©IDOSR PUBLICATIONS
International Digital Organization for Scientific Research ISSN: 2550-794X
IDOSR JOURNAL OF SCIENTIFIC RESEARCH 4(1) 125-132, 2019.

Optical Switching System Operatons Using Self-Healng Ring Implementation

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

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

ABSTRACT

Networks are characterized by having relatively few nodes but supporting large communication channel bandwidths. Such large bandwidths are transport cost-efficient on optical fibres, which have been deployed in the networks. A process of simple point-to-point fibre links using just one wave-length was deployed but later upgraded to exploit the fibre optical capacity by attaching wavelength division multiplexing (WDM) equipment at the nodes. This equipment consists of tunable or fixed-wavelength transmitters/receivers andde-multiplexers that enable simultaneous communication in the same fibre using different wavelengths. This helps to satisfy the exponential increase in communication demand for the providence of reliable communication over long distances with low delay. When the path from source to destination node involves several hops, the optical signal is at each DXC and converted into electrical form before it is switched and converted back into an optical signal for the next hop. This process is calledOptical-Electrical-Optical (OEO) conversion which is a delay bottle-neck in current opticalnetworks and has spurred the development of the all-optical network (AON). This piont as well has necessitated the use of Self-healing method implementation for the enhancement of its switching operatons.
Keywords: Telecommunication, switching, system, multiplexing, bandwidth.

INTRODUCTON

Telecommunication networks are supposed to have relatively few nodes but with supporting large communication channel bandwidths. Such large bandwidths are transport cost-efficient on optical fibres, which have been deployed in the networks. At first, simple point-to-point fibre links using just one wavelength were deployed but later upgraded to exploit the fibre optical capacity by attaching wavelength division multiplexing (WDM) equipment at the nodes [1].

This equipment consists of tunable or fixed-wavelength transmitters/receivers andde-multiplexers that enable simultaneous communication in the same fibre using different wavelengths. This helps to satisfy the exponential increase in communication demand. Optical fibres can provide reliable communication over long distances with low delay,despite that delays are low in fibres, it is not so in the conventional digital cross connect (DXC). When the path from source to destination node involves several hops, the optical signal is at each DXC, converted into electrical form before it is switched and converted back into an optical signal for the next hop. This Optical-Electrical-Optical (OEO) conversion is a delay bottle-neck in current opticalnetworks, which has spurred the development of the all-optical network (AON).

The All-Optical Network (AON)

The AON utilizes the low delay in optical fibres by keeping the signal in the optical domain from source to destination. Each node of the AON is equipped with an optical cross-connect (OXC) or an Optical

Add/Drop Multiplexer (OADM), both of which are able to pass on the optical signals without OEO conversion, thus eliminating electrical delay.A good overview of WDM and AON can be found in the literature [2].

When wavelength division multiplexing(WDM) is used in the AON, we obtain the *wavelength routed optical network* (WRON). WRONs transmit signals entirely in the optical domain, reducing delay, but imposing a new restriction, the *wavelength continuity constrain.:* When routing a connection, all links along the route must use the same code. The connection is thus assigned a *lightpath,* identified by its route and wavelength. The wavelength continuity constraint restricts the number of multihop paths that can be accommodated, because two different demands cannot use lightpaths that share a fibre if they have the same wavelength [3]. This gives rise to the *routing and wavelength assignment* (RWA) problem, where all traffic demands must be assigned lightpaths.Hence, designing an AON usually means that traffic demandsi.e., requests for transferring data between pairs of nodesmust be satisfied by specifying how much capacity in the form of fibres and switches must be used in the AON links and nodes. If there are given limits on the number of fibres on each link or the switch size in each node, the network design problem is said to be *capacitated,* otherwise it is *uncapacitated.*

Research on AON design has considered dynamic traffic demands [4]; [5]: [6]; [7] in which connection requests arrive and are routed one at a time, as well as static traffic demands [8]: [9]: [10]; [11]; [12]; [13]; [14]; [15]: [16]; [17]; [18] in which the demands are given as a fixed set. Dynamic traffic demands may experience *blocking:* if there are not sufficient network resources to accommodate a request when it arrives, it is blocked.

Blocking Probabilities for Dynamic Traffic

Blocking probabilities exist in a scenario where the capacities in a network have been decided and dynamic traffic demands, known as *calls* arrive.Call arrivals can be modeled as stochastic point processes, typically one for each node pair in the network. Such an arrival process can be characterized by the distribution of the inter-arrival time; that is, the time between two successive arrivals. An arrival process is *stationary* if it does not depend on the absolute time at which it is observed: it is *independent* when future arrivals depend only on the state the process is in and not how this state was reached; and it is *regular* if two arrivals never occur at exactly the same time.

The most basic arrival process used to characterize arrivals in telecommunication networks is the Poisson process which is stationary, independent and regular. The interarrival timet of the Poisson process follow a negative exponential distribution $F(t) = 1 - e^{-\lambda t}$where λ is the *arrival intensity* indicating the average number of arrivals per time unit. The Poisson process is best for modeling call arrivals from a large set of sources that are not expected to be correlated (e.g., telephone subscribers). A multitude of other distributions have been devised for modeling other scenarios like overflow traffic from a limited set of sources. Each call would be associatedwith a *holding time*, which is the time that the call will occupy the connection when it is served. As for the inter-arrival times of the arrival process, holding times are also characterized by a distribution [19].

The *offered traffic*,***A,*** of a traffic demand is the amount of data transmission performed if no calls are blocked. For a Poisson process with intensity λ and mean holding time "I/μ" the offered traffic is λ/μ. When a call arrives the system may decide (i.e., because there is no unused capacity left) to *block*, meaning not serving the call. The *carried traffic*, ***Y***, of a traffic demand is the amount of traffic which is not blocked.A system serving calls can be modeled using the *lost calls held model*, where blocked calls are put on hold and served when the system again is able to do so.However, in this work, itonly considered the *lost calls cleared* model, where any blocked calls disappear and donot affect the future behaviour of the system.The *call blocking* is the probability that a call is blocked, while the time blocking is the fraction of the time that any arriving calls would be blocked whether or not any arrived in the time, and the *traffic blocking* is the fraction of traffic which is blocked, i.e., $(A - Y) / A)$.

Circuit Switching and Packet Switching

When data is to be transported from a source node to a destination node that are not connected by a direct link, the network must make several intermediate links and nodes known collectively as a *path or route*whichwork together to supply the requested bandwidth. There is a spectrum of ways between two extremes of *circuit switching* and *packet switching,* by which this can be accomplished.

In circuit switched networks, a route is selected and the intermediate nodes set up before the data are transmitted and subsequently turn down when the connection is no longer needed [20]. Conversely, *in packet switched networks,* data are forwarded hop-by-hop, where each node examines the packet header to determine the next node to which it must be forwarded. This can change due to network failures and congestion, causing packets between the same source-destination node pair in order to use different paths which can increase the risk of receiving packets in the wrong order. However, packet switching is generally more robust against failed elements.An asynchronous transfer mode (ATM) network is an example of a connection oriented packet switched network, in which *virtual channels* are created by setting up the switching tables in the intermediate nodes.

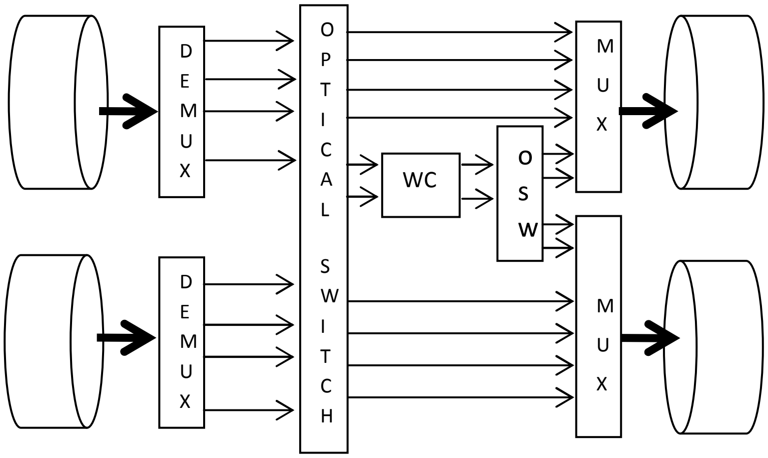
Data are then transferred in cells, and each node needs only to perform very simple loop ups in switching table to determine next hops [21]; [22].

Traditional Internet Protocol (IP) networking is an example of connectionless packet switching where each IP packet contains the destination address, usually based on matching a prefix of the address—to decide the direction in which the packet must be sent.When considering dynamic traffic, arrival intensities are given for each node pair demand, and the design goal is to determine the capacities of the network links and nodes, minimising the blocking probabilities. In most cases, if it is not given as input, the *routing* of each connection is also a result of the design process. Alternatively, Jan presented an algorithm for maximising “system reliability” which is a measure of the probability that two nodes are able to communicate with each other, given a certain reliability for each link [23].

DISCUSSION

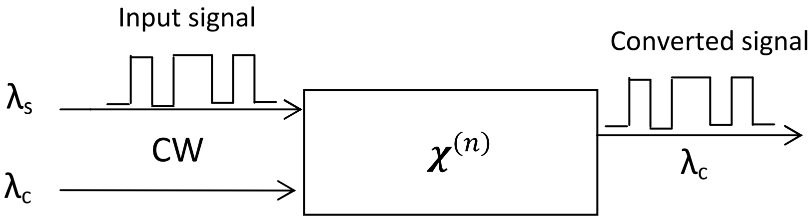
As wavelength converters become readily available, a vital question comes to mind: where do we place them in the network? An obvious location is in the switches (or cross-connects) in the network. A possible architecture of such a wavelength-convertible switching node is the dedicated wavelength convertible switch. In the architecture, each wavelength along each output link in the switch has a *dedicated* wavelength converter, i.e., $M \times M$switch in an N- wavelength system which requires $M \times N$ converters. The incoming optical signal from a fiber link at the switch is first wavelength demultiplexed into separate wavelengths. Each wavelength is switched to the desired output port by the nonblocking optical switch. The output signal may have its wavelength changed by its wavelength converter. Finally, various wavelengths are multiplexed to form an aggregate signal couple to an outbound fiber link. However, the dedicated wavelength-convertible switch is not very cost-efficient since all of the wavelength converters may not be required all the time. An effective method to cut costs is to share the converters. Two architectures have been proposed for switches sharing converters. In the share-per-node structure, all the converters at the switching node are collected in a converters bank. A converter bank is a collection of a few wavelength converters, each of which is assumed to have identical characteristics and can convert any input wavelength to any output wavelength. This bank can be accessed by any of the incoming light paths by appropriately configuring the conversion as directed by the converter bank. The converted wavelengths are then switched to the appropriate out bound link by the second (small) optical switch. In the share-per-link structure in Fig. 2.11(b), each outgoing link is provided with a dedicated converter bank which can be accessed only by those light paths traveling on that particular outbound fiber link. The optical switch can be configured appropriately to direct wavelengths towards a particular link, either with conversion or without conversion. When optoelectronic wavelength conversion is used, the functionality of the wavelength converter can be performed at the access stations instead at the switches. However, control algorithms are required in a network to manage its resources effectively. An important task of the control mechanism is to provide routes (i.e., set of fiber links) to the lightpath requests and to assign wavelengths on each of the links along the route while maximizing a desired system parameter.

The architecture of the different scenarios are showen below in fig. (a & b).



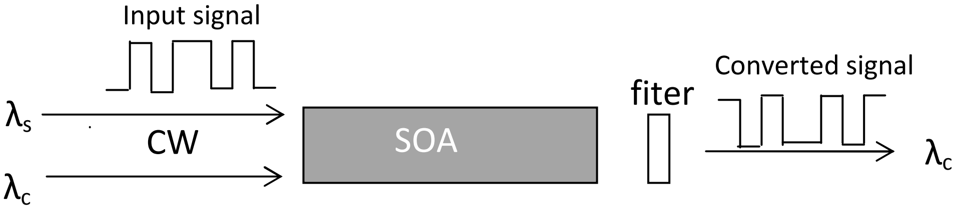
Share-per-node wavelength-convertible switch architecture.

A switch architectures that have dedicated converters in each output port of nodes and links for each wavelength.

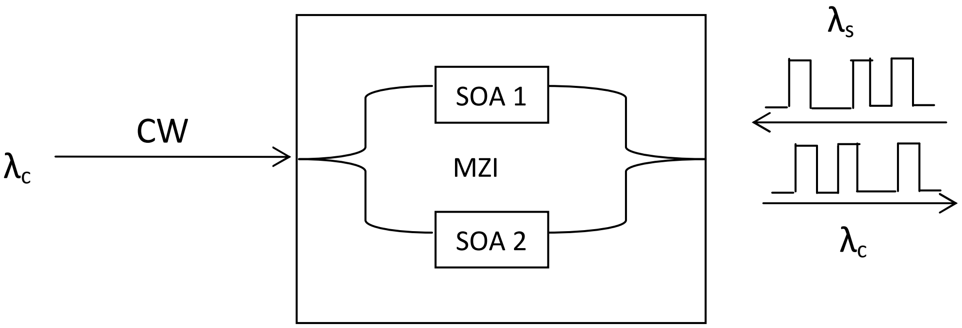


$$f_c = (n-1)f_p - f_s$$

A wavelength converter based on nonlinear wave-mixing effects.



A wavelength converter based on XGM in an SOA.



An interferometer wavelength converter based on XPM in SOAs

RESULTS/BENEFIT ANALYSIS

As mentioned above, the availability of full wavelength conversion simplifies the easy management of the network, the wavelength assignment algorithm in such a 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. However, the benefits of wavelength conversion in rendering blocking and improving other performance metrics are not near as universal or apparent.But then, 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 loading. Efforts have been made to quantify these benefits in typical networks using analytical models and simulations.

A Probabilistic Model with Independent Link-Load Assumption

An approximate analytical model is developed for a fixed-path (deterministic) routed network with an arbitrary topology, both with and without 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. 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 approachdetermined 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 pathL_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

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

For a connection requiring a single hop, the blocking probability is equal to $P_W^{(i)}$, meaning 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 $q_k^{(1)}.k\,E\,I\,\ldots.W$. 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

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

if $\max(0.n_a + n_b - W) \leq k \leq \min(n_a, n_b)$is equal to zero otherwise. Using this conditional probability, the distribution of “busy” wavelengths over the-hop path follows:

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

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)

$$q_k^{(n)} = \sum_{i=0}^{W} \sum_{j=0}^{W} R(W -$$

$$kW{-}i,\ \ W{-}jqi(n{-}1)Pj(n) \qquad (4)$$

and

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

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

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

The above analysis (for the path blocking probabilities) assumes that the link-loads along the path are already known. 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).

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). However, to make the analysis of the network without wavelength conversion tractable, the approach in making an approximation by assuming Poisson arrivals at the links is upheld in this case also.

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. Eke, J. (2006). "Empirical determination of the bending loses in optical fibre. Ph.D thesis, ESUT. Enugu, Nig.
3. Kovacevie, M. andAcampora, A. S. (1996). "Benefits of wavelength trandition in all-optical clear-channel networks," IEEE j. SELECT. Areas commun. Vol. 14. Pp. 868-880.
4. Krähenbühl, R., Burns, W. K. (1999). "Enhanced crosstalk suppression for Ti: $LiNbO_3$ digital optical switches," in *Proc. Photon. Switching*, pp. 110–112.
5. Ludwig, R. AndRaybon, G. (1994). "BER measurements of frequency converted signals using four-wave mixing in a semiconductor layer amplifier at 1,2,5,5 and 10 Gbitls," IEEE,D edition: vol.30.pp.338-339.
6. 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.
7. Ma, X., and Kuo, G. S. (2003). "Optical switching technology comparison: optical MEM's vs. other technologies" *IEEE Optical Communications*, pp.S16–S23.
8. Maier, G., Pattavina, A., Patre, S. andMartinelli, M. (2002). Optical network survivability, Protection techniques in WDM layerphoton. Network communication, Vol. 4,pp. 251-269.
9. Mynbaev, D. K. and Scheiner, L. L. (2008) "Fiber Communication Technology" 4th impression,*Pearson Education*, London.
10. Noguchi, K. (2007). "Ultra high speed $LINbO_3$ modulatus" optical and fibre communication report. Vol. 4, pp. 1-13.
11. Nord, M. (2002). "Optical switching technologies for optical line, burst and packet switches" *Scientific report, Telenor communication*, pp. 361- 470.
12. OptiBPM (2006). "Technical background and tutorials" *Waveguide optics modeling software system*, Version 8.0, second edition, Optiwave Inco.
13. 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.
14. Patent, E. A., Vander Tol, J.J.G.M. and Calabretta, N. (2001). "A pattern-effect compensator", Proc. 2001, *Annual Symposium IEEE/LEOS*, Benelux Chapter, Brussels, pp.233–236.
15. Rahman, M. S. A.,Shaktur, K. M. andMohammad, 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.
16. Ramasubramanian, S. and Harjani, A. (2006). "Comparison of failure dependent protection strategies in optical network," Photon. Netw, Commun., vol. 12, pp. 195-210.
17. Ramaswami, R. AndSivarajan, K. N. (1998). "*Optical Networks, a Practical Perspective*". San Francisco, CA: Morgan Kaufmann.
18. Ron, A. and Spanke, G. M. (1986). "Architectures for large nonblocking optical space switches" *IEEE Journal of Quantum Electronics*, vol. QE–22, no. 6, pp.964–967.
19. 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.
20. Saleh, B. E. A. andTeich, M. C. (2007). "Fundamentals of photonics" 2nd edition, *Wiley series in pure and applied optics*. USA.
21. Tekin, T.,Schlak, M.,Schmidt, C. H. andSchubert, C. (2004). 'The

Influence of Gain and Phase Dynamics in the Integrated GS-SOA on the Switching Performance of the Monolithically Integrated GS-MZI', *Integrated Photonics Research*, pp. 89 - 100

22. Tkach, R. W. and*et al*. (1995). "Four-photon mixing and high-speed WDM systems," IEEE/OSA J. lightwave Technol., vol 13.pp. 844-849.
23. Vlachos, K., Raptis, L.,Teixeira, A.,Beleffi, G. M. T. And Yiannopoulos, K. (2009). "Optical switch fabrics and their application" Enabling Optical Internet with Advanced Network Technologies, *Computer Communications and Networks*, pp.155-190.