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A Brief Review on the Methods that Improve Optical Burst Switching Network Performance

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Abstract: In this tutorial, we give an introduction to optical burst switching (OBS) networks and compare different methods that have been given to improve performance of these networks. OBS is an alternative to optical circuit switching and optical packet switching by separating data from control packets and sending them in a different wavelength. OBS networks suffer from an issue based on their bufferless nature, burst contentions. In these networks, when two data bursts are competing on the same wavelength, one of them is dropped and it leads to a significant reduction on the performance of the network. A lot of researches have been done to solve this problem. Some of them are addressed in this paper.

Keywords: Optical Burst Switching (OBS) networks, data burst contention, performance

1 Introduction

In the last few years, the demand for high bandwidth on the Internet has increased drastically. As time passes, more and more devices are connected to the Internet and the necessity of the need for high bandwidth and improving the techniques of routing and switching packets is inevitable. Due to the mentioned reasons, the use of fiber in communications was introduced and it was a breakthrough in computer networking and the Internet [1]. Different techniques for switching have been introduced in optical networks such as optical circuit switching (OCS), optical packet switching (OPS) and optical burst switching (OBS). Among them, OBS is a technique that can achieve an efficient and dynamic bandwidth allocation for handling a large amount of traffic on the Internet [2]. Using WDM (wavelength-division multiplexing) technique in OBS networks is one of the upsides of the network to the others [3]. The first technique, OCS, has long reconfiguration delay, inefficient utilization of bandwidth and large granularity; however, it is a mature technology and has been studied for a long time. Comparing to OCS, OPS has a familiar architecture and great flexibility and statistical multiplexing but it has some other flaws such as the need for an overhead for each packet that wants to be switched, it has stringent synchronization and switching requirements, its lack of optical RAM and one-way reservation technique [4,5]. OBS has moderate granularity, moderate processing overhead, asynchronous switching and high statistical multiplexing. In this technique, the setup latency is low, bandwidth utilization is high, switching speed is acceptable, processing complexity is not so high and the traffic adaptivity is appropriate [4]. Table 1 shows a comparison between different switching techniques. An OBS network is bufferless in its nature. In this network, packets are aggregated into a burst then each data burst is traversed through the OBS domain following the corresponding control packet by using a one-way signaling resource reservation protocol [2].

The most important advantages that OBS networks have comparing to others are WDM technique and burst aggregation in ingress nodes. Because of the high bandwidth in fibers, using OCS and OPS can waste a considerable amount of the available bandwidth; as a result, the performance of the network will be reduced. By using WDM and burst aggregation, the use of fiber bandwidth is utilized. WDM means that the available bandwidth of a fiber can be divided into several channels that can work individually and do not interfere each other; so, instead of using one link in one fiber, we can have several links that work separately. Burst aggregation means that packets that arrive at ingress nodes are aggregated into a collection called data burst, and then instead of sending packets one by one through the network, collections of packets are sent. This can save a considerable amount of time, it will affect switching time because instead of

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Table 1: Comparison between different switching techniques [4].

Criteria	OCS	OPS	OBS
Granularity	coarse	Fine	Moderate
Bandwidth utilization	Low	High	High
Setup latency	High	Low	Low
Switching speed	Slow	Fast	Moderate
Processing complexity	Low	High	Medium
Traffic adaptivity	Low	High	High

switching one packet, a burst is switched and the bandwidth is used in an efficient way [1,3,4]. Figure 1 shows the process of burstification.

IP packets are received at ingress nodes, and then they are assembled into bursts and delivered to an OBS network. After that, bursts are delivered to egress nodes and they dissemble bursts into individual packets. Figure 2 shows this process.

In OBS networks, a delayed reservation scheme is used. It means that a burst header packet (BHP) is sent in advance of the primary data. The goal of this packet is to reserve optical bandwidth before sending the data. Then, data are sent through the optical network in collections called bursts by common destination or other suitable attributes. With an adequately provided delay between the header and burst, the data in the burst can be transferred across all intermediate nodes from source to destination without any buffering. OBS networks have a lot of advantages; however, there is a significant drawback in this kind of networks that needs to be tackled with. In OBS networks, packets can be dropped because of two reasons: (1) congestion and (2) contention. Congestion can happen when the traffic load is high in the networks and the network cannot handle the existing traffic so some of the packets are dropped. Because of the bufferless nature of the networks, we have contention in the networks. It means, when two bursts are competing on the same bandwidth to allocate, one of them is going to drop. These problems, especially the contention, can make a huge reduction in the performance of the networks. Because we use wired protocols such as TCP (transmission control protocol) in optical networks, the contention issue can be more important. Wired protocols are not aware of an issue like contention and they handle all the drops on the same way, reducing the sending rate. Sometimes, the network is not so congested and the traffic is smooth and a contention happens; in this case, an unnecessary reduction in the sending rate is performed that leads to reducing the final performance of the network [6,7].

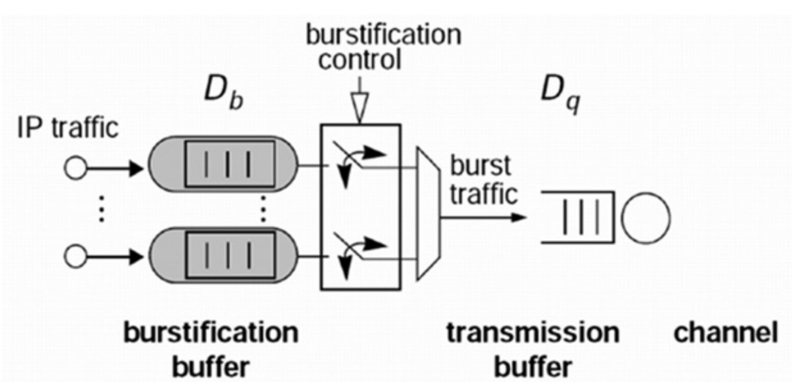

Figure 1: Burst transmission process at the ingress OBS nodes.

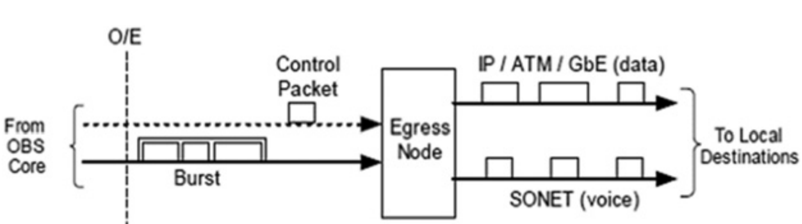

Figure 2: Burst transmission process at the egress OBS nodes.

To solve the contention problem in OBS networks and improving its performance, a lot of schemes have been proposed. In the next section, we are going to investigate the solutions and their advantages and disadvantages, then we will talk about future schemes.

2 Improving performance of optical networks

The first algorithm that we intend to investigate is called FRPI algorithm that was proposed in Ref. [3]. This algorithm tries to solve the performance reduction of optical networks by adjusting packets sending rate in an appropriate way. The algorithm uses a threshold-based approach to tackle the problem. The first step in this algorithm is to divide the network into three areas by using fuzzy logic. It uses a congestion indicator called CI to divide the network into empty, normal and congested areas. Each of these areas shows the status of the network. When it is empty, it means that the network is not congested and if a burst drop occurs, it is more likely because of a contention and we do not need to decrease Congestion Window (cwnd), instead, we increase it by once. If the network is in the normal area, it shows that neither the network is congested nor empty; so, if a drop happens, it can be because of congestion or a contention. In this case, we do not change the value of cwnd. If the network is in the congested area and a burst drop happens, the probability that it is due to congestion is so high, then we decrease the value of cwnd. Figure 3 shows how the first phase of this algorithm works.

In the second phase of the algorithm, it tries to gain some suitable thresholds and then compare them to the current round trip time and based on the result, it decides to change the value of cwnd. The background concept of this scheme is separating drops caused by congestion from drops caused by contentions. Figure 4 shows how the second phase works.

In the second step, the algorithm uses minthrtt and maxthrtt to set the final values of cwnd. This paper could achieve a higher performance in optical networks and that is one of its upsides. Beside, packet delivery count in this method has been improved and it does not increase the overhead of the network; however, it suffers from a low packet loss ratio (PLR) comparing to conventional wired protocols like TCP Vegas. Fairness is another parameter that could be investigated in this paper but it was not. For future work, these issues could be considered.

One of the most important aspects of OBS networks is signaling. There are three main signaling techniques in OBS networks: one-way signaling, two-way signaling and hybrid signaling. In one-way signaling, a packet is sent to reserve the resources in the networks and the corresponding burst is sent without waiting to get an acknowledgment. It has a short delay but the data loss rate is high. On the other hand, in two-way signaling, a burst wait for the acknowledgment then is sent through

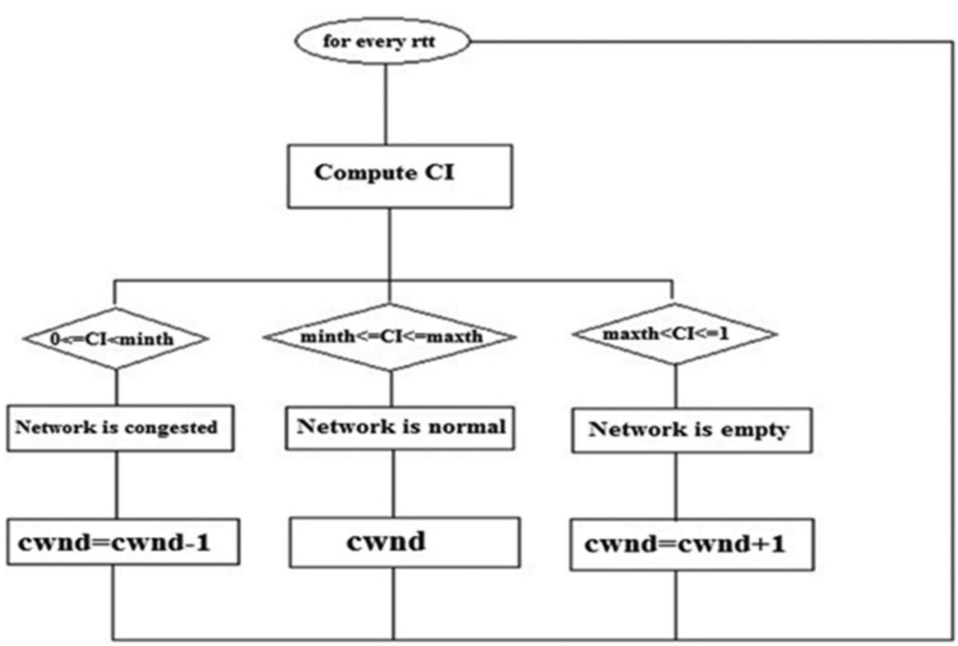

Figure 3: How FRPI fuzzy phase works.

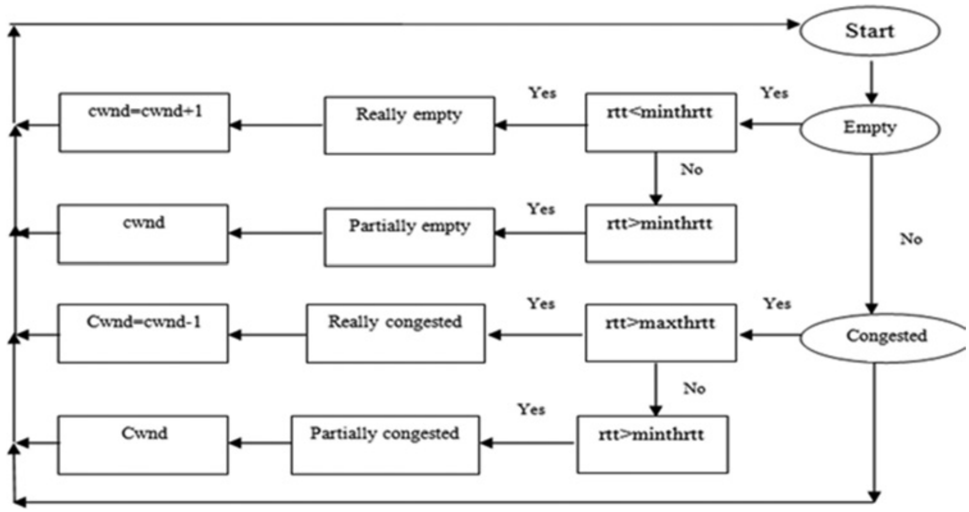

Figure 4: How the second phase of the FRPI algorithm works.

the network. It has a low loss rate in the cost of end-to-end delay. Hybrid signaling tries to make a tradeoff between the two mentioned techniques [5]. A new method of signaling for OBS networks called inverse two-way signaling was proposed in Ref. [5]. The most important difference between two-way signaling and inverse two-way signaling is that in two-way signaling, the collection of links' state is after the completion of burst assembly; however, in inverse two-way signaling, link state collection and burst assembly are performed simultaneously. Simulation results show that the end-to-end delay for inverse two-way signaling and one-way signaling is similar and it is less than two-way signaling delay. The loss rate of inverse two-way signaling is more than two-way signaling but less than one-way signaling, so it shows a tradeoff between them.

One of the most important drawbacks of OBS networks is Data Burst Contention. The proposed scheme in Ref. [8] tries to solve the problem. In order to tackle this problem, a contention-free OBS ring topology was proposed. The aim of this paper is to design a multi-transceiver OBS ring scheme that all data wavelengths are slotted and slots on different wavelengths are not synchronously but irregularly distributed. In this topology, each node has a wavelength for itself and for generating control packets and slots they perform periodically. Moreover, slots on different data wavelengths are irregularly distributed but not synchronously. This scheme is categorized under a multi-transceiver one. Figure 5 indicates the course that slots travel on a single-wavelength ring.

This scheme can improve the performance and fairness of the network.

An electronic buffering for contention resolution was proposed in Ref. [9]. The purpose of this method is to reduce the number of new contentions. Then it tries to have a closer look on the stream-line effect to device an efficient routing. The aim is to continue a loss-free framework called CAROBS and investigate in details. The main goal is to reduce the impact of secondary contention, for attaining that, an insight into the traffic behavior was investigated, and then a delaying mechanism limiting the impact of secondary contention was suggested.

A scheme for tackling the contention problem in optical networks was proposed in Ref. [10]. This paper says that one of the most important problems in OBS networks is not dividing the fiber links into wavelengths in an appropriate way. It says that lack of a good method for dividing wavelengths leads to contentions and if we have a suitable number of wavelengths for data and control packets, the reservation and sending process will be handled more efficiently. It uses a three-way step algorithm to utilize the use of the bandwidth in the network. (1) Finding the best numbers for data wavelengths. (2) Finding the best numbers for control packet routes. (3) Finding the best combination of 1 and 2. Equation (1) is used to find the best number for the data wavelengths.

$$Wn + 1 = 2Wn \tag{1}$$

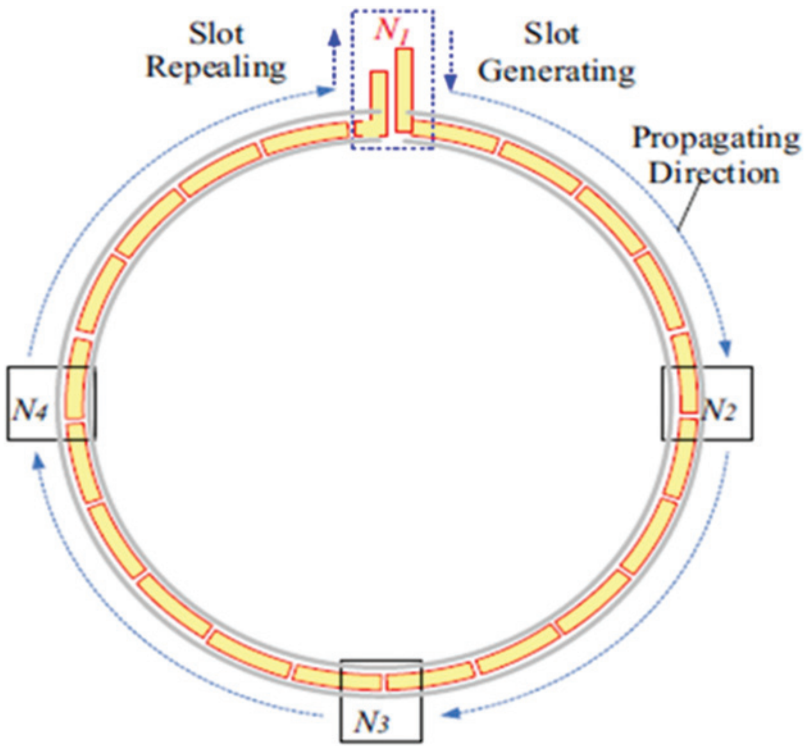

Figure 5: The course that slots travel on a data wavelength.

More than 30 wavelengths were tested and Table 2 shows the most important ones.

Table 2: The number of data wavelengths.

W1	W2	W3	W4	W5
2	4	8	16	32

Equation (2) is used to find the best number for control packet routes.

$$Cn + 1 = 2Cn \tag{2}$$

Again, more than 30 values were tested and the most important ones are shown in Table 3.

Table 3: The number of control packet routes.

C1	C2	C3	C4	C5
1	2	4	8	16

Table 4 shows the third step, the combination of Tables 1 and 2 to achieve the best numbers.

Table 4: The number of wavelengths and control packet routes.

C1–W1	C2–W2	C3–W4	C4–W4	C5–W5
1–20	1–40	1–80	2–160	2–320

The most important advantage of using this method is finding the best number for data wavelengths and control packet routes. However, this method is static and is not flexible. If any changes happen in the network or the situation of it, the algorithm cannot behave in a dynamic way.

In Ref. [11], there is a new scheme to find the best burst size to improve the performance of the network. When a burst drops, it has an effect on the performance of the network so we need to adjust this value by considering this fact. This paper tries to use a linear formula in this way. Equation (3) is the used formula.

$$Y_n = Y_{n-1}/2 \tag{3}$$

In this formula, Y_n is the next burst size.

In Ref. [12], analytical results have been presented for OBS networks. The result of this paper is to determine optimal network parameters for a specific burst loss rate. It investigated different burst lost probabilities and found out that given BLR of 10^{-4}, required wavelength conversion capability is less for a high number of WDM channels. It shows that for some certain number of WDM channels and given BLR of 10^{-4}, for more slot's number, wavelength conversion capability required is higher. The best number of slots for an individual burst is also found for a given wavelength number, BLR of 10^{-4} and wavelength conversion capability. Analytical results are achieved for a WDM burst-switched optical network for various values of parameters in the network, i. e. wavelength conversion capability, number of slots per burst, burst arrival probability and number of wavelengths. The best value of network parameters is evaluated for a given BLR of 10^{-4} and 10^{-10}. The results will be useful for the design of optical burst switched network.

In Ref. [13], the focus of the paper is on the importance of burst loss ratio in OBS networks. When a burst arrives at a source node, if it finds the server free, it will reserve the server and get transmitted immediately. However, when the server is blocked, the incoming burst waits in a buffer in the source node of the selected pair and tries retransmission till it reaches the destination successfully. This paper investigates a method that combines buffering and retransmission to solve the contention problem and the effect of maintenance activity and buffer search of the server on the bursts being handled in the network. Figure 6 shows how this method works. A single server retransmission queue is considered in this scheme. If the server is free when the burst arrives at the source node, it can begin the service. Whenever the server is blocked, the incoming burst is buffered for the retransmission. When a service is completed, the server may go for maintenance activity.

Once it is over, the server may search for the burst in the buffer or waits for the new burst.

In order to avoid burst loss, buffering and retransmission techniques are used together and the effect of maintenance activity and buffer search of the server on the number of bursts being processed in the network is investigated in this method. Sometimes, bursts need to wait for a long time to be sent and that is an important flaw in this method. Although this method can increase the performance of the network, we need to use buffers that can have their own cost and using retransmission has its own complexity.

In OBS networks, data and control packets are sent in a different wavelength. This separation can cause OBS networks susceptible to threats like denial- or degradation-of-service attack (intentional or otherwise). This problem is addressed in Ref. [7]. It tries to explain the problem and find a method based on monitoring network traffic on the control and data channels. The

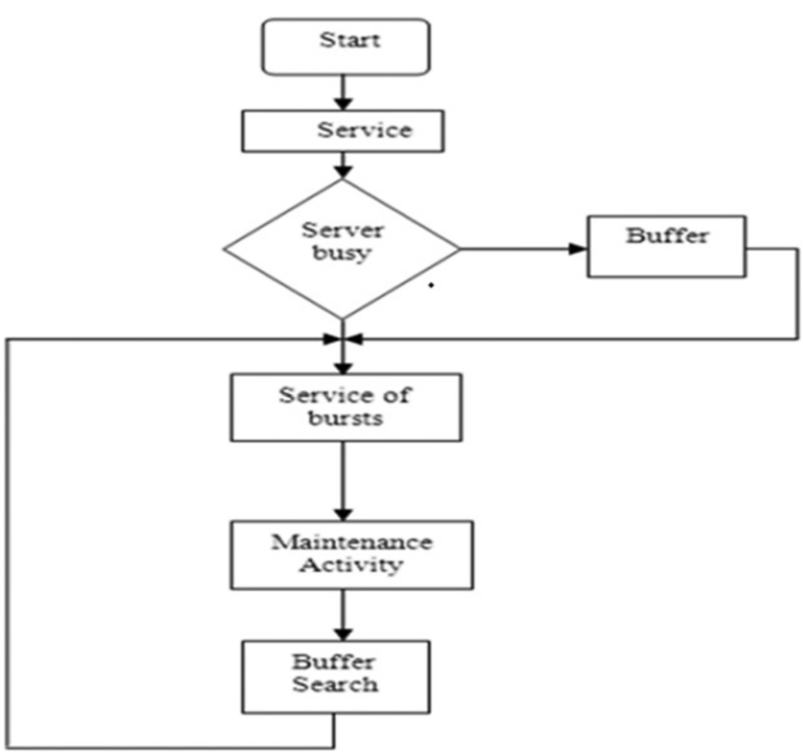

Figure 6: How combined buffering and retransmission method works.

strategy that this method uses is to face the BHP flood threat by blocking or throttling the traffic coming from nodes that are considered to be misbehaving. Misbehaving nodes are determined by tracking some statistics in the network such as the rate of BHPs, the rate of bandwidth reservations and the amount of unused but reserved bandwidth. We need to monitor the network, for characterizing and detecting misbehaving nodes, and for throttling or blocking the misbehaving nodes. For accomplishing this strategy, we need to do complete three steps, first, it collects network statistics from selected nodes in the network; then it analyzes the resulting data stream to detect malicious activities; after that, it acts on the results of these analyses to throttle or block misbehaving nodes. This paper has focused on the second step. For this, the necessity of investigating a lot of numbers is required which can waste some time but is an effective way of improving the performance of the network. In Ref. [14], one of the most important issues of OBS networks called BHP flooding attacks has been investigated. This problem can have a significant effect on the quality of service of the networks and can lead to more important problems like denial of service (DoS) attacks. This paper uses a predictive machine learning (ML) algorithm to calculate the risk of BHP flooding attacks experienced in OBS networks, and then it suggests a decision tree-based architecture as a suitable solution. It has a learning algorithm that extracts new rules from tree models using data processed from various simulation runs. This method can classify the BHP flooding attacks into either behaving (B) or misbehaving (M) by the accuracy of 93 %. In addition to classifying the attacks, it can divide the misbehaving nodes into four categories with 87 % accuracy: Misbehaving-Block (Block), Behaving-No Block (No Block), Misbehaving-No Block (M-No Block) and Misbehaving-Wait (M-Wait). It tries to prevent burst drops caused by DOS attacks.

Malicious BHPs can reserve sources in core nodes and occupy the sources, so when other bursts arrive at core nodes, they cannot find free wavelengths; as a result, they are dropped because of some malicious packets may never arrive. The main benefit of classifying is that malicious nodes can be identified and blocked. A study of blocking probability and the mean delay of an asynchronous single-wavelength optical buffer was done in Ref. [15]. Level crossing method was used to derive the integral equations in order to model the dynamics of the buffer. After that, a method was proposed for solving this equation. Eventually, mathematical expressions of blocking probabilities and the mean delays for the optical buffer with general burst size distribution were introduced.

Because of the high bandwidth of optical networks and the architecture of OBS networks, they can be used in data centers. By using OBS in data centers, the performance of the data center plus its flexibility will increase and the cost will decrease. In Ref. [16], a new architecture has been proposed called Openscale architecture. This architecture has a lot of advantages for OBS networks including high scalability, fault tolerance and effective load balancing. It uses clustering coefficient and average path length to approximately evaluate networks vicinity connectivity and arbitrary reachability, respectively.

A new approach based on generalizing multi-protocol label switching-based control plane architecture for OBS networks was proposed in Ref. [17]. Metropolitan area networks (MANs) are going to use optical switching technique more and more because they can make a better access to resources, they are more flexible and have a good tradeoff between complexity and performance. Because of it, MAN networks will over different regional and core networks. So, proposing architecture like Ref. [16] in order to improve the performance of OBS networks is essential.

An attempt to find the weakness of TCP/OBS networks was done in Ref. [17]. Data bursts that traverse through OBS networks are not secure. The reason behind this insecurity is that before sending a burst, its corresponding control packet is sent through an outband link, so there is a probability that someone can manipulate or duplicate it. In this case, he can steal the data inside the burst. There are different ways for performing this kind of attacks such as burst header flooding attack, fake burst header attack, DoS attack, land attack, malicious burst header injection and circulating burst header attack. In burst header flooding attack, a malicious attack compromises a node then copies a header and floods the next nodes by using these copies and those nodes try to reserve resources for the fake bursts. The aim of this attack is that the other nodes cannot reserve resources for their data bursts because they are reserved by the fake ones. In fake burst header attack, intruders try to inject a fake control packet to an intermediate node; as a result, he can route the data burst toward fake destinations. In DoS attack, intruders try to make unoccupied wavelengths busy in intermediate nodes; so, when new data bursts arrive at intermediate nodes, they cannot find free wavelengths to be routed, as a result, they are dropped. In land attacks, attackers try to compromise core nodes, then make a copy of the burst control packet change its destination to the source address. The purpose of this attack is to waste the resources of the network. In malicious burst header injection, attackers try to introduce a fake control packet at the right time, so they can misguide the corresponding data burst. In circulating burst header attack, intruders try to compromise two nodes to establish the attack. Then they make a control packet to circulate between those two nodes. The goal of this attack is making delay in reaching the data burst to their destinations. In [18], a study of a horizon-based single-channel multi-class OBS node was observed. This method investigated the horizon-based single-channel multi-class OBS networks with general burst size distribution. The per-class blocking probabilities were available by using ML.

Another approach to deal with the contention problem is deflecting routing [19,20]. When two bursts are trying to reserve the same resource, one of them is going to be deflected to another path in order to prevent the contention. It can prevent contention between data bursts and helps to increase the performance of networks.

Fiber delay lines [21,22] can perform like buffers in OBS networks. The solution is using fibers in intermediate nodes to prevent packet loss. When two bursts are trying to reserve on output, one of them is sent to the fiber to circulate over there to make some delays like buffers. These fibers can replace buffers in some ways but do not have the same functionality.

One of the solutions for preventing contention between bursts is using wavelength conversion [23,24]. In this case, when two bursts are trying to reserve the same resource, for preventing the contention, one of them is sent to another wavelength and the output wavelength is changed for it.

3 Conclusion

OBS networks can be used in the backbones of the Internet. These networks are suffering from an important flaw called burst contentions. This issue can lead to a significant reduction in the final performance of the network. In this paper, some of the researches that have been done to tackle the problem were investigated.

References

1. Poorzare R, Jamali S. Optimizing TCP vegas for optical networks: a fuzzy logic approach. (IJCSIS) Int J Comput Sci Inf Secur. 2015;13:33–45.
2. Shihada B, Zhang Q, Ho P-H, Jue JP. A novel implementation of TCP vegas for optical burst switched networks. Opt Switching Networking. 2010;7:114–26.
3. Poorzare R, Abedidarabad S. Improving performance of optical networks by using FRPI algorithm. J Opt Commun. 2018.
4. Quality of Service in Optical Burst Switching Networks. Alvaro Barradas, 2009.
5. Yuan J, Zhou X, Wang J, He Y, Wang K. Inverse two-way signaling scheme for optical burst switched networks. Opt Switching Networking. 2012;9:214–23.
6. To H-L, Lee S-H, Hwang W-J. A burst loss probability model with impatient customer feature for optical burst switching networks. Int J Commun Sys. 2014;28:1729–40.
7. Chawathe SS. Analysis of burst header packets in optical burst switching networks. 2018 IEEE 17th International Symposium on Network Computing and Applications, 2018.
8. Yuan J, Zhou X, Wang J, Li X, Lin F. An irregularly slotted ring scheme for contention-free optical burst switching. Opt Switching Networking. 2014;12:45–55.
9. Kozak M, Jaumard B, Bohaca L. On the efficiency of stream line effect for contention avoidance in optical burst switching networks. Opt Switching Networking. 2015;18:35–50.
10. Poorzare R, Abedidarabad S. Optimizing optical networks by using CWN algorithm. Rev Comput Eng Stud. 2017;4:98–102.
11. Poorzare R, Jamali S, Poorzare A. Maximum burst size adjustment for improving packet delivery ratio in Optical Burst Switching (OBS) networks. Int J Innovative Sci Eng Technol. 2018;2:823–8.
12. Akhter R, Majumder SP. Performance evaluation of a WDM optical network node with wavelength convertible optical burst switching. International Conference on Smart Computing and Electronic Enterprise, July 2018.
13. Veera Vanitha D, Sumitha D, Sabrigiriraj M. Analysis of combined buffering and retransmission with maintenance activity in OBS networks. 2018 International Conference on Current Trends towards Converging Technologies, 2018.
14. Rajab A, Huang C-T, Al-Shargabi M. Decision tree rule learning approach to counter burst header packet flooding attack in optical burst switching network. Opt Switching Networking. 2018;29:15–2.
15. Tang S, Tan L. Single-wavelength optical buffers with general burst size distribution: blocking probability and mean delay. Opt Switching Networking. 2018;27:1–6.
16. Zhang D, Guo H, Chen G, Zhu Y, Yu H, Wang J, et al. Analysis and experimental demonstration of an optical switching enabled scalable data center network architecture. Opt Switching Networking. 2017;23:205–14.
17. Sreenath N, Muthuraj K, Vinoth Kuzhandaivelu G. Threats and vulnerabilities on TCP/OBS networks. 2012 International Conference on Computer Communication and Informatics (ICCCI –2012), Jan 2012.

18. Tang S, Tan L. Analysis of blocking probability of multi-class OBS with general burst size distribution. IEEE Commun Lett. 2016;20:2153–6.
19. Borgonovo F, Fratta L, Bannister JA. On the design of optical deflection-routing networks. INFOCOM, 1994.
20. Thachayani M, Nakkeeran R. Deflection routing in OBS networks. Int J Comput Appl Technol Res. 2013;2:340–4.
21. Kwak KJ, Coffman EG. Retransmission in OBS networks with fiber delay lines. 2007 Fourth International Conference on Broadband Communications, Networks and Systems, 2007.
22. Wang J, Man D, Lijun W. Study on contention resolution with fiber delay lines in OBS network. Proceedings Volume 6783, Optical Transmission, Switching, and Subsystems V, Nov 2007.
23. Maranhao J, Waldman H, Soares A, Giozza W. Wavelength conversion architectures in OBS networks. NOMS 2008–2008 IEEE Network Operations and Management Symposium, April 2008.
24. Rosberg Z, Zalesky A, Vu HL, Zukerman M. Analysis of OBS networks with limited wavelength conversion. IEEE/ACM Trans Networking. 2006;14:1118–27.