A Novel Path Tracing Scheme In All-Optical Networks Using Benes Network

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Abstract

A novel path tracing scheme is described in this paper which is known as Prime number encoding scheme using Benes network. In this scheme every data packet consist a label which is default 1 and every node consist of a prime number tag, as this data packet pass through the network label will be multiplied with the tag of the node. Prime number multiplication is done with encoder. At the receiver end factorization is done which gives the information of travelled path. In this scheme optical cross connects (OXC) is replaced with the Benes network which gives the better result than OXC. System having Benes network gives less attenuation than OXC and complexity of the system also decreases.

Keywords: Path Tracing Scheme, Optical Network Management, Optical Cross Connect (OXC), Benes Network, All-optical Network (AON).

1. INTRODUCTION

In All-optical networks switching is an essential part, it helps to route the data from source to destination. There are two types of switching in a network infrastructure: Circuit switching and Packet switching, both techniques have own advantage and disadvantage. In circuit switching, a guaranteed amount of bandwidth is allocated to each user and this connection available to the user for all the time, once the connection is set up. The sum of the bandwidth of all the circuits, or connections, on a link should be less than the link bandwidth. Example of circuit switching is Public-switched telephone networks (PSTN), these networks are provide to support voice stream and for other bulky data. Now days circuit switching is also known as private line service, which is used for security purpose [1].

Another type of switching is Packet switching in which data is broken into small parts and known as packet. Packet switching is used for small amount of data and it doesn’t create the physical path between the source and destination. In All-optical networks packets are always carried on a carrier that can be of different wavelengths, signal generated from one source can be delivered at the different destination nodes using wavelength division multiplexing (WDM) which helps to route the data in optical network. At each network node routing decision is made that based on its current traffic loading and the destinations addresses of the data packets received. When an optical data packet arrives at a node in network, its packet header that contains usually of lower data rate is first extracted and detected, to retrieve its destination address. The high-speed packet payload portion is buffered through fiber delay lines, before the optical packet is being switched, via the optical cross-connect (OXC), based on the routing decision formed.

In this paper, a circuit switched based network infrastructure is used named as Benes network. Benes network is basically a circuit switched network but it also used in the case of packet switching [2]. It is well known that Benes network is a rearrange-able type of interconnection networks. It can be used as a switching system in telecommunications or a communication device in multiprocessor systems for linking processors and/or memories at its inputs and outputs. The Benes network has less complexity compare to cross-bar interconnection network (OXC) in terms of the number of switching elements. However, the Benes network is not easy to setup as the network with O (N2) connections. The main problem is that Benes network needs
O ($N\log_2 N$) time steps to realize N! Permutations between its inputs and outputs. Many studies on fast algorithms to setup Benes networks have been made. Nonblocking conditions are the bases of the setting-up algorithms [3].

For reliable data transmission and delivery in WDM networks the path should be well managed and having high monitoring facility. During the travelling time packet can be routed to wrong destination or alternate ports of the optical cross connects (OXC) due to error in switching operations and malfunctioning of switches, this problem can be minimized with Benes network that is implemented in this paper. So at reception of the optical data packets at the destination node, identification of the exact physical network nodes or fibre links that the received optical data packets have actually traversed, is very useful to derive and estimate its complete actual physical path. This information is very useful to detect any possible network routing error due to possible malfunction of the reconfigurable optical routing devices, and diagnose the possible causes of signal quality degradation in the received optical data packets, by examining the optical impairments along the retrieved path.

Moreover, when there exists any malicious or attack traffic, it will be useful to trace down the source of the attack through examining the path information of the received packets. In addition, if path tracing is performed at certain strategic nodes in the network, the traced path information on the previously traversed network nodes or links of the data packets could be used to deduce the actual or relative amount of accumulated optical impairments or temporal delay suffered by the dynamically routed data packets. Such information is beneficial to estimate the signal quality, and make strategic scheduling and routing decisions to meet the quality of service (QoS) requirement of the network.

Many techniques proposed and implemented for path tracing but all techniques have some advantage and disadvantage also very first technique was pilot tone based path tracing in which pilot tones of low frequencies used to trace the path in the network. A pilot tone at a distinct frequency was added to each input port of the OXC, as the input port identifier. By examining the pilot tone frequencies contained in the switched optical signal at each output port of the OXC, the switching connections of the OXC could be derived [4], [5].After that time delay recognition technique come into picture every node have some delay instead of the pilot tones. Regarding to the time-delay recognition schemes, the optical pulses at different input or output ports in an OXC would experience different time delays, via some delay circuits. Hence, by examining the unique temporal pulse patterns generated, connection states between the input and the output ports of the OXC could be derived. The scheme could be further extended to realize path monitoring by assigning different time delay patterns to different network nodes. However, the scheme suffers from poor scalability, in terms of the amount of fibre delay required at each node in order to avoid any ambiguity among between different possible paths. Besides, precise synchronization is needed [6]-[9].

Recently, a novel of path tracing was proposed and implemented in which a distinct prime number was assigned to each node as the path information tag. Through employing optical label encoders based on prime number multiplication at the outputs of the network nodes, path information tags carried by simple computation on the optical packet label at the receiving node. Optical encoder can manipulate the labels on the fly [10].In this paper, prime number encoding scheme further extended which helps to improve the Quality of Service (Qos) of the system. Next section illustrates the principal of path tracing by employing the extended prime number encoding technique.

2. PRINCIPLE OF PRIME NUMBER ENCODING PATH TRACING SCHEME

To trace the path in a network there are two ways one is network link tracing and other is named as network node tracing. Network link tracing identifies all the links that the optical packet has traversed. Network node tracing identifies all the nodes that the optical packet has traversed. Both of schemes can be realized using extended path tracing scheme.

2.1 Network Link Tracing

Wavelength routing network with six nodes is shown in Figure 1and Table 1. Each link is assigned with a prime number. In network link tracing every link has a prime number tag it can be 3, 7, 11, 13 etc. Whenever a signal passes through a particular link its label is multiplied with its prime number tag. Therefore, all the fibre links that the optical data packet has traversed can be identified at the receiving node, via prime-number factorization of the received label value. Figure 1 shows an example that the individual fibre links in the network have been assigned with their distinct prime-number tags. Link every link tag is multiplied with its label which is default set as 1.

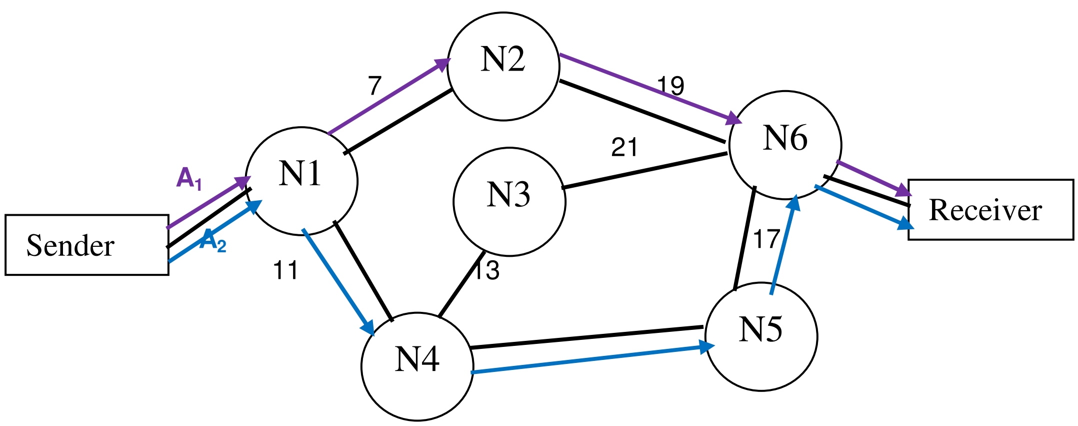


FIGURE 1: Example of Network link tracing.

A_1	N1	N2	N6	
Label Value	1	7	133	
A_2	N1	N4	N5	N6
Label value	1	3	39	633

TABLE 1: Example of Network link tracing.

2.2 Network Node Tracing

Wavelength routing network having six nodes is shown in Figure 2 and Table 2. Network node tracing is modified from network link tracing technique, in this technique each node is comprises with AWG based OXC and assigned with a prime number. Whenever a signal passes through a particular node its label is multiplied by the prime number of the node. Therefore, all the nodes that signal traversed identified at the receiver end, by prime number factorization of the received label value. An example of prime number encoding technique in which node assigned with a prime number is shown in Figure 2.

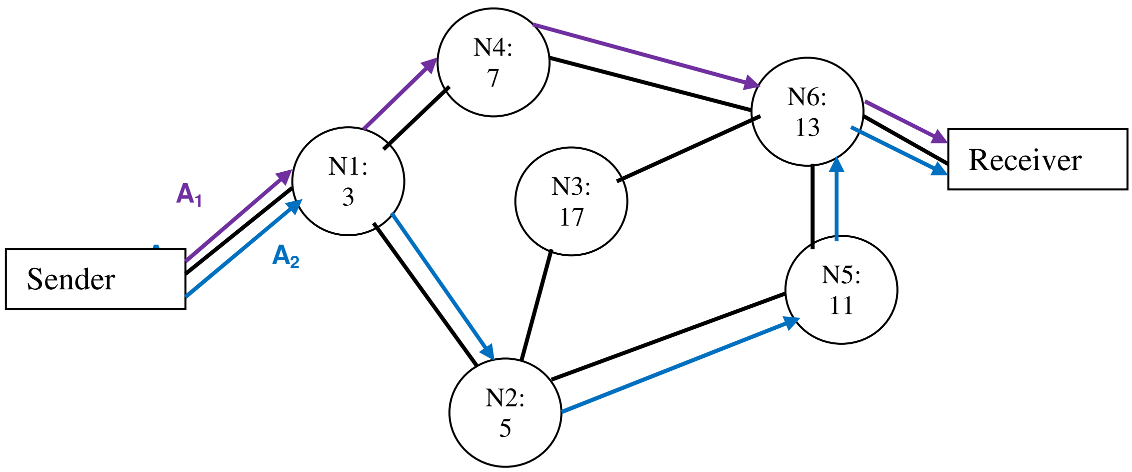


FIGURE 2: Example of Network Node Tracing.

A_1	N1	N2	N3	
Label Value	3	21	273	
A_2	N1	N4	N5	N6
Label value	3	15	165	2145

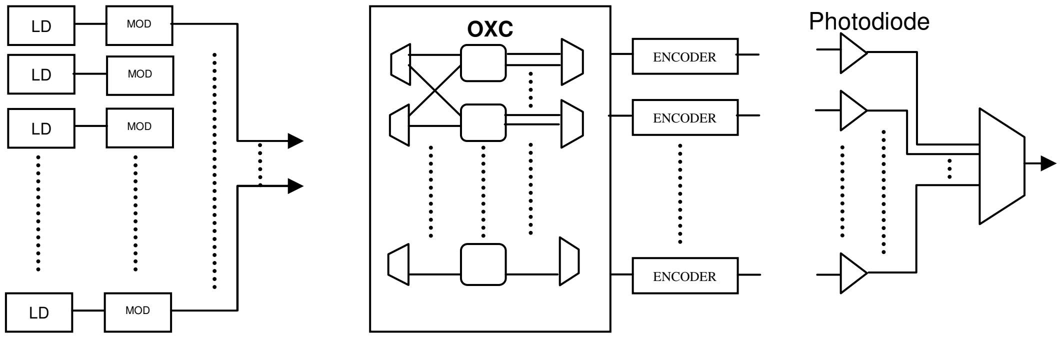
TABLE 2: Example of Network Node Tracing.

3. EXPERIMENTAL SETUP OF PRIME NUMBER ENCODING PATH TRACING SCHEME USING OXC

To realize path tracing scheme laser diode is used as a source. Eight laser diodes are used to generate eight signals. These signals are divided into two parts, first four signals are taken as a data signals and another four signals are taken as a pilot signals. Data signals are of 193.1, 193.2, 193.3 and 193.4THz, all signals are having a power of 25dBm. Pilot signals frequencies are 193.5, 193.6, 193.7 and 193.8THz that contains label value for each frequency, all pilot signals are having a power of 10dBm. Transmitter module is shown in Figure 3(a). Further signals are modulated using frequency modulation for transmission purpose.

Signals are further pass through the channel which consists of a OXC and Encoder, encoder is used to calculate the travelled path of the packet on fly.

Fully implemented experimental setup is shown in Figure 3.

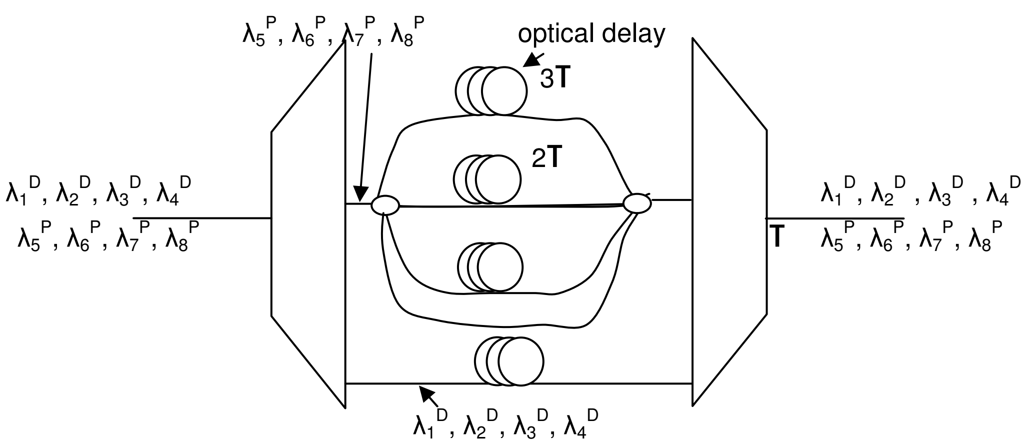


(a) (b) (c)

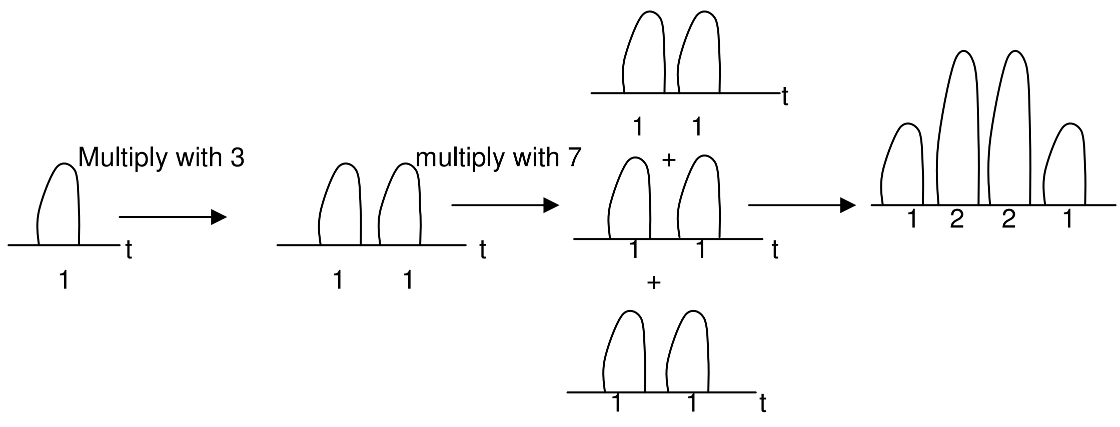
FIGURE 3: (a) Transmitter generating eight signals, (b) Channel consist of Optical cross connect (OXC) and Encoder, (c) Photodiodes at Receiver End.

At each output port of the OXC, the switched data wavelengths and their corresponding encoded labels from different inputs are fed into an optical encoder to perform multiplication of its assigned prime-number tag to the incoming label, and its structure and principle are illustrated in Fig. 4(a). The data frequencies and the pilot frequencies (i.e. label) of the incoming composite signal are first separated such that the label wavelengths are fed into an optical delay line circuit for multiplication of the label values with the prime-number tag of the OXC. The optical delay line circuit comprises an optical power splitter, an array of fiber delay lines, followed by an optical power combiner. By setting appropriate number of fiber delay lines, it can generate an impulse response which represents a particular binary number. Thus the resultant output pulse sequence corresponds to the product of the input label value and the tag value [10].

For instance, as shown in the Fig. 4(b), when an incoming label with a value of 1 (i.e., one optical pulses) is fed into the optical delay circuit with fiber delays of 0, τ, which represent a tag value of 3, the output will have two pulses with identical amplitudes and thus represent the decimal value of 3 in binary form. Next, the label further passes through another optical delay circuit with fiber delays of 0, τ, 2τ, which represent a tag value of 7, the output will have four pulses with relative amplitudes 1, 2, 2, 1, respectively. By substituting these relative amplitudes as the coefficients of the polynomial expression,$1\times y^3+2\times y^2+2\times y^1+1\times y^0$ with y=2 , a decimal value of 21 is obtained and this corresponds to the product of the input label value (3) and the tag value (7).



(a)



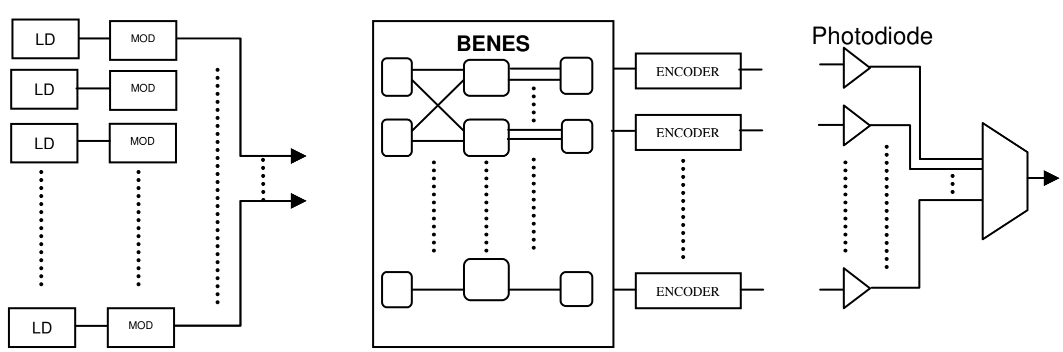
(b)

FIGURE 4: (a) Structure of encoder for prime number multiplication. (b) Example showing Multiplication of tag 3 & 7 with label 1.

4. EXPERIMENTAL SETUP OF PRIME NUMBER ENCODING PATH TRACING SCHEME USING BENES NETWORK

Experimental setup of prime number encoding path tracing scheme using Benes network is shown in Figure 5. Whole setup is divided into three parts that are Transmitter, Channel and Receiver End. Transmitter part is shown in figure 5(a), which consists of eight laser diode sources. Laser diodes generate the eight frequencies signals i.e. 193.1, 193.2, 193.3, 193.4, 193.5, 193.6, 193.7 and 193.8THz. Four signals are data signals having frequencies 193.1, 193.2, 193.3 and 193.4THz, data signals are of 25dBm power. Another four signals are pilot signals having frequencies of 193.5, 193.6, 193.7 and 193.8THz, each pilot signal have a prime number label. All pilot signals have power of 10dBm.

In this scheme OXC is replaced by Benes network which is reduce the complexity and increase the power and also avoid the crosstalk like OXC. Basically Benes network is a switching network it can be a multistage network for large networks as shown in Figure 5(b). The advantage of Benes network is that connection between a large number of input and output ports can be made by using only small-sized switches. A bipartite matching between the ports can be made by configuring the switches in all stages.



(a) (b) (c)

FIGURE 5: (a) Transmitter generating eight signals, (b) Channel consists of Benes network and Encoder, (c) Photodiodes at Receiver End.

The Benes network is rearrangeable nonblocking network which can realize any arbitrary permutation. The Benes network of dimension n is shown to be strictly nonblocking if only a Suitable chosen fraction of l/n of inputs and outputs is used. In Benes network, the r-dimensional Benes network connects 2^r inputs to 2^r outputs through 2r-1 levels of 2x2 switches. Here, each level of switches consists of 2^{r-1} switches, and therefore the size of the network has to be a power of two. The Benes network has been proposed for use in telephone networks. It and other closely related networks were also used as interconnection networks for parallel computers [11]. Basic structure of Benes network is shown in Figure 6.

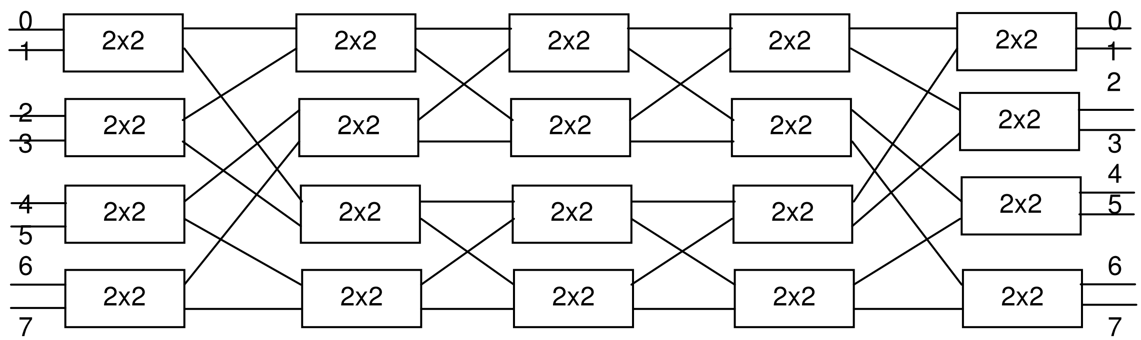


FIGURE 6: Basis Structure of Nonblocking Benes Network.

Encoder functionality is same as explained in the previous section. At the receiver end eight photodiodes are used, one for each frequency as shown in Figure 5(c). Basically photodiodes converts the optical signals into electrical signals. At last eight signals are multiplexed. Next section is about results analysis and comparison of both systems.

5. SIMULATION RESULTS

Prime number encoding techniques are implemented and simulated on optisystem software by optiwave. As earlier discussed two types of technique are simulated, one technique is having OXC and other technique is consists of Benes network. Both techniques are compared on the basis of two parameters that are Complexity and power.

Complexity is main issue in optical networking less complexity gives better results. A simple structure of optical cross connects, which is more complex than Benes network, OXC consists of 24 components. These components are 8 switches and 16 MUX/DEMUXs. Therefore these components are responsible for much power consumption. MUX and DEMUXs consumes more power and that's by are MUX/DEMUXs are omitted in the proposed work. MUX and DEMUXs leaks some information at every operation which leads to crosstalk. So reducing complexity also reduces the crosstalk. Benes network, which have 20 components. It consists of 20 switches are of 2x2. Complexity is decreased from the previous scheme i.e. using OXC; it also helps to increase the power of the system. Less power consumption means less attenuation in the network. If a system consume more power and received power is less than attenuation will be high. Therefore, System with OXC have more attenuation but system with Benes network have less attenuation that's by much power is received in the case of Benes network.

Power is also a important factor in optical communication. Power received at receiver side matters a lot, signal having high power will travels more distance. Optical spectrum of system with OXC is shown in Figure 7(a), electrical signals spectrum shown in Figure 7(b) and optical power meter is shown in Figure 7(c).Received power of system with OXC is just 7.269dBm.

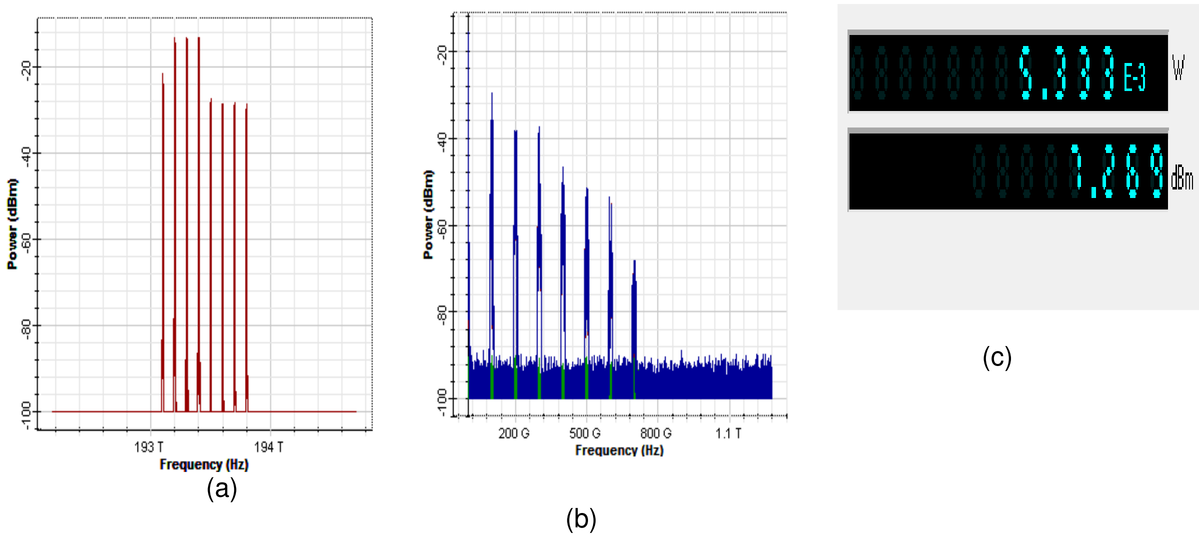


FIGURE 7: (a) Optical spectrum of system having OXC, (b) RF spectrum of system having OXC, (c) Power analyzer showing total received power.

System with Benes network has better results than system with OXC as shown in Figure 8. Optical spectrum of received signals is shown in Figure 8 (a). It shows the power of individual frequencies, power of data signals that are first four signals are higher than the power of pilot signals that are remaining four signals. RF spectrum of electrical signals is shown in Figure 8(b) and optical power meter is shown in Figure 8(c). Received power with benes network is 12.198dBm.

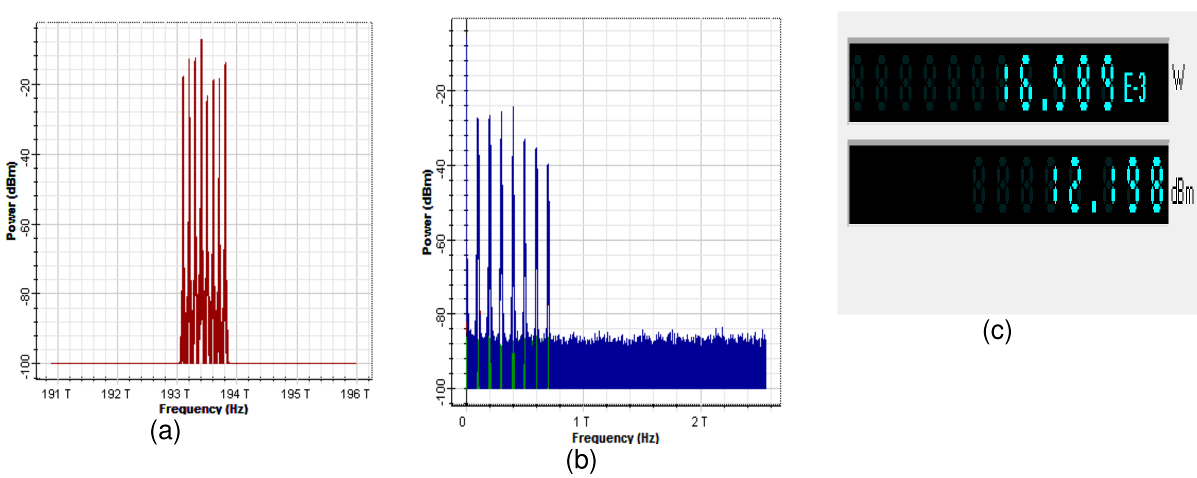


FIGURE 7: (a) Optical spectrum of system having Benes network, (b) RF spectrum of system having Benes network, (c) Power analyzer showing total received power.

Therefore from the above results it is clear that by replacing OXC with Benes network gives better performance in terms of power and it also reduces the complexity. As complexity decreases then cost of the system also decreases. Therefore system with Benes network will reduce the cost of the system.

6. CONCLUSION

Complexity and power are two important factors in optical communication. To measure and improve the both factors two techniques are implemented, first is prime number encoding technique using OXC and second is prime number encoding technique using Benes network. Technique using Benes network gives better performance in terms of power and it also reduces the complexity. Therefore Benes network can be used in the place of OXC to obtain better results. Future work can be extended by making a new network with less complexity and less switching. Network with high capability to reduce the crosstalk can replace the existing networks.

7. REFERENCES

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