New Optical Parameters Dependent Metric for OSPF Protocol for OBS Networks

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***Abstract*–Based on an extensive simulation analyses on various optical parameters effect on burst loss ratio (BLR) for optical burst switching (OBS) networks. A comparison between routing decision based on standard open shortest path first (OSPF) routing protocol and a proposed new OSPF metric is performed. The proposed new OSPF metric takes into account optical parameters in its dependency as number of channels, load and link bandwidth. The result shows better routing decisions leading to better BLR and utilization for OBS networks.**

***Index Terms*–Optical burst switching, Routing metric, optical routing, open shortest path first (OSPF), fiber delay line, traffic load, channel bandwidth, number of channels.**

I. Introduction

Optical burst switching (OBS) is a switching concept which lies between optical circuit switching and optical packet switching. A dynamic optical network is provided by the interconnection of optical cross connect circuits to transfer a group of packets called burst [1].

Optical Burst Switching operates at the sub-wavelength level and is designed to better improve the utilization of wavelengths by rapid setup and teardown of the wavelength/light path for incoming bursts. In OBS, incoming traffic from clients at the edge of the network are aggregated at the ingress of the network according to a particular parameter (commonly destination). Therefore, at the OBS edge router, different queues represent the various destinations. Therefore based on the assembly/aggregation algorithm, packets are assembled into bursts. From the aggregation of packets, a burst is created and this is the granularity that is handled in OBS [2].

In OBS electrical processing is decoupled from the Optical process. Therefore the burst header generated at the edge of the network is sent on a separate control channel which could be a designated out-of-band control wavelength. At each switch the control channel is converted to the electrical domain for the electrical processing of the header information. The header information precedes the burst by a set amount known as an offset time. Therefore giving enough time for the switch resources to be made available prior to the arrival of the burst. The one-way signaling paradigm obviously introduces a higher level of blocking in the network as connections are not usually guaranteed prior to burst release [3]. This Blocking is calculated as burst loss ratio (BLR) which is one of the most important parameters in OBS networks.

II. Routing

A. Routing Concept

Routing is the process of selecting paths in a network along which to send network traffic between source-destination networks. Routing is one of the most important network factors. Routing can be classified as [4]:

1. Optical routing.
2. Electrical routing.

While optical routing is required in all optical networks for higher bandwidth and utilization header processing in optical domain still needs more time to mature to deliver optical packet switching.

The most used routing technique in today's networks is header processing in electronic domain (electrical routing). But this downgrades the link speed to the electronic processing speed. OBS solves this problem as stated before.

Our concern about this routing is to select the best routing path that gives best utilization and minimum BLR through the OBS network. Routing protocols are used to solve this problem.

B. Routing Protocol

A *routing protocol* is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select routes between any source and destination on a network cloud. The choice of the route is done by using routing algorithms. Each router has knowledge only of networks attached to it directly. A routing protocol shares this information among neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network.

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C. Routing Metric & OSPF Default Metric

Routing protocols use routing algorithms that depend on a metric (cost) technique to determine the best route path. One of the most recognized, standard and used routing protocol is OSPF.

RFC 2178 describes OSPF path cost as its basic routing metric, the path cost is the aggregation of link costs (defined by the administrator) in the path between source-destination nodes, so the network designer could pick a metric which has a required effect on the design, that's the key used in this paper. In practice, link cost is determined by the speed (bandwidth) of the link, although that needs a scaling factor. Many of the routers manufactures uses link cost equals to the inverse of the bandwidth with a scaling factor. Cisco one of the biggest routers manufactures uses link cost equals to 10^8/bandwidth (scaling factor is 10^8 by default and can be adjusted). So, a 100Mbit/s link will have a cost of 1, a 10Mbit/s a cost of 10 and so on. But for links faster than 100Mbit/s, the cost would be <1 so we need to change the scaling factor as we are dealing with fiber links with big bandwidth, Thus in this study we will fix this scaling factor to be 10^15. In our detailed analysis one can see that OBS networks have other optical parameters that have a great effect on utilization and BLR so they must be taken into consideration when calculating the optimum routing path.

D. Optical Parameters Used in Routing Metric

Our mission is to get a new metric for OSPF routing protocol that takes into account the optical parameters. We will refer in the rest of this paper to the OSPF protocol with the new metric as OBS OSPF or OOSPF. We used a detailed simulation that studied the effect of some parameters which include:

1. Traffic load.
2. Link bandwidth.
3. Number of channels.

In the end we will try to get an optimized metric that depend on the BLR, taking into account the effect of these parameters on our routing decision. It will be seen later that this will lead to better routing, thus better utilization and minimum BLR

III. Simulation

A. Simulation Software

Network simulator 2 (NS-2) is used as a simulation software in this parametric study. It is one of the best tools in the network simulation market. NS-2 is an open source code with many references and documentation [5-7]. OBS version 0.9 which is an OBS module under the NS-2 is used. Many papers have used these network simulation tools. These papers are published in the most respected magazines and conferences [8-10]. Also all results were validated with the OBS module and also with some published paper working on the same module [11].

B. Simulation Topology

Different load generation is experimented on a single segment. Our simulation topology is composed of two core nodes (C0 and C1) and one segment in between. Input traffic is generated towards C0 and output traffic comes out of C1.

Traffic distribution follows Poisson distribution [12] with burst size equals to 120,000 byte. Traffic flows are launched between the source and destination across studied segment. No fiber delay line (FDL) is used. By using this topology we can simulate contention over a single core link between two core nodes.

IV. Numerical Results

In this simulation we study a set of traffic load values from 10 Gbps to 100 Gbps with different link bandwidth from 10 Gbps to 100 Gbps at different number of channels (1, 5 and 10). These data can be stored on a router chip with larger ranges of load, link bandwidth and number of channels (n). These selected ranges are just for demonstrating the idea.

Figure 2 shows a three dimension illustration of the effect of these parameters on BLR.

Also due to the complexity of reading points on the 3D figure a break down of three 2D figures are shown in figures 3,4 and 5 each for different number of channels.

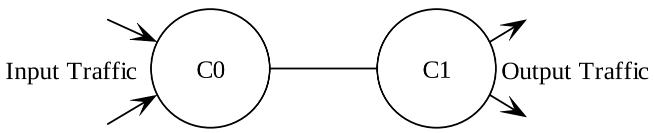

Fig. 1 OBS one segment simulated network topology

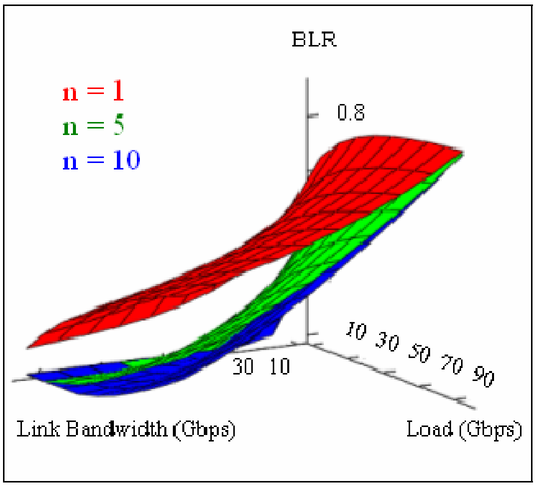

Fig. 2. Relation between link bandwidth, load and BLR at different number of channels, n.

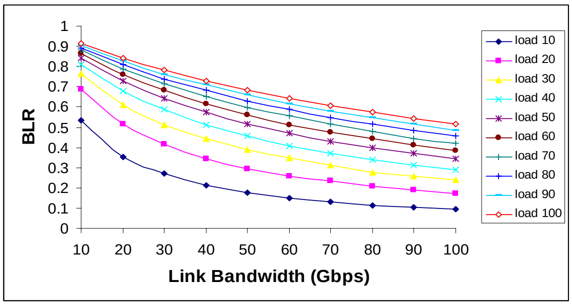

Fig. 3 Relation between link bandwidth and BLR at different loads and n=1

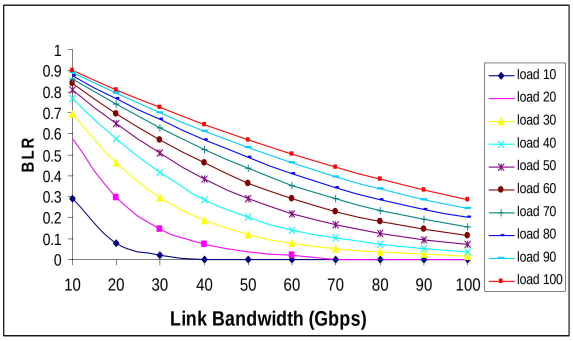

Fig. 4 Relation between link bandwidth and BLR at different loads and n=5

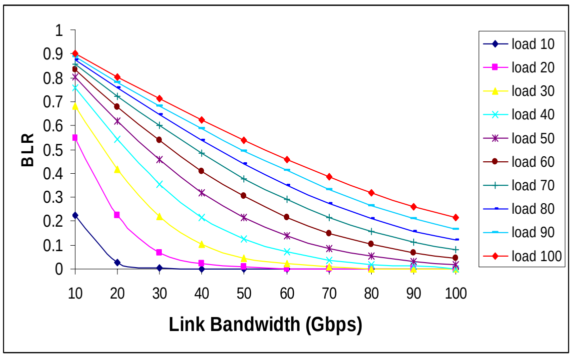

Fig. 5 Relation between link bandwidth and BLR at different loads and n=10

V. Routing Topologies

This section demonstrates the benefit of the new routing metric; some topologies will be shown as an example.

A comparison is shown between the default OSPF metric and the proposed OOSPF on these topologies and the increase in performance will be calculated.

Topology 1 can be shown in Fig. 6 showing two routers, router A and router B having three links in between. These links forms three paths x, y and z. The parameters of these links are as follows.

Link X: Bandwidth=20 Gbps, n=10
Link Y: Bandwidth=40 Gbps, n=5
Link Z: Bandwidth=60 Gbps, n=1

We will assume a load of 20 Gbps going from node A to node B.

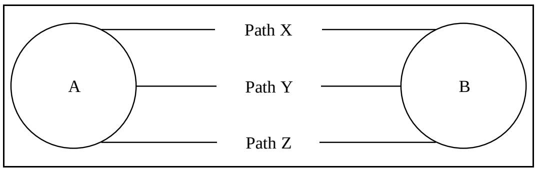

Fig. 6. two core nodes topology

A. Default OSPF Calculation

$$\text{Cost} = \sum_{s=1}^{M} \frac{C1}{BW_s} \quad (1)$$

Where BW is link bandwidth for i segment, and M are the number of link segments in the path, C1 is our scaling factor and we will assume it 10^15 in this paper

B. OSPF calculation for Selecting Best Path for Topology 1

For path X the cost (x) = C1/(20*10^9)=50000
For path Y the cost (y) = C1/(40*10^9)=25000
For path Z the cost (z) = C1/(60*10^9)=12500

OSPF always select the best path with the lowest metric and insert it in its forwarding table (routing table). In this example the best path will be through z, also if z is down then through y and then x.

C. OOSPF Calculation for Selecting Best Path.

In OOSPF calculation we will depend on the BLR as our selecting factor and we will use a scaling factor (C2) equals to 10^5. BLR values can be extracted from the figures 3, 4 and 5 based on link parameters and traffic load used on the link. In practical implementation these values will be stored in a chip on the router.

$$\text{Cost} = \sum_{i=1}^{M} C2 \times BLR_i \quad (2)$$

Where C2 is constant representing scaling factor, we will assume it 10^5 in this paper, BLR is the burst loss ratio for i segment, and M is the number of link segments in the path.

D. OOSPF Calculation for Selecting Best Path for Topology 1

Using previous figures and link parameters one can extract the BLR values for links x, y and z.

BLR (x) = 0.22258 , BLR (y) = 0.07231, BLR (z) = 0.25639
For path X the cost (x) = C2 * BLR (x) = 22258
For path Y the cost (y) = C2 * BLR (y) = 7231
For path Z the cost (z) = C2 * BLR (z) = 25639

The best path will be through y, also if y is down then through x and then z. One can see that this is totally different than before.

In this example it can be seen that by using the OOSPF metric the BLR is decreased by 18% (BLR is 25% through path z and 7% through path y).

Another example is shown in Fig. 7. Topology 2 is composed of four routers connected with four segments. The parameters of these link segments are as follows:

Link S1: Bandwidth=60 Gbps, n=1
Link S2: Bandwidth=90 Gbps, n=5
Link S3: Bandwidth=40 Gbps, n=10
Link S4: Bandwidth=50 Gbps, n=10

We will assume a load of 30 Gbps going from node A to node D.

E. OSPF Calculation for Selecting Best Path for Topology 2

By using equation 1 one can calculate the total cost as follows.

Total Cost (path x) = cost (s1) + cost (s2)

Cost (s1) = C1/(60*10^9)=12500
Cost (s2) = C1/(90*10^9)=11111

Total cost (path x) = 23611

By the same method we can calculate total cost for path y

Total Cost (path y) = cost (s3) + cost (s4)
Total cost (path y) = 25000 + 20000 = 45000

In this example the best path will be through x, also if x is down then through y.

F. OOSPF calculation for Selecting Best Path for Topology 1

Based on equation 2 and the proposed simulation results one can calculate the BLR for the four segments and use these results to select the routing path.

BLR (s1) = 0.34920 , BLR (s2) = 0.02454
BLR (s3) = 0.10467 , BLR (s4) = 0.04507

Path X the cost (x) = cost (s1) + cost (s2) = 37374
Path Y the cost (y) = cost (s3) + cost (s4) = 14974

It can be seen that path y is preferred when using the OOSPF.

BLR for path x and path y can be written as :

BLR (x) = BLR (s1) + BLR (s2) = 0.37374
BLR (y) = BLR (s3) + BLR (s4) = 0.14974

It can be seen that we gained a benefit of 22.4% decrease in the BLR when we used OOSPF.

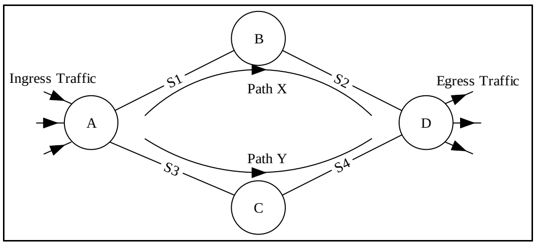

Fig.7. Four core nodes topology.

VI. CONCLUSION

Extensive simulations show that OSPF metric that depends only on bandwidth doesn't give the optimum path for OBS networks. This paper proposes a new OSPF metric taking into account optical parameters. This was shown through simulations to be promising routing metric. It was observed that the number of channels has huge effect on BLR as opposed to link bandwidth and traffic load. Results show better routing decisions lead to better BLR and link utilization for OBS networks.

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