Clustered Cooperative Architecture for OBS Networks

Ihsan Ul Haq[1,2,3], Henrique M. Salgado[1,2] & Jorge C.S. Castro[1]

[1]INESC PORTO, Porto Portugal.

[2]Faculdade de Engenharia da Universidade do Porto, Portugal

[3]Deptt of CSE, NWFP University of Engineering & Technology Peshawar, Pakistan

ihaq@inescporto.pt, hsalgado@inescporto.pt, jcastro@inescporto.pt.

Abstract: **Optical Burst Switching is an emerging and promising technology to fulfill the requirements of future Internet. In this article, a novel architecture called Clustered Cooperative Architecture for OBS Networks (C2OBS) has been proposed where an optical network has been divided into small overlapping manageable units called zones/clusters. Each zone has a Zone Head, having the knowledge of available resources within the zone only. The proposed architecture has a shared Wavelength Converter/ Fiber Delay Lines (WC/FDL) bank within the zone which is comparatively, both technically and economically, a more feasible alternative to full wavelength convertors and sparse wavelength convertors placement in OBS networks. The WCs bank is either placed at a central location within the zone or at a node having the highest effective degree in the zone. For illustration, the C2OBS architecture has been applied to the European Optical Network (EON) and the COST 239 Network Topology.**

Index Terms: Optical Burst Switching, Optical Network Architecture

I. INTRODUCTION

Optical Burst Switching (OBS) combines the benefits of the fine-grained Optical Packet Switching (OPS) and the coarse-grained Optical Circuit Switching (OCS). An OBS network consists of Edge and Core nodes. Edge nodes may be ingress or egress nodes. The edge nodes are the electronic transit points between the burst-switched backbone and the legacy networks. In the existing OBS architecture, the ingress node performs burst assembly, routing, wavelength assignment, signaling and edge scheduling. The main tasks performed by core nodes are signaling, core scheduling, routing/forwarding, and contention resolution. The core nodes are mainly composed of an optical switching matrix and a switch control unit which is responsible to forward optical data bursts [1- 4].

The ingress node receives packets from the client networks, assembles a burst and sends a corresponding Burst Header Packet (BHP) on the control channel. The BHP is received at the input module of core node containing source and destination addresses, burst offset time, burst length and the Class of Service (CoS) of the corresponding burst. The purpose of the BHP is to reserve the wavelength channel at each core node along the route for transmitting the data burst.

Optical Burst Switching is envisioned as one of the promising technologies to fulfill the requirement of high bandwidth on demand bursty traffic applications running on the Internet. Unfortunately, resource contention is a major concern in OBS networks that leads to a relatively high burst loss probability. The probability of resource contention further increases when both the traffic load and the number of nodes increase in the existing OBS network architecture. As the number of nodes and link capacities are increasing, as can be seen in Table 1 for USA [5,6,7,8], two important issues arise that lead to an increased blocking probability in OBS networks. Firstly, the resource reservation using centralized [9], distributed [10] or intermediate node initiated (INI) [11,12] schemes becomes an increasingly difficult problem to tackle in case of large number of nodes and heavy traffic load. Secondly, assigning routes and wavelength channel that will avoid contention at the intermediate nodes also become problematic in the existing network architecture for a large network. Therefore, this article presents a more manageable network architecture for OBS networks which can function satisfactorily even under high expected traffic load and with a large number of nodes.

The balance of this article is organized as follows. In Section II, an enhanced architecture called Cooperative Clustered Optical Burst Switching Network (C2OBS) architecture is presented. In this section the same concept has been applied to the European Optical Network (EON) and COST 239 Network topology for illustration. Section III discusses the expected benefits of the proposed C2OBS architecture by comparing it with the existing architecture. Finally, section IV provides conclusions and highlights future work directions.

Table 1: Network Expansion

S.No	Year	Network	Link capacity	No of Nodes
1.	1986	NSFNET	56 kbps	6
2.	1987-91	NSFNET	1.5Mbps (T-1)	13
3.	1992	NSFNET	45 Mbps (T-3)	16
4.	1995	vBNS	622 Mbps (OC-12c)	More than 100 universities, research and engineering institutions via 12 PoPs
5.	1999	vBNS	2.5 Gbps (OC-48c)	
6.	2004	Abilene Network	10 Gbps (OC-192)	
7.	2007	Internet2 Network	100 Gbps	More than 210 educational institutions, 70 corporations, 45 non-profit and government agencies

II. PROPOSED ARCHITECTURE

In the C2OBS architecture, the network is partitioned into overlapping zones/clusters as shown in Figure 1.The zone is defined in terms of number of hops and not physical distance, because we can limit the dissemination of control information based on the number of hops, by using the Time to Live (TTL) value as in IPv4 header, or the HopLimit value as in the IPv6 header [13]. The zone size should be small to reduce

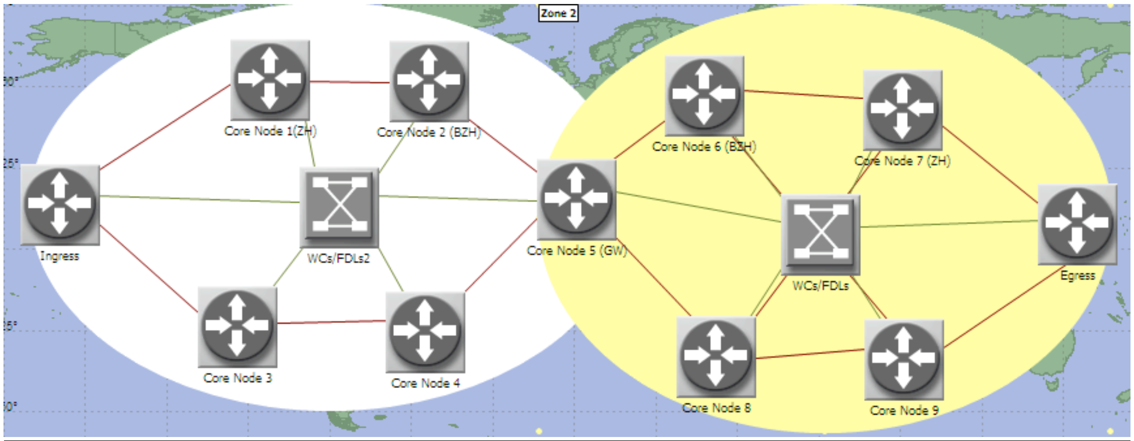

Figure 1: OBS Network Architecture showing ZH, BZH and shared WCs/FDLs

dissemination of control information. Furthermore, the gateway (explained later) does not allow the broadcast "Hello messages" from the Zone Head (ZH) to pass through, as such information is not required in adjacent zones. As the zones are overlapping, there will be one or more nodes that will be part of more than one zone as shown in Figure 1, 2 & 3. For example, in Figure 2, Copenhagen (COP) serves as a gateway between Z-3, Z-4 and Z-5 because it is common to the three zones. Similarly, Prague (PRA) is common between zone two and four and functions as a gateway between these zones. Each zone has a Zone Head (ZH) and Backup Zone Head (BZH). For example, the node at Paris (PAR) is a ZH for Z-1. The ZH keeps the information of all of the nodes within the zone relating to routing and wavelength assignment called Zone Base (ZB). The ZH also maintain a Short History Base (SHB) related to resources reserved. These two information bases will be utilized for effective resource utilization.The BZH duplicates the tasks performed by the ZH, either in case of failure of the ZH or if the ZH is overburdened with other processing tasks like performing the job of a gateway and stops broadcasting its "Hello messages". The other members of the zone are referred to as Zone Members (ZM).

The ZH is dynamically elected with a criterion as the node with the highest effective degree in the zone. The degree of a node is the number of connections or edges it has to other nodes in the network and by effective degree, we mean the number of edges connecting with the nodes within the zone only. This condition has been imposed because in most cases the ZMs will be directly connected to the ZH and it will be possible for ZMs to communicate with the ZH with the least propagation delay for resource reservation etc. Furthermore, the ZH needs not to be fixed, because if a node is busier in processing other jobs and cannot efficiently process the ZM's requests, it will leave its role as ZH and BZH will take over its responsibility. As the BZH will become the ZH, other ZMs will take part in election to become BZH and the node with higher degree will win and will become the BZH. Even in case of failure of ZH, the similar procedure will take place.

Each zone will have common shared wavelength convertors (WCs)/ Fiber Delay Lines (FDLs) bank for contention resolution. This shared bank of WCs/FDLs in a zone is our novel idea and has never been proposed in literature as per our knowledge. This shared bank can be installed at a central location as in Figure 1 or may be placed along with of optical switch having higher degree as shown in Figure 2 and 3. Optimal wavelength converter placement in optical networks has been shown to be NP-hard, and many heuristics have been proposed to resolve this problem [14] but still this is an open research area. In OBS networks, where do we optimally place WCs/FDLs is a vital question. One of the possible solutions is to place the WCs at each output port of the optical switch. This solution is not cost effective as WCs may not be required all the time and it is the wastage of expensive resource. As wavelength convertors are still expensive, providing dedicated wavelength convertors is not a cost effective solution [3, 14], the proposed shared WCs/FDLs bank architecture provides a reasonable solution for placement of WCs in the optical OBS network. The WCs/FDLs bank can be accessed by any incoming burst that needs wavelength conversion/buffering.

This will also make the network planning simpler and economical because this module can be upgrade as per requirement keeping in view the future increase in traffic without upgrading/replacing the optical switches. This will make the switch fabric architecture simpler and will improve the utilization of this resource (WCs/FDLs). Since all the nodes within the zone will use the same resource for wavelength conversion and optical buffering. This will make the OBS networks economically more feasible as augmenting each node with WCs/FDLs is an expensive solution [10]. Although, the use of WCs/FDLs will be minimized as much as possible by using effective resource reservation scheme and this will act as a last resort to save the burst from blocking. In this way, the requirement for number of WCs/FDLs will be reduced which is both technically and economically more attractive.

The proposed architecture has been named Cooperative Optical Burst Switching Architecture because the Gateway nodes in the network cooperate for successful resource reservation in the adjacent zone and tries to reduce the burst blocking probability.

As an illustration, the same Divide and Conquer rule has been applied to European Optical Network (EON) [15, 16] as shown in Figure 2. The EON consists of 20 nodes and 38 links. The network has been divided into five zones (Z-1 to Z-5) and detail about the role of each node in the zone is depicted in Table 2. The table elaborates the status of each node in its respective zone, i.e. whether the node is Zone Head (ZH), Zone Member (ZM) and Gateway (GW). It also indicates the degree of the node in the network and effective degree within the zone, which is a key selection criterion for the selection of ZH. In Figure 2, the WCs/FDLs bank (BNK) has been shown along with the ZH and the circle, oval and cloud shapes have been used to represent different zones in EON and has been labeled as Z-1 to Z-5.

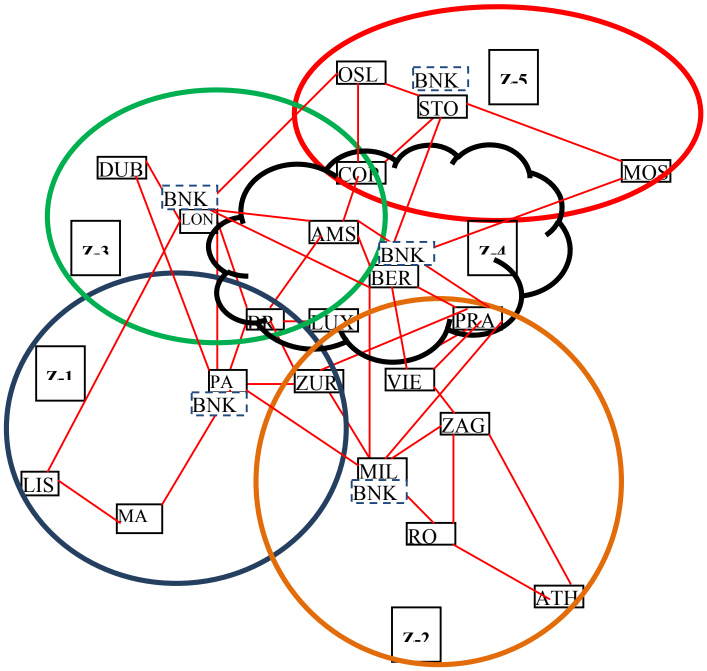

Figure 2: Cooperative Clustered OBS Network Architecture for EON

Table.2: Node Description of EON

S.No	Location of Node	Zone Member	Member Status	Degree of Node	Effective Zonal Degree
1.	Libson (LIS)	Z-1	ZM	2	1
2.	Madrid (MAD)	Z-1	ZM	2	2
3.	Paris (PAR)	Z-1	ZH	**6**	**3**
4.	Brussels (BRS)	Z-1, Z-3 & Z-4	ZM & GW	5	2
5.	Zurich (ZUR)	Z-1 & Z-2	ZM & GW	4	2/2
6.	Athens (ATH)	Z-2	ZM	2	2
7.	Rome(ROM)	Z-2	ZM	3	3
8.	Zagreb (ZAG)	Z-2	ZM	4	4
9.	Vienna (VIE)	Z-2	ZM	3	2
10.	Milan (MIL)	Z-2	ZH	**6**	**4**
11.	Prague (PRA)	Z-2 & Z-4	ZM & GW	5	3/2
12.	London (LON)	Z-3	ZH	**7**	**3**
13.	Dublin (DUB)	Z-3	ZM	2	1
14.	Amsterdam (AMS)	Z-3 & Z-4	ZM & GW	5	2/3
15.	Berlin (BER)	Z-4	ZH	**7**	**2**
16.	Luxemburg (LUX)	Z-4	ZM	1	1
17.	Copenhagen (COP)	Z-5 & Z-3	ZM & GW	3	½
18.	Moscow (MOS)	Z-5	ZM	2	1
19.	Stockholm (STO)	Z-5	ZH	**4**	**3**
20.	Oslo (OSO)	Z-5	ZM	3	2

As another illustration, the same Divide and Conquer rule has been applied to COST-239 Network Topology [17] as shown in Figure 3. This backbone network is interconnecting 11 European cities with 26 bidirectional links. The network has been divided into three zones (Z-1 to Z-3) and detail about the role of each node in the zone is depicted in Table 3. The table elaborates the status of each node in its respective zone, i.e. whether the node is Zone Head (ZH), Zone Member (ZM) and Gateway (GW). It also indicates the degree of the node in the network and effective degree of the node within the zone, which is a key selection criterion for the role of ZH. In Figure 3, the WCs/FDLs bank has been shown along with the ZH and the oval, diamond and hexagon shapes has been used to represent different zones that has been labeled as Z-1 to Z-3.

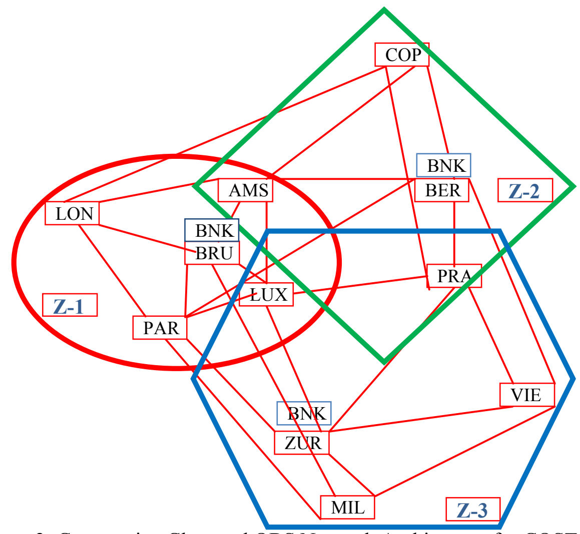

Figure 2: Cooperative Clustered OBS Network Architecture for COST 239 Network Topology

Table.1: Node Description of COST-239 Network Topology

S.No	Location of Node	Zone Member	Member Status	Degree of Node	Effective Zonal Degree
1.	London (LON)	Z-1	ZM	4	3
2.	Paris (PAR)	Z-1	ZM	6	3
3.	Brussels (BRU)	Z-1	ZH	5	4
4.	Amsterdam (AMS)	Z-1 & Z-2	ZM & GW	5	3/2
5.	Luxemburg (LUX)	Z-1 & Z-3	ZM & GW	5	3/1
6.	Copenhagen (COP)	Z-2	ZM	4	3
7.	Berlin (BER)	Z-2	ZH	5	3
8.	Prague (PRA)	Z-2 & Z-3	ZM & GW	5	2/2
9.	Vienna (VIE)	Z-3	ZM	4	3
10.	Zurich (ZUR)	Z-3	ZH	5	4
11.	Milan (MIL)	Z-3	ZM	4	2

III. EXPECTED BENEFITS

The aim of this section is to discuss the benefits of the C2OBS architecture and compare it with the extant OBS Architecture. In C2OBS, the whole network has been divided into more manageable smaller units called zones, with a ZH that maintains ZB and SHB. This information will be utilized for effective reservation of resources. As compared to the distributed resource reservation protocols like JIT, JIT+, E-JIT, JET, and Horizon, where the knowledge of each node (ingress or intermediate core nodes) about resource availability is limited only to adjacent links, the ZH in C2OBS has the information about the ZMs, Gateway(s) and resources available on these nodes within the zone. This zonal information can be effectively utilized to avoid contention at intermediate nodes and to reduce the burst drop probability in the overall network.

As compared to the centralized reservation scheme, where all resource assignment is accomplished by a single central node, the proposed architecture is following a distributed strategy having ZHs and BZHs in each zone for resource assignment and reservation. In the case of the centralized reservation scheme, when the central node fails, the whole network performance will be affected. So the central node becomes a performance bottleneck in the network. In contract, in the C2OBS architecture, the failure of a ZH will affect a single zone within the network till the BZH takes responsibility of ZH.

Another advantage of the proposed architecture is its scalability. If the number of nodes in the network is increased, the network can be redesigned by either adding the new node to an existing zone or creating a new zone to maintain the network performance.

Wavelength convertors are still immature and expensive, full wavelength conversion is still not a realistic solution. The alternative solution is to place the wavelength convertors sparsely. Optimal placement of sparse wavelength convertors in optical networks is a vital question but it has been shown to be NP-hard. The proposed shared WCs bank in the zone is comparatively a more feasible alternative because the WCs bank is either placed at a central location within the zone or at a node having the highest effective degree in the zone, which will mostly provide direct connectivity between any switching node (ZM) and the bank. This solution is also attractive from network planning perspective because this module can be easily enhanced or replaced keeping in view the future estimated traffic load. In existing architecture where wavelength convertors are an integral part of the switch, there is no such flexibility. This will also make the switching fabric architecture simple to implement.

Based on the above comparative analysis with existing architecture, it seems that the proposed design is both more flexible, scalable and efficient.

IV. CONCLUSION & FUTURE DIRECTIONS

In this article, a Divide and Conquer approach has been applied to OBS network by splitting the whole network into small more manageable units called zones. Each zone has a Zone Based information repository in the Zone Head. This information will be utilized for effective resource reservation. Furthermore,it is not realistic to provide full wavelength conversion in the optical networks, an improvement in the network architecture has been suggested by implementing the bank of WCs/FDLs as a separate module from the switch within the zone and all zone members can use the same bank when required.

As for as future work is concerned, the next objective is to implement a simulation model for analyzing the performance of the C2OBS network architecture, presenting a resource reservation scheme and Routing & Wavelength assignment strategy that utilizes the information available in the ZH. It is expected that resource reservation, routing and wavelength assignment based on information with help to reduce the blocking at the intermediate nodes even in large size networks with heavy traffic load. The strategies will be compared with the extant resource reservation schemes and routing and wavelength assignment strategies for verification and validation.

REFERENCES

[1] C. Siva Ram Murthy and Mohan Gurusamy, "WDM Optical Networks: Concepts, Design and Algorithms" Prentice Hall PTR, 2002.

[2] Jason P. Jue, Vinod M. Vokkarane, “Optical Burst Switching Networks”, Springer Science + Business Media Inc, 2005

[3] Biswanath Mukherjee, “Optical WDM Network”, Springer Science + Business Media Inc, 2006.

[4] Ihsan Ul Haq, Henrique Salgaso, Jorge Castro, “Survey and Challenges for Optical Burst Switching Networks: A High Data Rate Network for Future Internet” 2nd International Conference on Intelligence and Information Technology, 28-30 October, 2010, Lahore, Pakistan, Page(s) 381-386.

[5]http://en.wikipedia.org/wiki/National_Science_Foundation_Network#cite_ref-19 (visited on 16th June, 2011)

[6] http://en.wikipedia.org/wiki/VBNS (visited on 16th June, 2011)

[7] http://en.wikipedia.org/wiki/Abilene_Network (visited on 16th June, 2011)

[8] http://en.wikipedia.org/wiki/Internet2 (visited on 16th June, 2011)

[9] Polina Bayvel, “Wavelength-Routed or Burst-Switched Optical Networks,” 3rd International Conference on Transparent Optical Networks, 2001.

[10] Jing Teng, George N. Rouskas, “ A Detailed Analysis and Performance Comparison of Wavelength Reservation Schemes for Optical Burst Switching Networks”, Photonic Network Communications, vol 9, Number 3, 2004,Page(s) 311-335.

[11] R. Karanam, V.Vokkarane, J. Jue, “Intermediate Node Initiated (INI) Signaling: A Hybrid Reservation Technique for Optical Burst Switched Networks”, Optical Fiber Communication Conference, 23-28 March 2003, Page(s) 213-215.

[12] Joel J.P.C. Rodrigues, Binod Vaidya, “Evaluation of Resource Reservation Protocols for IP over OBS Networks”, 11th International Conference on Transport Optical Networks, 28th June to 2nd July 2009, Page(s) 1-4

[13] Larry L. Peterson & Bruce S. Davie, “Computer Networks: A Systems Approach” 3rd Edition, 2003, Morgan Kaufmann Series in Networking.

[14] Bo Li and Xiaowen Chu, “Routing and Wavelength Assignment vs Wavelength Converter Placement in All-Optical Networks”, IEEE Communication Magazine, vol 41, issue 6, 2003, Page(s) 522-528.

[15] M.J.O’ Mahony, “A European Optical Network: Design Considerations”, IEEE Colloquium on Transport Optical Networks: Applications, Architectures and Technology, 1994, Page(s) 1-6.

[16] M.J.O’ Mahony, D. Simeonidou, A. Yu, and J. Zhou, “The Design of a European Optical Network”, Journal of Lightwave Technology, vol 13, issue 5, May 1995, Page(s) 817-828.

[17] A.L. Barradas, and M.C.R. Medeiros, “An OMNET++ Model for the Evaluation of OBS Routing Strategies”, Ist International conference on simulation tools and techniques for communications, networks & systems, Brussels, Belgium.