©IDOSR PUBLICATIONS
International Digital Organization for Scientific Research
IDOSR JOURNAL OF COMPUTER AND APPLIED SCIENCES 4(1):14-22, 2019. ISSN: 2579-0803

Enhanced Performance of All-Optical Network Shared-Paths Protection.

[1]Anyigor, I. S,[1]Nweke, F. U, [2]Ezeagwu,C. O and [3]Alor, M. O.

[1]Department of Industrial Physics, Ebonyi State University Abakaliki, Nigeria.
[2]Department of Electronics and Computer Engineering, Nnamdi Azikiwe University Akwa, Anambra State, Nigeria.
[3]Department of Electrical/Electronic Enginerrng, Enuugu State University of Science and Technology, Enugu, Nigeria.
Email: stanleyanyigor@gmail.com

ABSTRACTS

This research work investigated the survivability (protection and restoration) for supporting multicast services, against multi and double link failures in the optical domain of the wavelength division multiplexing (WDM) mesh networks and proposed a new algorithm called improved shared-path protection(ISPP) to completely tolerate failures. The work presented some ways for optimizing design of network protection for analysing blocking probabilities of the all-optical networks. A two-stage greenfield optical network design optimiser was developed, based on the shortest path algorithms and a comparatively new matheuristic called simulated allocation. It was able to handle design of all-optical mesh networks with optical cross-connects considering ducts, fibre and node costs for designing protected networks.
Keywords: Network, All-Optcal, Multiplexing, Wavelength, Domain.

INTRODUCTON

Due to increasing demand of services from network operators and owing to poor planning operations, there are bound to have network failures often such as call-drops, interferences, partial or total loss of data and others as always complained by network users [1]. This research is focused on protecting network from link or path failures and blocking probabilities of optical fibre network system. The work was to improve on the removal of link failures by providing the necessary infrastructural development of nodes, links, switches and also the development of the primary paths, backup paths and disjointed links. This would apply wavelength of various values to different links and an algorithm was made to archieve the ideal network protections [2]. A simulation of the dynamic network environment was applied to automatically switch from one path to the other when any path fails. Nodes were developed and analysed with corresponding links. Primary and Back-up paths were also developed to share mixed wavelength links. Similarly, some mixed backup links were transformed into primary links during bottleneck situations. The basis of this arrangement is for easy sharing of resources by network links to prevent failures and then improve the overall performance operations of the network [3] for the net generation.

It is very critical in network operations when links fail due to congestions, hence the high demand of the numerous services make it imperative that the network must be expanded. In order to expand the network for proper and smooth usage, procedures must be followed which are either to replace the existing fibre core by increasing the bandwidth which implies that the old one has to be aboundoned and replaced with new core of higher bandwidth [4]. This has the disadvantage of high cost. The second and better option is the provision of facilities to expand the link/path without incuring the cost of replacing with new cores. To achieve this, the paths and links were created with the incoperation of wavelengths of various values and optical carrier group of various values. This is asisted by the (Synchronous Optical Network (SONET) and Synchronous Digital Hirachy (SDH) families [5].

Operatonal Princples

The simple algorithm is that each request is directed to a primary path and towards disjointed links (backup link) [6]. Such that if one failure link is on the primary path and another failure link is on the first backup path then there is still an available backup path to carry the traffic. The simple plan of the proposed system is to allow two backup paths to share same wavelength [7]. Thus; fig.1.1, illustrates the switchng system link where P_n, b_n^1 and b_n^2denote the primany path, first backup path, and second backup path for connection request n, respectively. It is assumed that each connection requires the bandwidth of one wavelength channel, the network node has the full wavelength conversion capacity, and each fiber link is bi-directional [8]. Three kinds of wavelength links are defined for this purpose: (1), Primary wavelength-links that are used by primary path; (2), Backup wavelength-links that are used and shared by backup paths; (3), mixed wavelength-links that are used and shared by primary and backup paths. In this Shared Path Protection (SPP), the backup wavelength-link w_2 on link “k” needs to be assigned to the backup paths b_1^2, and the backup wavelength-link w_3 on link j needs to be assigned to the backup path b_1^1. However, the backup wavelength w_2 and w_3 are redundant, becauseb_1^1 can share the primary wavelength-link w_1 on link j used by the primary path p_0, and b_1^2 can share the primary wavelength-link $w_0$on link k used by the primary path p_0. The reason for this is that the links traversed by p_1 are all traversedby p_0, so that if $p_1$fails, p_0 must fail simultaneously [9]. If the cut of links x and j leads to the failures of p_0 and p_1, the primary wavelength-link w_0 on link k used by p_1 can be released, so that w_0 is now free and it can be re-used by b_1^2. Then, the redundant backup wavelength-link w_2 can be saved. Since w_0 can be used (or shared) by primary path p_1 and backup path b_1^2, it can be changed to the mixed wavelength-link. Based on the same principle, the primary wavelength-link w_1 on link j also can be changed to the mixed wavelength-link and can be shared *by* b_1^1, and then the redundant backup wavelength-link w_3 also can be saved [10]. In this work, the protection algorithm allowing the primary and backup paths to share the mixed wavelength-link is to be improved in shared-path protection (SPP), [11].

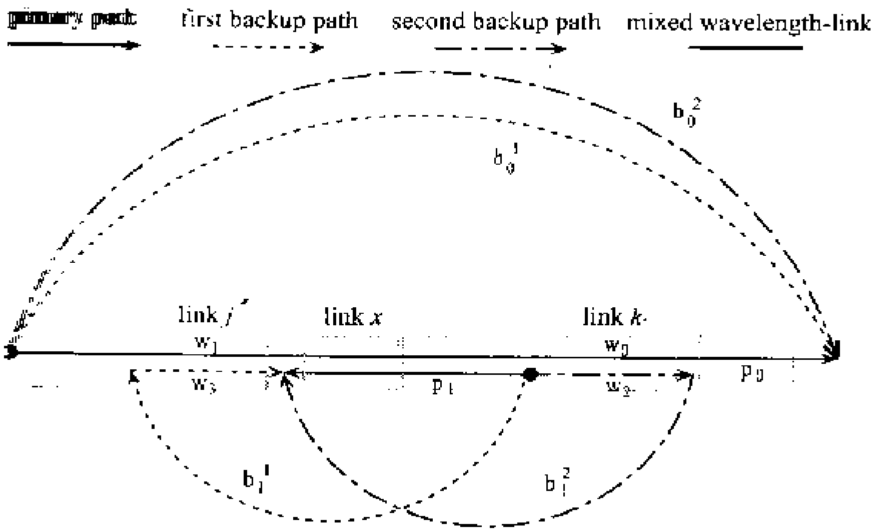


Fig.1; Wavelength Assignment of SPP

Wavelength division multiplexing (WDM) technology

With the advent of wavelength division multiplexing (WDM) technology, more number of wavelengths per fiber (≥ 100) is accommodated with each wavelength operating at the rate of at least 10Gbps [12]. An optical switch capacitate signals in optical fibers or integrated optical circuits to be selectively switched from one circuit to another, which is the basic underlying principle of telecom applications. Photonic switches are the systems that perform and control switching of light, unconstrained of how the light itself is switched. A significant portion of the optical switches in use are made up of photonic switches.

In optical communication networks, an optical coupler enables signals in optical fibers or integrated optical circuits (IOCs) to be selectively coupled from one path to another or one circuit to another [13]. The Optical Switchis a unit that actually switches light between two adjacent waveguides, which also performs switching by exploiting nonlinear material properties to propagate light. Any generic fiber optic data link, transport and provide the optical data through the fiber optic components based systems only. Generally, a fiber optic data link divides into threebasic operations as;

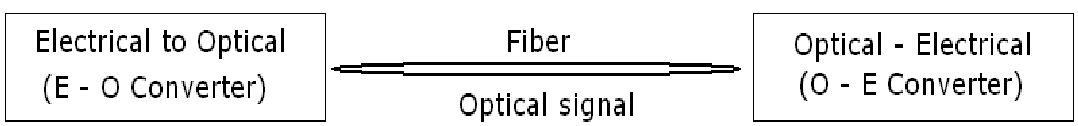


Fig.2: A block diagram of an E – O – E optical communication link.

Intra-light Emitting Signal Conversons

Primarily, an optic fibre communication system is made up of a transmitting device that converts an electrical energy into light signal and then an optical fibre cable that carry the signals, [14] and the receiver that converts the light signal back into electrical signal as shown in the block diagram of Fig.2. The schematic diagram is shown in fig.3 below.

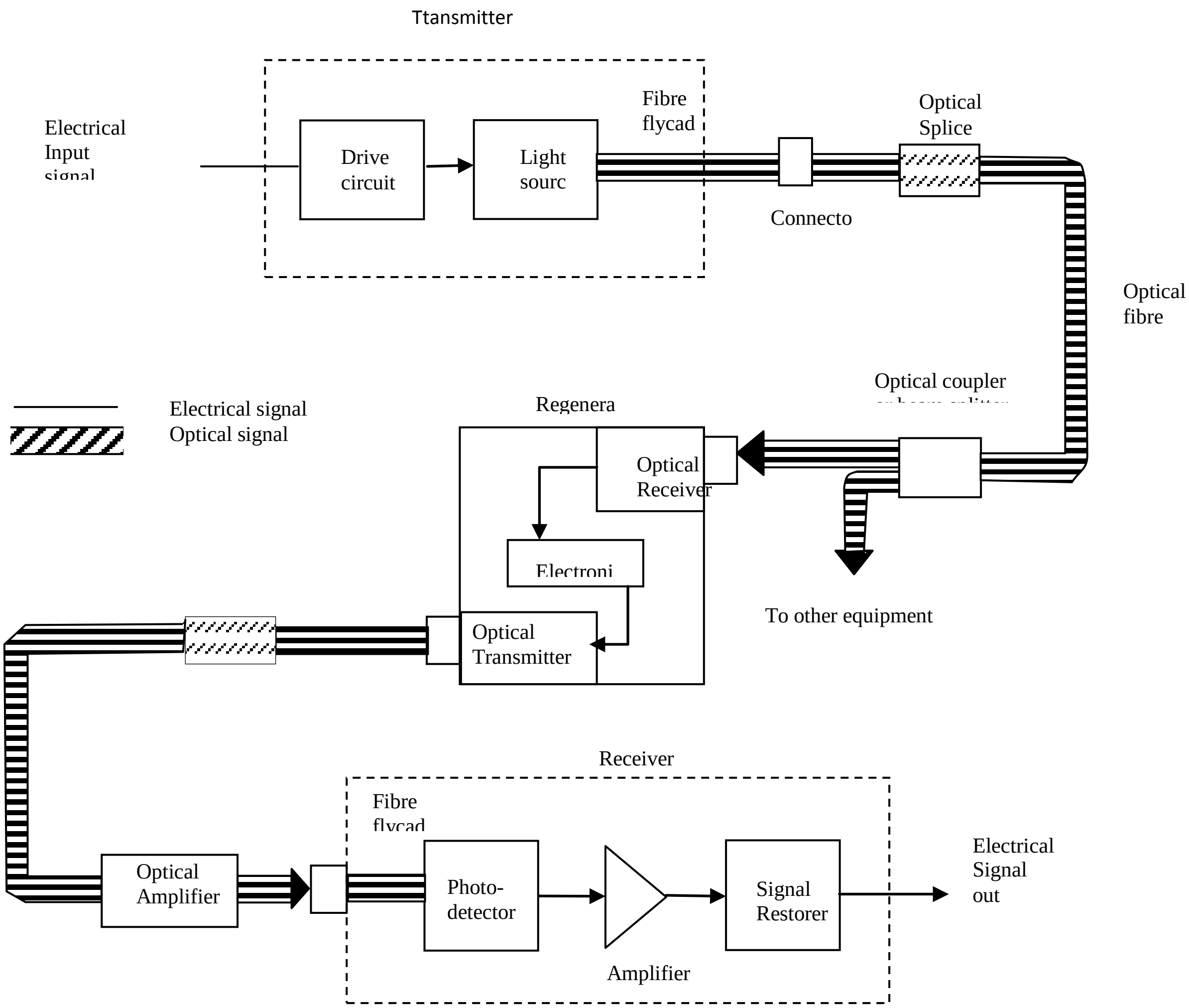


Fig.3, schematic diagram of optic fibre communications system

The requisite conversion must be achieved in such a way, that original electrical signal remains at the input and output port. However this needs the networks to go through the process of conversion from and vice versa. Therefore to avoid this conversion that wastes much power consumption and slows the speed of signals, there is the need of inserting all optical components which do not have any need of conversions [15]. Hence, Optical couplers are important components, which are very much required in optical networks or communication links for their day to day operations and various applications. With the advent of multimedia and scientific computing, there is an exponential growth in bandwidth demand raised by many users possessing the internet connections, this has great impact for their use particularly in military and in academic communities [16].

Therefore WDM technology based all-optical mesh networks have been in use to adjust the Internet's ever growing bandwidth demand. Internet backbones are proven to be much capable in terms of efficiency and reliability [17]. In telecom applications, an optical coupler can be used for selective coupling from one circuit to another in optical fibers or integrated optical circuits (IOCs). In present scenario, electronic coupling is more popular between fiber transponders. Photonic couplers perform this function by physical coupling of light signals among the fibers, independent of how the

light itself is coupled.All-optical coupling devices in principle are capable of performing the same functions as electronic coupling devices, e.g. guide the signal flow in an optical network as desired and constitute the basic component of the optical computational systems [18].
The capability of transmitting large amounts of information over long distances at nearly the speed of light and without any significant loss of data or interference has made optical fibers perfect choice to use in modern communication systems. In O–E–O devices, the conversion of optical to electrical and vice versa requires extra power and generates unavoidable extra heat, which put great impact on the device cost, if the conversion has to take place quickly or many times. Besides, it is almost impossible for electronic conversion circuitry to keep pace with very high speed optical data transfer, creating a bottleneck situation and thus decreasing the overall efficiency of optical links and communication channels [19]. The guidance of the signals in all – optical domain improves the efficiency of a communication system exponentially.

DISCUSSION/RESULTS.

Probabilistic Modelling with Independent Link-Load Assumption

An approximate analytical model is developed for a fixed-path (deterministic) routed network with an arbitrary topology, both with wavelength conversion. This model is then used along with simulations to study the performance of three examples of networks: the nonblocking centralized switch, and the ring network and the shared-path lnk. The traffic loads and the wavelength occupancy probabilities on the links are both assumed to be independent. A wavelength assignment strategy is employed in which a lightpath is assigned a wavelength at random from among the available wavelengths in the path. The blocking probability of the ligtpaths is used to study the performance of the network. The benefits of wavelength conversion are found to be modest in the nonblocking centralized switch and the ring: however, wavelength conversion is found to significantly improve the performance of a large two-dimensional-torus network.First, we considered the case when there is no wavelength conversion in the network. In this case, a connection request is blocked when there is no wavelength available on every link of the path. The approach in [20] determined the conditional probability that k wavelength are available for a connection on a two-hop path and extends the analysis for an n-hop path. Let "W" be the number of wavelengths per fiber, "T" be the average duration of a connection, and "λ_i be the arrival rate on the i^{th} link of the path L_i. the average offered load on the i^{th} link of the path is then given as$L_i = \lambda_i T$. Let $Pk^{(i)}$ be the probability that k wavelengths are used on the i^{th} link of the path. Assuming Poisson arrivals on the link and exponential holding times, we have

$$Pk^{(i)} = \frac{(\lambda_i T)^K}{K!} Po^{(i)} = \frac{\frac{L_i^k}{K!}}{\Sigma_{1=0}^{W} \frac{L_i^1}{I!}} \qquad (1)$$

For a connection requiring a single hop, the blocking probability is equal to $P_W^{(i)}$, the probability that all W wavelengths are busy on the link connecting source and destination. Let $q_k^{(n)}$ be the probability that there are k "busy" wavelengths over the first n hops of the path. For a one-hop connection, we have $q_k^{(1)}.k\,E\,I\,....W$. For a two-hop path the conditional probability that there are k wavelengths available for a connection, given that n_a and n_b wavelengths are free on links a and b (assuming that the distributions of assigned wavelengths at links a and b are mutually independent) is

$$R\left(k/_{n_a n_b}\right) = \frac{\binom{n\,a}{k}\binom{W-n\,a}{n_b-k}}{\binom{W}{n\,b}} \qquad (2)$$

$if\ \max(0.n_a + n_b - W) \leq k \leq \min(n_a, n_b)$ and is equal to zero. Then, using this conditional probability, the distribution of "busy" wavelengths over the-hop path follows as;

$$q_k^{(n)} = \sum_{i=0}^{W} \sum_{j=0}^{W} R(W-k/W-i)P_1^{(1)}P_2^{(2)} \quad (3)$$

The blocking probability for the two-hop connection is thus $P^{(2)} = q_W^{(2)}$. Hence, for a *n*-hop path, we have (using recursion).

$$q_k^{(n)} = \sum_{i=0}^{W} \sum_{j=0}^{W} R(W- \quad kW-i, \ W-jqi(n-1)Pj(n) \quad (4)$$

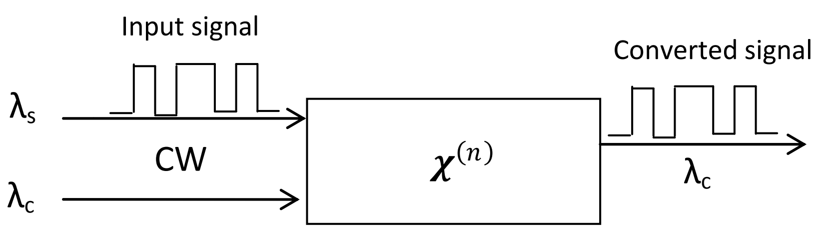
and

$$P^{(n)} = q_W^{(n)} \quad (5)$$

Next, we considered, a case when wavelength conversion is available in the network. Noting that a lightpath is blocked only when one or more links on the path have all of their wavelength occupied. Thus the blocking probability for an *n*-hop connection equals

$$P^{(n)} = 1 - \pi_{i=I}^{n}\left(1 - P_W^{(i)}\right) \quad (6)$$

The above analysis (for the path blocking probabilities) assumes that the link-loads along the path are already known [21]. However, in practice, it is the traffic matrix (which represents the offered load between a pair of stations), which is usually known and not the link-loads. For a network with wavelength conversion, the arrival process onlinks is independent of the number of the connections carried by the link (assuming independent link-loads) [22]. Thus, the arrivals on the link can be considered to be Poisson arrivals, and the number of occupied wavelengths can be represented by the distribution given in Eqn.(1). The network blocking probabilities can be obtained by solving the set of coupled nonlinear equations called Exlang's map. It is shownthat this set of equations have a unique solution for the network with wavelength conversion. The authors provide an iterative procedure to solve these equations and compute the blocking probability for the network without wavelength conversion but that is outside the scope of this work.



$$f_c = (n-1)f_p - f_s$$

Fig.4: A wavelength converter based on nonlinear wave-mixing effects.

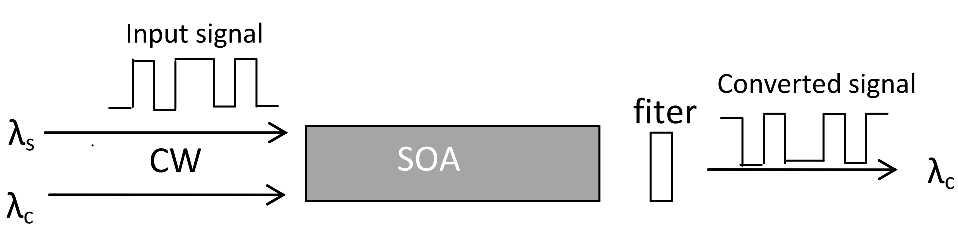


*Fig.**5:** A wavelength converter based on XGM in an SOA.*

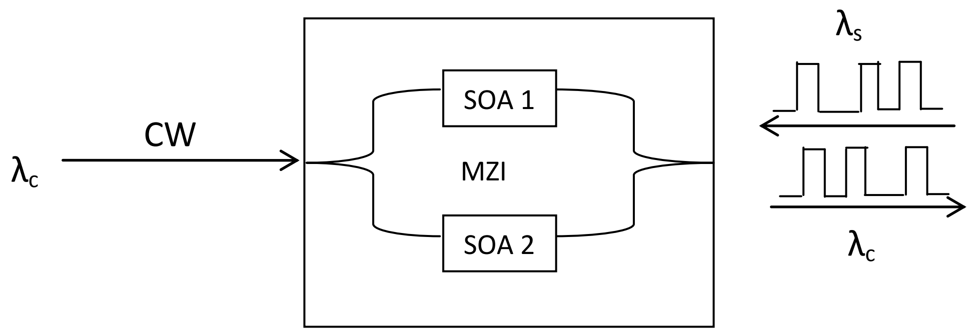


*Fig.**6:** An interferometer wavelength converter based on XPM in SOAs*

RESULTS ANALYSIS

As mentioned above, the availability of full wavelength conversion simplifies the management of the network – the wavelength assignment algorithm in such a way that network becomes simpler because all the wavelengths can be treated equivalently, and wavelengths used on successive links along a path can be independent of one another [23]. However, the benefits of wavelength conversion in rendering blocking and improving other performance metrics are not near as universal or apparent. While full wavelength conversion eliminates the wavelength-continuity constraint, the actual performance benefits available in a typical network are found to depend on factors such as connectivity and traffic load. Efforts have been made to quantify these benefits in typical networks using analytical models and simulations [24].

The wavelength division multiplexing (WDM) technology is widely used to cope with the ever rapidly increasing bandwidth demands. This is because the survivability of the optical connections or switching has grown into an issue of greatest importance for wavelength division multiplexing network especially in the area of all-optical (O – O - O) networks.

Modern optical networks are complex systems designed according to a layered approach. Several protocols can be stacked one over the other in various combinations [25]. It has become a universally accepted concept that the WDM optical layer must behave as a common platform able to carry all the possible protocol combinations. The WDM is standardized as circuit-switching oriented multiprotocol transport level. This refers to its ability of transparently supporting many different upper layers protocol stacks. So its main task is high connectivity and bandwidth provisioning to electronic layers in a client – server relationship.

The provisioning service offered by the WDM consists of setting up optical point-to-point circuits or lightpath in order to fulfill requests of a point-to-point connection issued by the upper layers. A lightpath is set up by reserving to the virtual connection a sequence of WDM channels linking the source to the destination node throughout the optical network. Each lightpath carries a high bit-rate digital stream [26]. It is added and dropped by electronic optical devices interfacing the WDM layer to the higher electronic layers which is transparently switched by each WDM switching device it crosses along its path. WDM switching is performed either by optical add-drop multiplexes (OADM) or by optical cross-connects (OXC) according to the network type which ring or mesh is under considerations in this work.

REFERENCES

1. Anyigor, I. S (2017). "All-Opptical Network Shared-Paths Protection and Enhancement of Switching Systems using Self-Healing Ring Implementations. Ph.D, Thesis, April, 2017, Electrcal Electroncs Department, ESUT, Enugu, Nig.
2. Binh, L. N., Huynh, T. L. and Rahman (2007). "Raman optically amplified MSK multi–span transmission Systems: simulation" Monash University China.
3. Chlamtac, I., Ganz, A. AndKarmi, G. (1992). "Lightpath Communications, An approach to high-band width optical. WAN'S' IEEE Trans.comm., vol. 40. Pp. 1171-1182.
4. Choi, H., Subramaniam, S. and Choi, H.A. (2004) "Loopback methods for double-link failure recovery in optical netw.," IEEE/ACM Trans. Netw., vol. 12, pp. 1119-1130.
5. Eke, J. (2006). "Empirical determination of the bending loses in optical fibre. Ph.D thesis, ESUT. Enugu, Nig.
6. Fredrick, M. and Somani, A. (2003). "A sign-fault recovery strategy for optical networks using subgrouping routing". ONDM 2003,pp. 549-568.
7. Guo, L., Yu, H. and Li, L. (2006). "Path-based protection in WDM mesh networks subject to double-link failures," AEU-Int. J. Elect. Commun., vol. 60, pp. 467-470.
8. Hee, R., Wen, H., Li, L. and Wang, G. (2004). "Shared sub-path protection algorithm in traffic-grooming WDM mesh network" Photon. Netw. Commun., vol. 8, pp. 239-249.
9. He, W., Sridharan, M. and Somani, A. (2005). "Capacity optimization for surviving double-link failures in mesh-restorable optical Netwk.," Photon. Netw. Commun., vol. 9, pp.99-111.
10. Jozsa, B., Orincsay, D. And Kern, A. (2003). "Surviving multiple network failures using shared backup path protection," in Proc. IEEE ISCC 2003, pp. 1333-1340.
11. Maat, D. H. P. (2001). "InP–based integrated MZI switches for optical communication". A PhD thesis, Department of Applied Physics, *Delft* University of Technology, The Netherlands.
12. Ma, X., and Kuo, G. S. (2003). "Optical switching technology comparison: optical MEM's vs. other technologies" IEEE Optical Communications, pp.S16–S23.
13. Maier, G., Pattavina, A., Patre, S. andMartinelli, M. (2002). Optical network survivability, Protection techniques in WDM layerphoton. Network communication, Vol. 4,pp. 251-269.
14. Mukheryjee, B. (1997). Optical communication networks. 2nd Ed. Mc-Graw-Hill, New York.
15. Mynbaev, D. K. and Scheiner, L. L. (2008) "Fiber Communication Technology" 4th impression,Pearson Education, London.
16. oguchi, K. (2007). "Ultra high speed $LINbO_3$ modulatus" optical and fibre communication report. Vol. 4, pp. 1-13.
17. OptiBPM (2006). "Technical background and tutorials" Waveguide opticsmodeling software system, Version 8.0, second edition, Optiwave Inco.
18. Pala, R. A., Ken, T. and Shimizu, E. L. (2008). "A nonvolatile plasmonic switch employing photochromic molecules" Nano letters, vol. 8, no.5, pp.1506–1510.
19. Rahman, M. S. A., Shaktur, K. M. and Mohammad, R. (2010). "Analytical and simulation of new electro–optic 3x3 switch using a Ti: $LiNbO_3$ waveguide medium" International conference on photonics, IEEEXplorer, ISBN: 978–1–4244–7186–7, pp.1–5.
20. Ramasubramanian, S. (2004). "On failure dependent protection in

optical grooming network," in Proc. DSN 2004, Vol. 16, pp. 440-449.
21. **Roy, J. N. (2009). "**Mach-Zehnder interferometer-based tree architecture for all-optical logic and arithmetic operations" Optik-International Journal for Light and Electron Optics, vol. 120, issue 7, pp.318-324.
22. Saleh, B. E. A. and Teich, M. C. (2007). "Fundamentals of photonics" 2nd edition, Wiley series in pure and applied optic*s*. USA.
23. Sapountzis, G. and Katevenis, M. (2005). "Benes switching fabrics with O(N)-complexity internal backpressure" IEEE Communications Magazine, PP.88-94
24. Wong, H. Y., Sorel, M., Bryce, A. C.,Marsh, J. H. and Arnold, J. M. (2005). "Monolithically integrated InGaAs-AlGaInAs MZI optical switch using quantum-well intermixing" IEEE Photon. Technol. Lett., vol. 17, no. 4, pp. 783-785.
25. Xiuping Xie (2006). "High gain parametric processes in quasi-phase matching proton-exchange Lithium Niobate waveguides" A Ph.D dissertation, theDepartment of Applied Physics, Stanford University, London.
26. Zhou, D and Subramaniam, S. (2000). "Survivability in optical networks", IEEE Netw., vol. 14, pp. 16-23.