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A NOVEL HYBRID SCHEME FOR CONTENTION MINIMIZATION IN OPTICAL BURST SWITCHED NETWORK

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Abstract

In Optical Burst Switched (OBS) Networks, data is transported in a bufferless network and hence there is fair amount of possibility of contention among the data bursts. This occurs when multiple bursts contend for the same link. The existing reactive contention resolution schemes attempt to address issue of contention without making any efforts to minimize the occurrences of contention in the network. Also, the existing proactive contention minimization schemes fail to provide improvement in contention loss at a very high load. Therefore, we are presenting new scheme for reducing the occurrence of contention in OBS network and it is known as Dynamic Hybrid Cluster and Deflection Feedback (DHCF) scheme. In proposed DHCF scheme entire OBS network is partitioned into many small clusters. In each cluster, one node acts as cluster head for gathering the information of resources in the network. The contention is minimized using clustering approach and it can be further improved with the help of deflection feedback mechanism. A performance metrics is considered to evaluate merits of the proposed DHCF scheme and its effects on overall network performance. Also, the comparison of the performance of the DHCF scheme with limited hybrid deflection and retransmission (LHDR) scheme and dynamic hybrid retransmission in deflection routing (DHRD) scheme is made. The simulation results show that the proposed scheme gives improvement in Burst Loss Probability (BLP) in the range of 31% to 38% and delay improvement in the range of 64% to 74% on vBSN network. The vBSN is network topology.

Keywords:

Optical Burst Switching, Contention Resolution, Burst Loss Probability (BLP)

1. INTRODUCTION

The burst switched networks have been evolved to make efficient utilization of terabits per second of bandwidth offered by core optical networks [1]. The data burst is created by aggregating multiple packets at the ingress node of OBS network and it is passed through network all optically. For each generated burst, the control burst packet is transmitted in advance for reserving the wavelength along path to destination. The time difference between the burst and control packet is known as offset time and it should be sufficient to make advance reservation along the path before arrival of data burst. Burst contention occurs when two or more control packets try to reserve a same wavelength channel at the same time, which may cause the drop of burst [2].

Several methods have been evolved in the literature to resolve the problem of burst contention [1], [3], [4], [5], [6]. The fiber delay lines (FDL) are used for delaying the optical signal to reduce the contention by buffering the signal through very a long fiber [3]. In wavelength conversion approach, the wavelength of the signal at the input port is converted to different wavelength at the output port to overcome the contention due to unavailability of the same wavelength on the next hop and thus reducing the contention [4]. With burst segmentation scheme [5], during contention the overlapping burst portion is divided into smaller segments and it is again transmitted. It results in lower burst loss ratio. Another scheme known as deflection routing used for contention resolution, wherein the data burst is transmitted to another route than the original route in contention. It results in poor network performance as it creates a long looping of data bursts [6]. A comparative investigation of all these reactive schemes clearly indicates that they do not provide technically and cost effective viable solution under all conditions. For example, to generate a delay of 1 millisecond requires approximately 200 kilometer long fiber [6] or deployment of wavelength converters at all nodes with high degree of conversion capability is an expensive proposition. In addition, they do not make an attempt to decrease the occurrence of contention in the OBS network.

Therefore, an alternative approach to control the contention loss using traffic management method in a proactive manner is very much desirable. In proactive scheme [7], the contention avoidance scheme makes sure that that the network is being prevented from entering the congestion state before any contention loss occurs. In general, the contention avoidance scheme must minimize the occurrence of contention, minimize the average end-to-end packet delay, and work with minimum additional signaling overhead [8]. Contention minimization scheme can be implemented in optical network with feedback and without feedback configuration setup [7]. In a non-feedback based network, the source nodes do not have any updated information about the available network resources and they cannot respond to changes in the network load. In a feedback based network, contention can be avoided by dynamically controlling the data burst rate at the source according to the latest network status and its available resources. Several proactive schemes [7]-[13] have been proposed to minimize the occurrence of contention and they give some improvement in occurrences of contention at the cost of generating additional delay in the OBS network. However, they fail to provide improvement in contention loss and average delay at a very high load.

Therefore, the Dynamic Hybrid Cluster and Deflection Feedback (DHCF) scheme is proposed in this paper to minimize the generation of number of contentions itself. In DHCF scheme, the entire OBS network is divided into group of small clusters and within each cluster one node acts as a cluster head. The contention avoidance clustering approach effectively handles the network from entering into heavy contention states. Also, the deflection routing based feedback scheme is employed in DHCF scheme along with cluster approach to further reduce the occurrence of contention. The dynamic deflection routing concept we have proposed in [14] and in DHCF scheme the same is used along with clustering approach in this paper. The designated cluster head collects the information related to network resources and transfer the updates of the resources to other cluster heads within network for the purpose of updating the status of entire network resources. Based on the value of updated status of network resources, the source node adapts the data burst transmission rate accordingly. The proposed mechanism includes dynamic combination of traffic based clustering approach and deflection and thereby improving the network performance. Hence, by proactively controlling the overall traffic, network is able to update itself in case of high contention and thus contention avoidance can be achieved efficiently.

The efficiency of proposed scheme is verified through simulation and its performance results are compared with existing limited hybrid deflection and retransmission (LHDR) scheme and dynamic hybrid retransmission in deflection routing (DHRD) scheme. The simulation results confirm that the DHCF scheme achieve extremely better contention minimization performance as well as improvement in the delay performance even at very high load.

The rest of the paper is organized as follows. The section 2 presents the developed model of cluster generation with deflection alternative to achieve contention minimization and it is analyzed for evaluating the network performance in terms of BLP, delay and throughput. The simulation environment is presented in section 3. The numerical results obtained from simulation are presented in section 4. A performance comparison of proposed DHCFscheme with two other contention resolution schemes (LHDR, DHRD) is also given in section 4. Finally, section 5 concludes the paper.

2. PROPOSED DYNAMIC HYBRID CLUSTER AND DEFLECTION FEEDBACK SCHEME

The Dynamic Hybrid Cluster Based Deflection Feedback (DHCF) scheme for contention minimization works in two parts. In the first part, the process of logical partition of entire network into a small size cluster is described in detail. In the second part, the actual burst data transmissions with reduction in the occurrence of contention over clustered network with deflection feedback is explained in detail.

2.1 THE GENERATION OF CLUSTER

First, the process of cluster generation is considered. The M_n is a set denoting the number of nodes in network and the P_r is a set denoting the degree of each node in the network. The N_r denotes one of node within the set P_r, where r is the degree of node n in the given network and C_j is a set denoting the number of nodes within the j^{th} cluster.

The cluster head is decided by looking at the node that have maximum degree in the set P_r. The first cluster is formed by adding all the nodes that are one hop distance to cluster head. The entry of selected nodes in the first cluster is deleted from the set M_n with their degree from the set P_r. Once the first cluster is created then the process of selecting second cluster begins, wherein the degree in set M_n for all the remaining nodes is checked. The node that has a maximum degree is chosen as second cluster head. Again, all the nodes that are one hop distance to second cluster head are added to form a second cluster. The entry of selected nodes in the second cluster is deleted from the set M_n with their degree from the set P_r. As long as the entire set M_n reaches zero node value, the process of new cluster formation is repeated. It may happen that the cluster has only one node. In DHCF scheme, the number of nodes in particular cluster is considered as the important design parameter and it is dynamic in nature. The minimum number of nodes that are taken for one cluster is four. The clusterthat has less than four nodes can be easily added to other cluster based on their hop distance. The minimum hop distance assumed to be the selection criteria for formation of cluster with added nodes. A 12 nodes vBSN network topology is considered as shown in Fig.1 for purpose of cluster formation. The set M_n and P_r for a given topology without any cluster can be written as,

$$M_n = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]$$

$$P_r = [13, 22, 33, 44, 53, 62, 73, 84, 92, 103, 113, 122]$$

In order to make first cluster, the cluster head needs to be decided. It can be observed from the set P_r that, four is the maximum degree with node 4 in a twelve nodes vBSN topology. The nodes which are one hop distance or adjacent to node 4 are 1, 2, 3, 4, 5 and therefore they are added to form the first cluster. Hence, all the selected nodes (1, 2, 3, 4, 5) in the first cluster are removed from the set M_n and their respective degree 13; 22; 33; 44; 53 from the set P_r. After formation of first cluster, the remaining nodes in the set M_n, P_r and C_1 can be written as,

$$M_n = [6, 7, 8,9,10, 11, 12]$$

$$P_r = [62, 74, 84, 92,103, 113, 122]$$

$$C_1 = [1, 2, 3, 4, 5]$$

In order to create the second cluster, the node 8 chosen as cluster head having the maximum degree four in set P_r. The nodes which are one hop distance or adjacent to node 8 are 6, 8, 9, 10 and therefore they are added to form the second cluster. Hence, all the selected nodes (6, 8, 9 and 10) in the second cluster are eradicated from the set M_n and their respective degree 62; 84; 92; 103 from the set P_r.

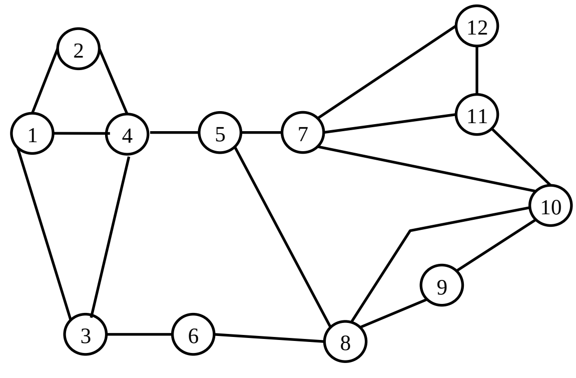

Fig.1. A 12 node vBSN network use for clustering

After formation of second cluster, the remaining nodes in the set M_n, P_r and C_2 can be written as,

$$M_n = [7, 11, 12]$$

$$P_r = [74, 113, 122]$$

$$C_2 = [6, 8, 9, 10]$$

Similarly, the other cluster can be formed and this process is repeated till the set M reaches the empty value. After formation of third cluster, the nodes remain in the set M_n, P_r and C_3 can be written as,

$$M_n = [0]$$

$$P_r = [0]$$

$$C_3 = [7, 11, 12]$$

The vBSN topology of Fig.1 is divided into three clusters as shown in Fig.2.The cluster heads are shown in Fig.2 by a node with a square shape. Here, only those clusters which have minimum four nodes are selected as final clusters in the set of clusters. It can be observed from Fig.2 that, the cluster 3 has only 3 nodes. In order to satisfy the minimum node criteria, the nodes of cluster three can be easily added to either the first cluster or second cluster based on their hop distance from respective cluster head. If any node has the same distance for more than the cluster head then it can be shifted to any of the clusters. The node 7 has two hop distances from cluster head node 4 and cluster head node 8. The node 7 is chosen to add in cluster 1. The node 11 has three hop distances from cluster head 4 and cluster head 8 respectively. The node 11 is added to cluster 2 by free choice. In the same fashion, the node 12 is included in the cluster 2. Ultimately, the four minimum node criterion is fulfilled in the form of two clusters as depicted in Fig.3. The final two clusters with number of nodes can be written as,

$$C_1 = [1, 2, 3, 4, 5, 7]$$

$$C_2 = [6, 8, 9, 10, 11, 12]$$

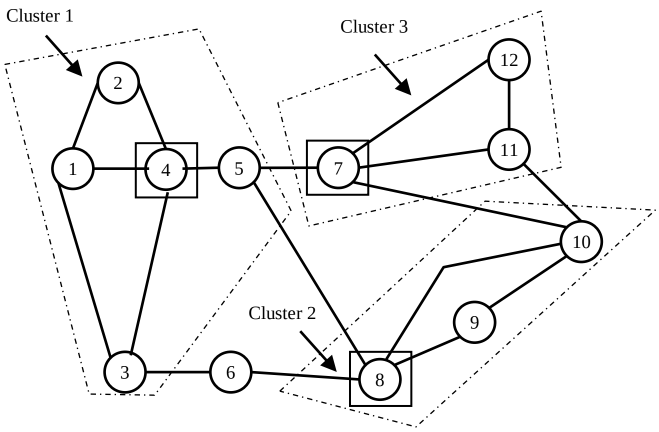

Fig.2. A vBSN network partition into three clusters

2.2 CONTENTION MINIMIZATION APPROACH OF DHCF SCHEME

In this second part, the actual burst data transmission with reduction in the occurrence of contention over clustered network is explained in detail. The increase in the occurrence of contention result into high BLP [6], [7] and thus, the focus in DHCF scheme is to reduce the contention for better burst loss performance. One of the ways for improving burst loss probability is to minimize the occurrence of contention in the network and that is the main objective of our DHCF scheme. In proposed scheme, three extra control packets on top of burst control packet (BCP) are introduced.

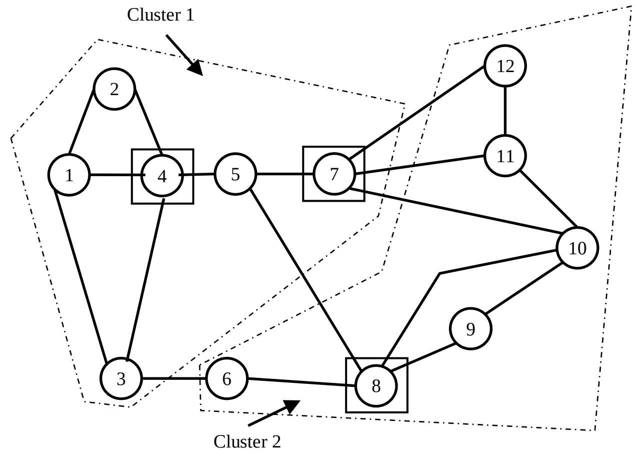

Fig.3. The vBSN network with final two clusters

The working of these control packets is explained below,

Resource seeking packet (RSP): Before transmitting the BCP, the node send the RSP as a request to cluster head for checking the free wavelength channel along the path from source to destination.

Resource acknowledgment packet (RAP): The resource acknowledgment packet (RAP) is sent by cluster head in response to RSP. If a wavelength channel is available on the path than the cluster head send a positive acknowledgment message (PAK) otherwise a negative acknowledgment message (NAK).

Statics Update Packet (SUP): The statics update packet is used for the purpose of transferring the updates of resources between cluster head. If the positive acknowledgment message (PAK) is sent by the cluster head to resource requesting node then the same cluster head sends a statics update packet (SUP) to all other cluster heads in the network for updating the resources.

In DHCF scheme, the separate wavelength is allocated for exchange of SUP packet between the cluster heads and thus SUP can easily get through without any interference by other nodes. Therefore, the cluster heads smoothly keep the update of network resources by transferring the SUP packets between the cluster heads. In the beginning, the cluster head acknowledges that all resources free and available for the burst transmission. The node sends the Resource Seeking Packet (RSP) as a request to cluster head for checking the free wavelength channel along the path from source to destination. Based on latest resource updates, the cluster head then selects the free wavelength channel by checking all the channels of all the links of all paths to the desired destination node. The cluster head then sends the PAK packet to a source node to acknowledge that the free channel is available and allocated for data burst transmission. Then the cluster head transmits the SUP packet to other clusters in the network for updating channel allocation status. Upon receiving the PAK packet source node transmit data burst after following the BCP packet. Thus, the wavelength channel provided by the cluster head is sure to be available for burst transmission as it continuously updates the status of available network resources. Hence, the cluster with feedback approach results into minimum occurrence of contention in the network. As load increases in the network the cluster approach may drop the burst due to contention. For example, if the two nodes of different clusters ask their cluster heads at the same time for the use of same wavelength channel than it leads to contention. In such condition, the deflection alternative is use to provide another path for contending data burst towards its destination. On the contrary, when two nodes of single cluster at same time send the RSP packet to cluster head for free channel, it does not lead to increase in occurrence of contention. This is due to the fact that cluster head has updated resource information and it selects a wavelength channel from resource database rather than random selection of channel. In addition, the cluster head makes sure that the selected channel does not give rise to contention. The cluster head updates the database with latest use of channel by receiving the SUP packet. Thus, the static of entire OBS network is continuously updated.

To graphically explain the concept of data burst transmission through proposed DHCF scheme, an example of the vBSN network topology (Fig.3) is considered. The data transmission process between two nodes is shown. The separate channel is available between cluster head node 9 and 6 through node 10 and is depicted in Fig.4 by a solid black line. The node 8 of second cluster has data burst for transmission to node 4 of first cluster. The node 8 then sends it to the cluster head received the PAK packet from node 6 to request the channel on path from source node 8 to 7 to 5 to destination node 4. Now, the cluster head begins the process of computing the wavelength channel that is free on the three links from node 8 to 7, 7 to 5 and from node 5 to 4. The assumed six wavelength channels dedicated (C_1, C_2, C_3, C_4, C_5, C_6) for the data transmission on each link (8-7, 7-5 and 5-4) and their status seen by cluster head node 9 is shown in Table.1. In Table.1, B indicates that the channel is busy for burst transmission and F indicate that the channel is free to use for burst transmission. However, the wavelength channel C_4 is free to use on all three link along the path from source node 8 to destination node 4. Then, the cluster head sends the PAK packet to inform node 8 about the free channel C_4 is available for burst transmission and it alsosend the SUP packet to the cluster head node 6 of first clusters for updating the resources. Once the node 8 gets the PAK packet then it transmits the burst control packet (BCP) to reserve the wavelength channel C_4 on all intermediate nodes along the path from source to destination. Upon reserving desired channel on the path (node: 8 to 7 to 5 to 4), data burst is transmitted from node 8 after an offset time. On other side, if the NAK is received by node 8 then it simply discards the burst indented for transmission to node 4.

Table.1. The status of six channels on each link observed by the cluster head node 9

Dedicated Channel On Each Link	**Link$_1$:-8 to 7**	**Link$_2$:-7 to 5**	**Link$_3$:-5 to 4**
C_1	B	F	B
C_2	F	B	F
C_3	B	B	F
C_4	F	F	F
C_5	B	F	B
C_6	F	B	B

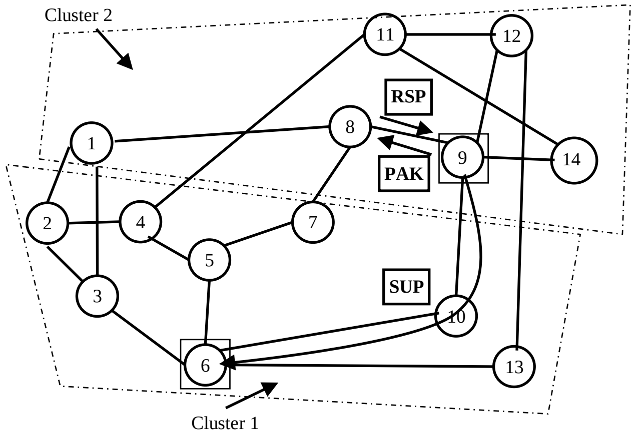

Fig.4. The process of burst transmission with final two clusters on NSF network

3. SIMULATION ENVIRONMENT

The 12 node vBSN topology is considered as the OBS core network as shown in Fig.3. The core OBS network is connected through vBSN topology with three source nodes (1, 2, 3) to three destination nodes (10, 11, 12). The C++ code is developed for the purpose of simulation which includes all the required OBS modules incorporated into it. The MBMAP assembly algorithm, JET protocol and LAUC-VF scheduling algorithm used in simulation [15]. To evaluate the performance of vBSN network, the following performance metrics are measured,

Burst loss probability: The percentage of the total number of dropped burst at source node over the total number of arriving burst. A burst is dropped at its source node if it reaches optimum value of number of deflections attempts.

Throughput: It is the ratio of total number of burst successfully transmitted out of total number of burst attempted for transmission.

Average delay: The cumulative transfer delay divided by the number of successfully transferred bursts. The average end-to-end delay is calculated as the total time taken by a successful data burst from source to destination.

Actual delay: The total cumulative transfer delay divided by the total number of arriving burst. The effective delay also takes into account the delay of dropped bursts.

The following simulation configurations are used:

The fixed rate of transmission is 10Gb/s on each wavelength. The mean burst size equals 1.2MB in vBSN network.

There are 28 wavelengths for data transmission and 4 control wavelength on each link.

Bursts are transmitted though cluster after a certain number of deflection attempts *N*. The *N* is selected, where we can get very low value of BLP. Also, we have selected the safe value of *N* to avoid drastic increase the end-to-end delay.

In simulation work, we are using probabilistic model given in [16] to compute the actual load on each link and each path of entire network. Then, the normalized traffic load is calculated by averaging the load over the entire network and it is varied from 0.2 to 0.9. Also, based on [16] we have evaluated the network wide performance in terms of four network parameters, the BLP, Actual delay, Average delay and Throughput. Initially, all four performance parameters is computed along the link passed through particular path and then added all the possible paths between all the source and destination pairs to measure the network wide performance. For reacting contention resolution scheme LHDR [17] there is only one possible deflection alternative available and multiple deflection alternatives are available in DHRD [18]. However, the occurrence of contention is minimized before it leads further contention into network in proactive DHCF scheme. The proposed scheme is validated and its dynamic nature proved to be very effective in terms of proactively reducing the occurrence of contention.

4. RESULT ANALYSIS AND DISCUSSION

The graph in Fig.5 depicts the burst loss probability (BLP) against variation in normalized load for vBSN network. It is observed that the DHCF scheme always outperform the LHRD and DHRD for all ranges of traffic load. For example even at very high load (load ≥ 0.8) in Fig.5, it can be clearly observe that proposed DHCD scheme gives better BLP performance, about 63.5% less BLP than DHDR and 74.56% less BLP than LHRD. Also, in the DHCF scheme the increase in BLP with increase in network load is more gradual than the LHRD and DHRD scheme.

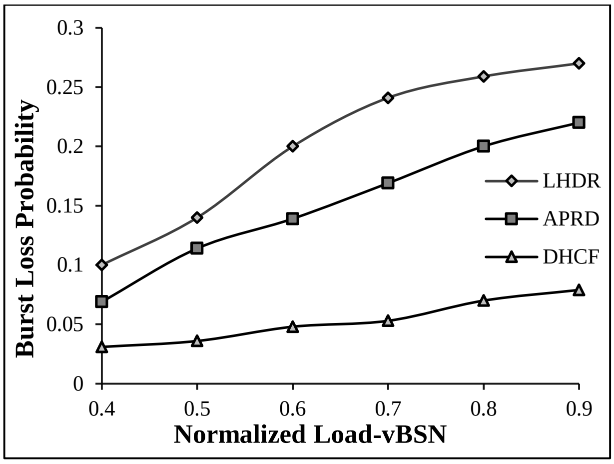

Fig.5. Burst Loss Probability (BLP) vs load on vBSN network

In LHRD, there is lack of dynamic control over the amount of additional load generated in core network due to deflection and retransmission at low and high load. Thus, it results into very high BLP at moderate and higher load than the DHCF scheme. In DHRD scheme, once the deflection fails as there is increases in load, the retransmission is dynamically applied to reduce both the extra load due to number of deflection attempts and contention loss in the core OBS network. However, at very high load (load ≥ 0.8) the contentions arise due to multiple retransmission attempts with many bursts waiting for a free path. It leads to higher BLP than the DHCF scheme. In DHCF scheme, the cluster based deflection approach allows to transmit the burst if the free wavelength channel is available along the path to desired destination otherwise it follow the dynamic deflection. Therefore, dynamic selection of free channel in DHCF scheme results into drastic reduction in occurrence of contentions and BLP even at a very high load.

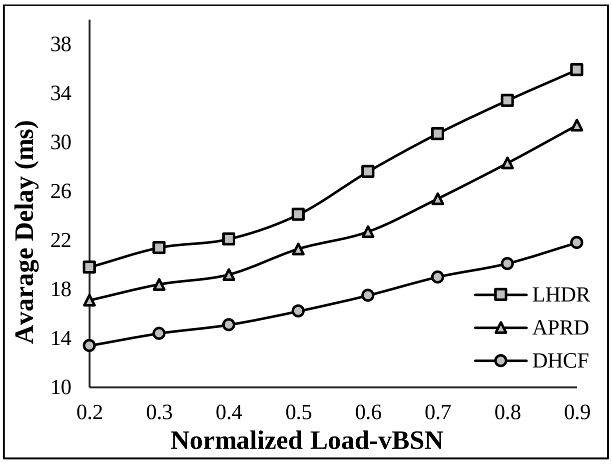

Fig.6. Average Delay vs load on vBSN network

The average end-to-end delay against load for vBSN networks is graphically illustrated in the Fig.6. It can be observed that DHCF perform extremely well at low to moderate load and perform better at very high load than the LHRD and DHRD. For example even at very high load (load ≥ 0.8) on vBSN network in Fig.6, it can be seen that proposed DHCF scheme gives better average delay performance, about 44.03% less average delay than DHDR and 64.67% less average delay than LHRD scheme.

The average delay in the cluster based scheme is addition of propagation delay between a source to destination and the delay between the source and its cluster head. But, the lower value of average delay at high load for our scheme contributes to drastically minimize the contentions and BLP. On the contrary, other schemes LHDR and DHRD produce high average delay with increase in load without contributing in reducing the contentions and BLP. Therefore, increases in the average delay with load in DHCF scheme are adaptively control and kept within the safe limit to avoid the higher BLP and contentions.

The Fig.7 shows the actual average delay against the traffic load. The advantages associated with DHCF scheme in terms of delay become clearer by considering the actual delay than the average delay as it take into status of the delay produced by drop burst. It can be observed that the proposed DHCF scheme outperforms other algorithms like LHDR and DHRD in terms of actual delay at all traffic loads (when the delay of dropped bursts is taken into account). For example in Fig.7 when network load is very high (load ≥ 0.8), the results shows that DHCF gives better delay performance, about 31.30% than LHDR and about 38.75% than DHRD. This is because the data transmission in DHCF scheme is carried out through clustering which gives the channel that is more likely to be free on the desired path. Also, if the channel is not available for data burst to reach the desired destination then the dynamic deflection provides free channel on alternative path. So, only few data bursts need to be dropped and it give rises to minimum contentions and minimum actual delay than other contention resolution schemes, the LHDR and DHRD.

Finally, the graph of throughput against normalized load for fourteen node vBSN network is shown in Fig.8. The throughput of proposed DHCF scheme is extremely bettercompared to reactive contention solving scheme LHDR and AHDR at all loads. The DHCF performs effective transmission of data burst by clustering approach with deflections, compared to LHDR which always uses the first available shortest path where the decision is made by static metrics like the number of hops. The dynamic nature of DHCF allows the successful transmission of burst at low load by clustering alone and at high load by cluster based deflection. Thus, it effectively handles the network from entering into heavy state of contention and it minimizes the occurrence of contention itself. Hence, throughput performance is improved withminimum contention in proactive DHCF scheme. It is clearly shown that DHCF achieves a higher throughput even at high network load because decisions to avoid contention are made dynamically and more efficiently. Considering comparison of all three schemes with high network load (load ≥ 0.8), the outcome reveal that DHCF gives better throughput, about 26.44% than LHDR and 19.52% than DHRD. In addition, as the network load increases, the DHCF scheme dynamically reduces the number of contentions by perfect combination of cluster with deflection and it can be verified by the curve of DHCF scheme in Fig.8. Furthermore, the overall throughput drops gradually rather than falling drastically even though the load is increased.

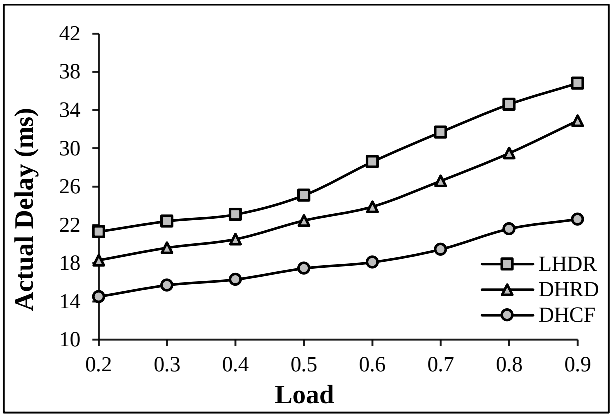

Fig.7. Actual Delay vs load on vBSN network

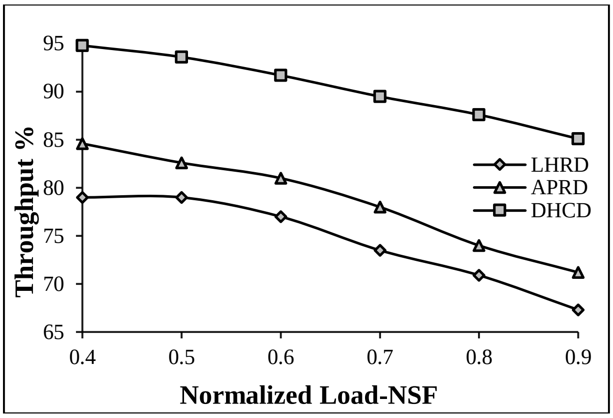

Fig.8. Network throughput vs load on vBSN

5. CONCLUSION

This paper proposed novel contention minimization scheme known as Dynamic Hybrid Cluster and Deflection Feedback (DHCF) for OBS networks. The scheme logically divides the optical network into group of sub networks referred as clusters. The cluster head continuously update use of the network resources. Any node can transmit the burst with help of a cluster head. Also, the DHCF scheme tested on a vBSN network and based on simulation results the proposed scheme is validated. The proposed DHCF has achieved significant improvement in network performance than the existing scheme even at very high load. The improvement in BLP performance in our scheme is attributed to the fact that cluster based approach ensures wavelength channel which is more likely to be free or least congested on the desired path to destination. The data burst transmission on secure wavelength channel ensures significant minimization in occurrence of burst contention. Also, the rise in the average delay with increase in network load in DHCF scheme is maintained in safe limit to prevent the higher BLP.

The proposed DHCF scheme can be potentially utilized for controlled burst transmission in the buffer-less OBS network where, the BLP and occurrence of contentions can be minimized by adaptive tuning of cluster and deflection alternative.

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