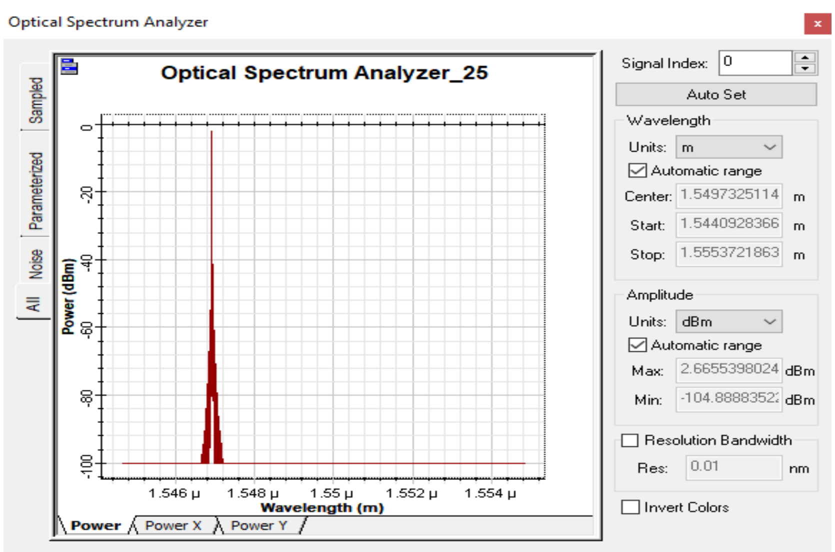


Fig 4.28 Output of Optical Switch at 193.8Thz

Fig 4.28 represents the output taken from the transmitter side and the above spectrum is input to the channel of ROADM at 193.8Thz of frequency.

4.5 Output received at WDM Add for Different Frequencies:

WDM Add will basically add wavelengths to the existing channels at different Wavelength or Frequency.

a)For Frequency 193.1Thz

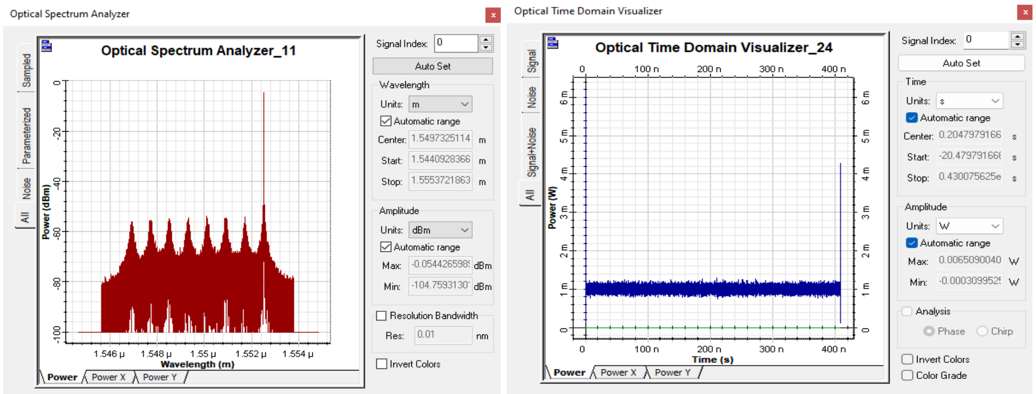


Fig 4.29 Output of WDM Drop at 193.1Thz

Fig 4.29 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.1 Thz.

b) For Frequency 193.2Thz

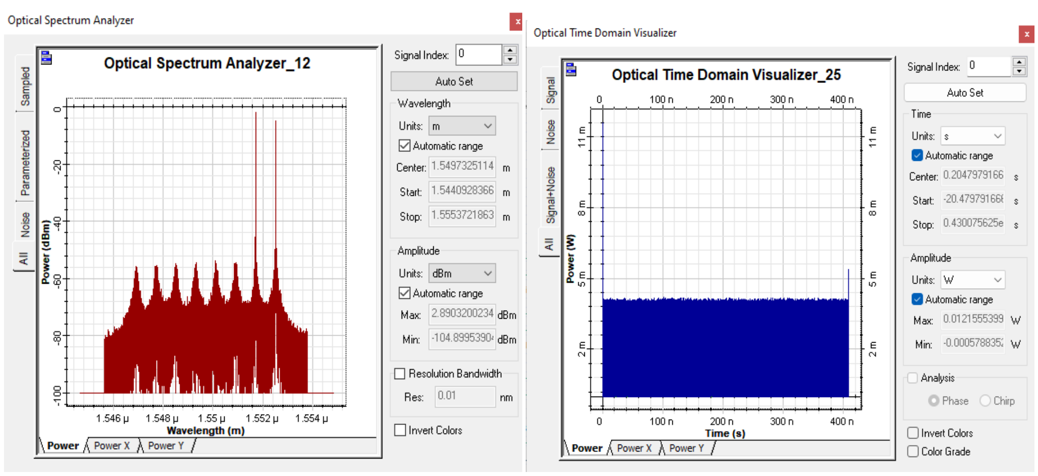


Fig 4.30 Output of WDM Drop at 193.2Thz

Fig 4.30 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.2 Thz here both the components are present at 193.1 Thz and at 193.2Thz.

c)For Frequency 193.3Thz

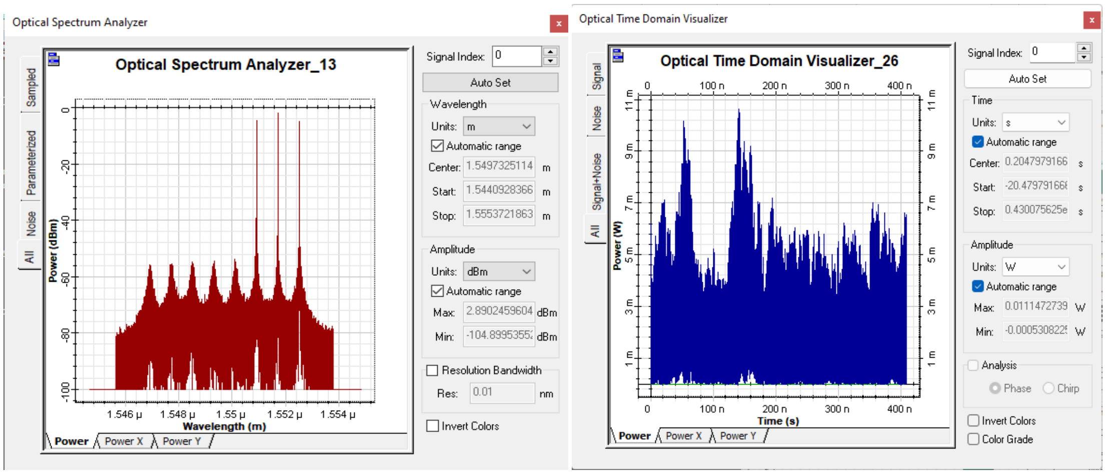


Fig 4.31 Output of WDM Drop at 193.3 Thz

Fig4.31 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.3 Thzhere the three components are present at 193.1 Thz, 193.2Thz and at 193.3Thz.

d)For Frequency 193.4Thz

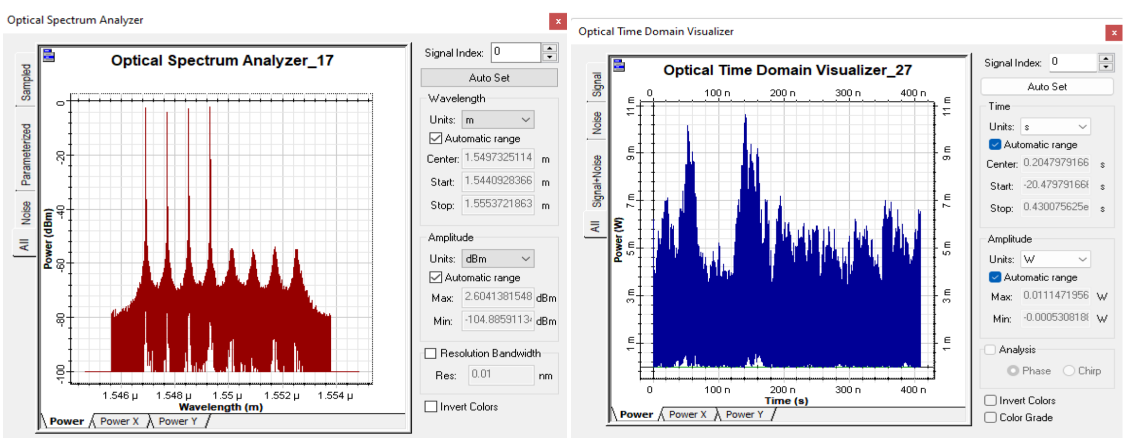


Fig 4.32 Output of WDM Drop at 193.4 Thz

Fig4.32 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.4 Thz here the four components are present at 193.1 Thz, 193.2Thz, 193.3Thz and at 194.4Thz.

e)For Frequency 193.5Thz

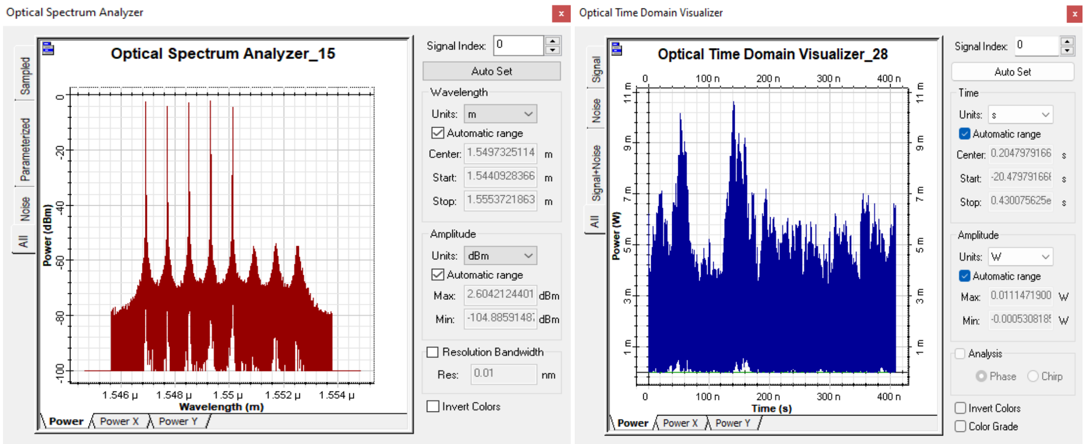


Fig 4.33 Output of WDM Drop at 193.5 Thz

Fig 4.33 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is 193.5 Thz here the five components are present at 193.1 Thz, 193.2Thz, 193.3Thz,194.4Thz and at 193.5Thz.

f)For Frequency 193.6Thz

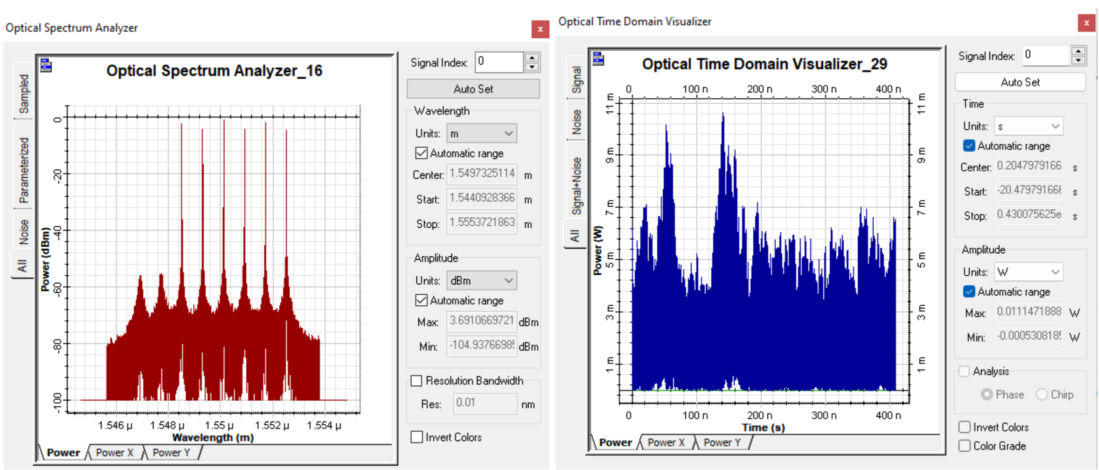


Fig 4.34 Output of WDM Drop at 193.6 Thz

Fig 4.34 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.6Thz here the six components are present at 193.1 Thz, 193.2Thz, 193.3Thz, 194.4Thz, 193.5Thz and at 193.6Thz

g)For Frequency 193.7Thz

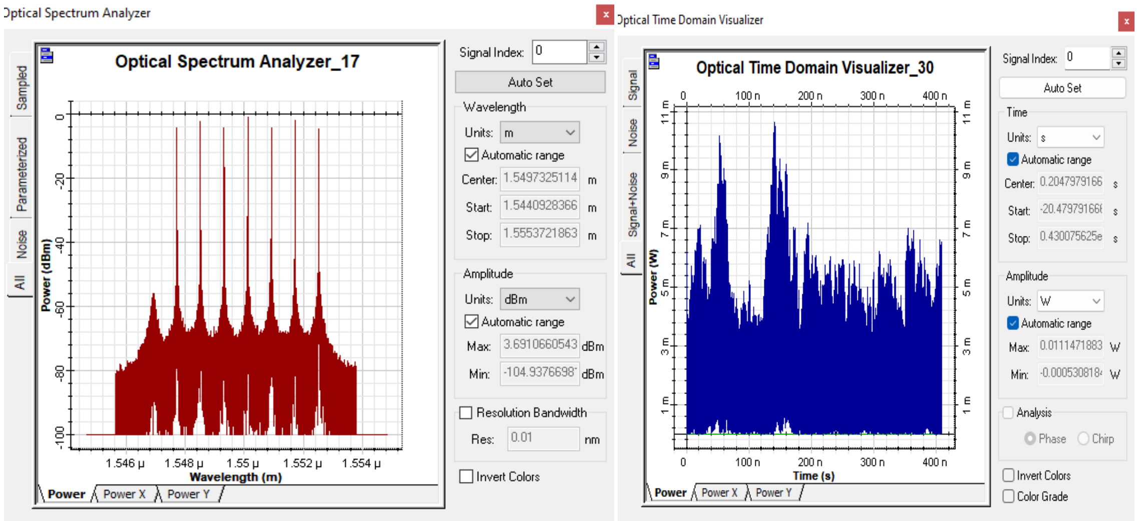


Fig 4.35 Output of WDM Drop at 193.7 Thz

Fig 4.35 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.7Thz here the seven components are present at 193.1 Thz, 193.2Thz, 193.3Thz, 194.4Thz, 193.5Thz, 193.6Thz and at 193.7Thz.

h) For Frequency 193.8Thz

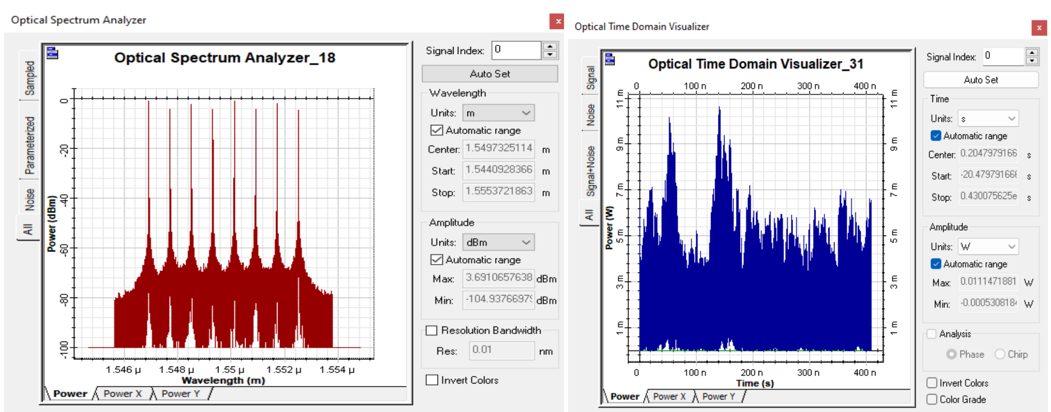


Fig 4.36 Output of WDM Drop at 193.8 Thz

Fig 4.36 is the output recorded from the optical spectrum analyzer applied on the output of WDM Drop at every particular frequency this is at 193.7Thz here all components are present at 193.1 Thz, 193.2Thz, 193.3Thz, 194.4Thz, 193.5Thz, 193.6Thz,193.7Thz and at 193.8Thz.

RESULTS AND DISCUSSION

4.6 Obtained Results

The Simulated ROADM on the Optisystem is consisting of several blocks including the main block to be WDM Drop and WDM Add block where once each particular frequency is dropped and then passed on to the WDM Add through the Optical channel consists of Attenuator.

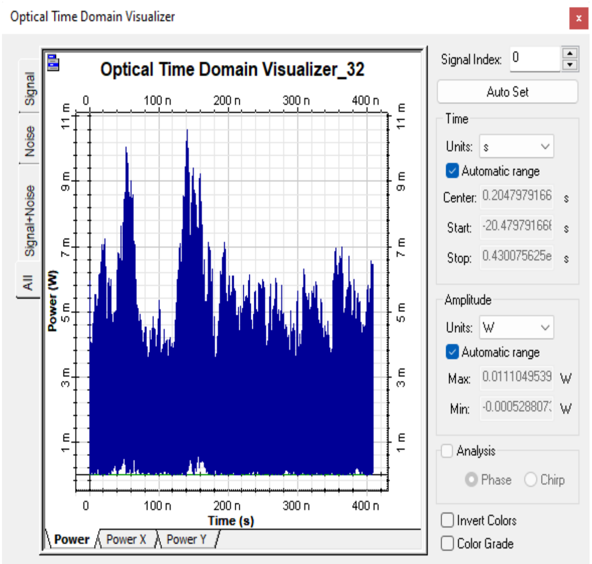
The results obtained were in the form of Spectrum and got the better results of all the frequency components through WDM Add. So it can be concluded that in order to use the OpenFlow Switch in SDN Controller the ROADM Layout can be used to act as a switch as many bits combination can be given to the controller through the Control for as many number of users.

4.7 ROADM layout

In ROADM the simulation was carried out for 8 channels under the Optisystem as 193.1Thz, 193.2Thz, 193.3Thz, 193.4Thz, 193.5Thz, 193.6Thz, 193.7Thz, 193.8Thz. The bit sequence which is fed as the input from user defined bit sequence generator to the Optical Switch has been done through the control from where we can control and change the data or bit sequence as and when required. The observations have been recorded for all the transmitted signals at time domain from the transmitter side of the design and then the observations have been recorded for both frequency and time domain for WDM Drop where it can be clearly seen one by one how the frequency component is being dropped and the similar case is for the WDM Add also. The bit sequence which is being sent to all the controls controlling the Optical Digital Switch has been set.

There could be the bit sequences or the user defined sequences which will be the controlling the Optical Switch. A particular bit of sequences and will get the output recorded from Optical Spectrum Analyzer. In the output taken from the WDM drop will get all the frequency components added together as a whole as the amplified version of theirs. The controlling of data which is being sent to the Optical Switch is being managed by the control applied in the system. For the above simulation, binary bit 0 has been taken for all the controls.

Transmitted Signal:



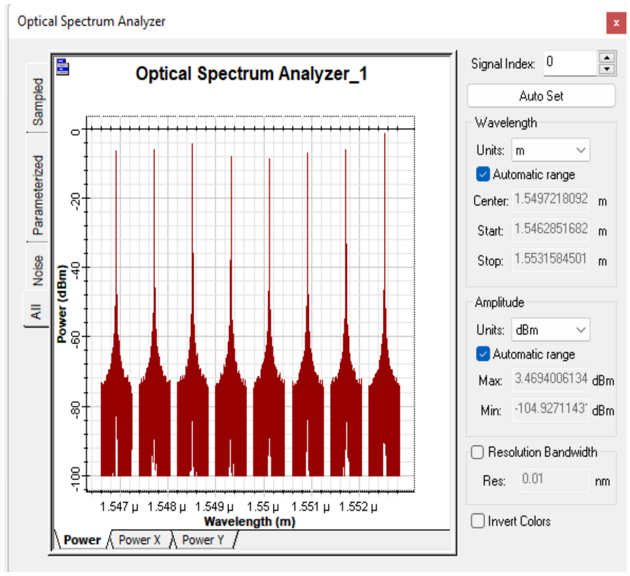
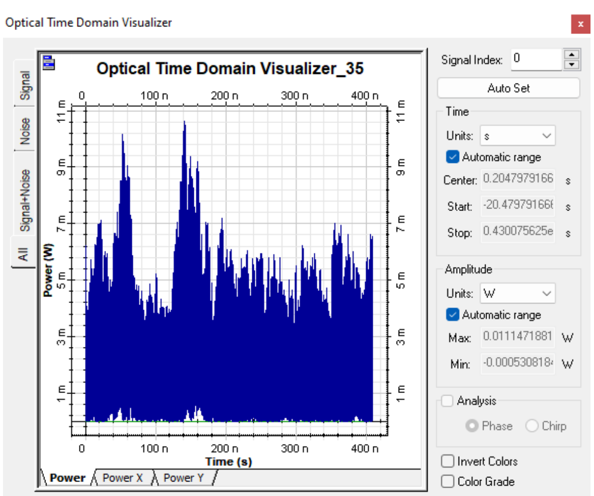


Fig 5.1Transmitted Signal

Fig 5.2 Transmitted Signal

Received Signal



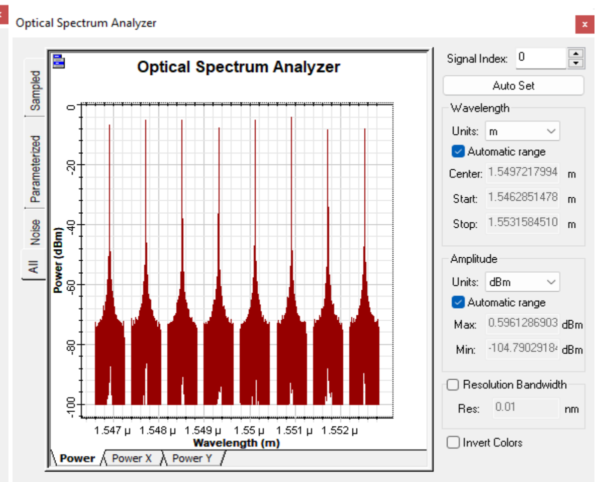


Fig 5.3 Received Signal

Fig 5.4Received signal

From Fig 5.1and 5.2observations can be made of the transmitted signal and from the Fig 5.3 and 5.4 the observations can be recorded for the received signal.

CHAPTER 5: CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

The ROADM Layout has been designed using Optical Switches. The data which is being sent to the Optical switch has been controlled by the User Defined Bit Sequence where the user can send the data to the Optical switch and can change the data as and when required. The spectrum for all the frequencies has been observed initially from the transmitter that consisted of 8 numbers of channels. The data signals have been studied in both the time and frequency domain. WDM Drop which has the provision to drop the signals at a particular frequency has been observed and the spectrum has been recorded and studied for both the frequency and time domain systems. WDM Add which has the specification to add any data signal of any frequency is also observed in both the time and frequency domain systems. Overall implementation and optical part of Software Defined Optical Networks has been studied and recorded using Optisystem version 19.0.

5.2 FUTURE WORK

For the future work Optical Switches can be controlled automatically through the MATLAB Programming. There will be the several stages that could lead to the design of SDON. So the initial could be the design of the input sequence that could be developed in the MATLAB which was previously used to generate NRZ sequence and then followed by the LASER array and can proceed in the normal way as any other optical network could propagate in the normal and usual manner till the optical receiver could receive the signal.

Further going on to the next stage add header could be added and payload of data which can be used in any Ethernet network which will be further designed. From the MATLAB component which has been generated will move on to or will pass further to NRZ sequence generator, the generated packet will be modulated and will be forwarded to the optical fiber or can be switched through the Optical switches which will add the flexibility and here the switches used will be ROADM switches.

Now in the final and last stage SDN will be fully developed following by the flow table, where flow table will provide the MATLAB codes for which the packet can be send to the controller or not, or whether any entry of the packet has been missed, or where the missed packet will be placed. Based on all these circumstances the flow table will be developed which will contribute to the controlling nature of SDON. So the decisions of forwarding the packets will be done by Open Flow Switches will are basically the ROADM switches. Then at the receiver side one MATLAB component will be present which will convert the received optical signal into the electrical one into the bit sequence that will contribute the signal which is arrived at the transmitter end.

In project simulations of optical networks have been carried out on Optisystem version 19.0, ROADM Layout which is basically an Optical switch for Software Defined Optical Networks.

The outputs for the network has been recorded and made the observations based on the results obtained from the software and the comparison were carried out on the basis of BER that is, Bit Error rate and Q-factor and the results were proved good for the design of the ROADM layout.

And also the algorithms for various MATLAB codes has been provided counting as the work for future in order to transmit the packet not only by the simple optical network but in place of that transmitting the packet with the help of Software Defined Optical Network. The network can also be reprogrammed according to the demands and also can reroute the packet by matching the packet header and also taking the decisions if the table miss entry is there for the packet that whether the packet has to be dropped or has to be rerouted and the SDON also improves the network programmability, flexibility and making it adaptable according to the different traffic demands for optical network rather than that of the simple Optical Networks.

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