Performance Analysis for Contention Resolution in Bulk Flow TCP Routing to optical IP Networks through Simulation

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Abstract. This paper describes some methods for contention resolution in bulk flow TCP routing in optical IP network through simulation. The various domains such as wavelength, time and space with respect to bulk flow TCP to resolve contention are studied. The results show that the flow based transmission under wavelength domain exhibits only the probability of contention is 27%. At the same time, the contention can be resolved to maximum of 97% when we increase the flow size. This also shows a significant improvement in performance that is the percentage to resolve contention on an average touches more than 80% when the system operates under lower wavelength region. The results also reveal that the probability of occurring contention is only 47% for a transmitter load of 0.7. But in the case of byte based transmission, the probability of occurring contention is 63% for the same transmitter load. We have also studied the packet loss rate, flow loss rate for fixed size and variable size flows. For a transmission of 200 packets, we achieved a flow loss rate of 0.038 for a variable size flow and a flow loss rate of 0.043 for a fixed size flow. But in the case of packet transmission mode, the packet loss rate is 0.063.

Keywords: Bulk flow TCP, Contention resolution, optical label switching (OLS), optical packet switching (OPS), optical performance monitoring, time-to-live (TTL), variable-sized packets, wavelength conversion.

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1 Introduction

The thrust towards the switching (or routing) functionally towards all optical networks has introduced a drastic change in the field of network design. The major and predominant area which is yet to be investigated and solved is contention. Normally the issue of contention arises while the data tries to leave switches from same output port with a common wavelength at the same time [15].

Fei Xue et al [2] proposed the contention resolution schemes viewing wave length, time and space. The performance was shown as improved at edge networks with reduced packet loss rate [PLR]. However this mechanism fails to produce same result at all nodes and also active contention resolution could not be achieved in this work. Jenny J He et al.[4] discussed about the enhancement of efficiency particularly if the traffic is dependent on long range case. This was mainly affected by the router performance and this work failed to suggest any novel technique to improve the performance of the router.Bong K. Ryu et al [10] introduced Four Fractal Point Process (FPPs) and concluded that these four models are categorized into two classes that is Renewal - based and Doubly Stochastic Poisson Process (DSPP) based on the construction and nature of these models. However the Hurst parameter 'H' alone is not enough to describe the burstiness and clustering in a self - similar process.

Fei Xue et al [13] tries to give solution for the work presented in [10] and they studied the self similar traffic characteristics by analyzing the packet assembly mechanism by using Hurst parameter and also introduce auto correlation function to analyze traffic [7]. This paper oncentrated on similar traffic but the different traffic conditions and traffic on end - to - end performance were not addressed. Fei Xue et al [14] suggested that the multi domain analysis could improve the performance and at the same time the delay time increases. We have also reported earlier that the bulk flow TCP reduces the latency and improves the performance [12]. In this paper, we are investigating the performance of the bulk flow TCP towards contention issues for the grid topology. We have considered all aspect of traffic conditions without sacrificing the latency and also improvement in the performance.

The contention occurs while more number of flows tries to leave from the same output port with same time and same wavelength. Here, the packets are encapsulated as a single entity, where in the first packet called as head packet to carry the information about the number of packets contained in that particular capsule, flow length and quality of service (QOS) etc., the packets followed by the head packet are pay load and the tail packet will indicate the end of flow which was reported earlier [12].

This paper has been organized as follows. Section 1 discusses the introduction and review of the literature in this area of research. Section 2 outlines the simulation criteria for contention resolution schemes in detail. Section 3 discusses the results and discussion of the paper. Conclusion and further scope of the work is presented in Section 4.

2 BULK FLOW TCP FOR WAVELENGTH CONVERTION AND CHANNEL ALLOCATION

The number of packets to be consolidated as bulk flow TCP for transmission from source to destination may vary from single packet to a maximum of seven. Here, the size of the packet may vary from 44, 516, 552 or 1500 bytes depending whether the information is user oriented or control oriented. In this work, we assume that the packet size is 1500. This flow [6]may choose any wavelength among the available 'n' number of wavelengths through its preferred output port and in such cases the flow may end up with contention since the preferred channel might not be available at that time. We can overcome this issue by converting the wavelengths it has so chosen and thus an alternate channel with another wavelength can be identified[3]. The bulk flow TCP occupying different channels and wavelengths was reported earlier [12]

3 NETWORK TOPOLOGY FOR SIMULATIONS

The topology under consideration is shown in Fig. 1. Here, the grid structure as shown below has 4x4 matrix comprises of sixteen nodes, where in each node behaves both as ingress node and egress node depending on the arrival or departure of flow. It is also shown that each node has got connection both horizontally and vertically in such a way that the shortest possible distance has been obtained for transmission of flows. Each flow in the node may be assumed to have "n" number of wavelengths and specified number of channels. Here, we have chosen that the number of wavelengths is two and the number of channel is three. The routing and deflection routing information can be shown in the matrix as described in Fig.2. The grid topology is so chosen such that this can better be utilized for IPv6 packet format, produces uniform traffic and the number of nodes can be increased based on the applications. As the consecutive nodes are connected in both directions the Round Trip Time (RTT) for each node will almost be similar[5].

The proposed Grid network topology for simulations assumes

- 1 Fixed number of ports in each node as reported in [12] near to the corresponding links for every router.
- 2 This network topology has two different wavelengths for wavelength division multiplexing (WDM).
- 3 Each node contains two local add ports and has a line speed of 2.5 Gb/s to ingress local traffic which is referred as i.

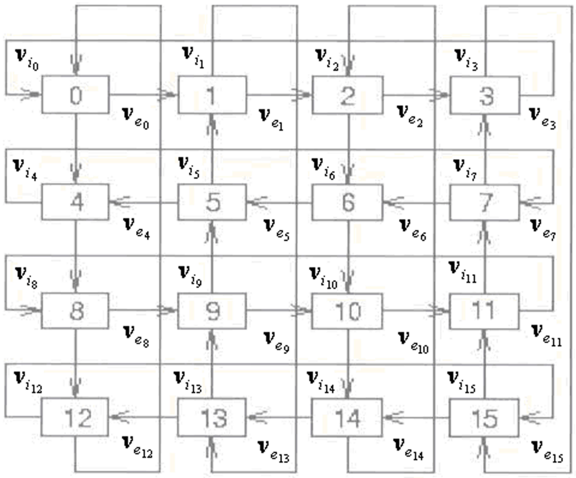

Figure 1: Grid Network topology

$$RT = \begin{bmatrix} a_{1,1} & a_{1,2} & \dots & a_{1,15} \\ a_{2,1} & a_{2,2} & \dots & a_{2,15} \\ \dots & \dots & \dots & \dots \\ a_{15,1} & a_{15,2} & \dots & a_{15,15} \end{bmatrix}$$

$$DRT = \begin{bmatrix} v_{1,1} & v_{1,2} & \dots & v_{1,15} \\ v_{2,1} & v_{2,2} & \dots & v_{2,15} \\ \dots & \dots & \dots & \dots \\ v_{15,1} & v_{15,2} & \dots & v_{15,15} \end{bmatrix}$$

Figure 2: Routing Table RT[i] [j] and Deflection routing Table DEF[i] [j].

- 4 There is no packet loss at local drop ports which means egress edge router referred as e has a sufficient number of drop ports to accommodate local packet.

For any specific local add port, there is one dedicated traffic source to generate IP packets following a realistic IP packet length distribution [11]. A uniform traffic matrix pattern which utilizes the IP traffic generated from a specific ingress node is equally dispersed into the other egress nodes. Fig. 2 shows the Routing Table (RT) and a Deflection Routing Table (DRT) used for contention resolution. The router will forward the flow to destination through any ports as per RT, has been represented as ai,j. If there is no free wavelength at port RT, the router will forward the contending flow to an available Fiber Delay Line (FDL). Each FDL operates on the WDM mode and can accommodate the incoming flow of packets. The number of FDLs is set to the router time distance (here, is the node degree of the optical router), and it's holding time is equal to the maximum optical flow length. If no FDL is available, the router will deflect the flow of packets to its secondary preferred output port DRT defined in Fig. 1. as . When the flow of packet goes through the FDL or the packet is transmitted from one node to another, it is counted as one hop.

The pseudo code for creation of flow and routing during congestion is illustrated in Fig.3. Here, the packet with the length (to constitute the flow) enters into the queue and is initialized to zero. The time is also initialized to zero with the help of a timer.

Increment the queue size according to the length of the packet and the process will continue to do till the fixed length 'n'. The creation of flow is by compared with the desired number of bytes. The value of flow size ranges from 44 to 1500 bytes. Based on these criteria the flow is created and if it attains the threshold value, then the tail packet is created and is padded to the flow. In the case of routing, flow will look for free channel and the wavelength.

If the free channel is available then the flow is converted into the freely available wavelength and the free channel is allocated for transmission. If there is no free wavelength or the channel then the flow is allowed to go through the FDL and the exponential time delay is allowed for the retransmission. Even after coming back from FDL if the flow could not find any channel of wavelength then the flow is ultimately discarded.

4 RESULTS AND DISCUSSION

The results and discussion of the contention resolution for the bulk flow TCP routing technique is presented in this section. Here, we have calculated the packet loss rate while resolving contention through wavelength, time and space.

4.1 Contention resolution through Byte, Packet and Bulk flow TCP

The simulated OPS networks accommodated the most natural form of IP packets generated from sources with a realistic IP packet length distribution [1].

```
When a TCP packet length 'n' arrives to assembly queue i ;
{
If(q(i) =o)
     {
     N=o;
     T(i) = o;  // start timer
    Get the incoming packet;
          q(i) = n+1;  // packets
 are added into queue
    }
else if (q(i) + b > FLOW max)
       {
Generates a flow with size
q(i);
    t(i) =o;   //start timer
        q(i)  = b;  //packets are added into queue
                    if (FLOW max)  - q(i) <
  44)
              {
              Generate of flow with size q(i);
               Clear timer t(i);
              }
      }
When t(i) reaches the threshold T(i)
  {
Generate the flow with size
q(I);
   q(i)  = o;
 }
Create and pad the head and tail packets for the generated flow
}
```

Figure 3: a Creation of Flow

```
For a flow qj(i) where j = o – FLOW max  ie. maximum flow length
{
if (free wave length ( ) and Channel (Ch) are available)
{
          j = o;
           =o
          Ch=o;
          Get the incoming flow;
Assign wavelength ( 1);
          Allocate channel;
          qj (i)   // forward through any part as per RT;
increment j;
}
else if(no space available in the present channel)
{
          Get the incoming flow;
          Convert the wavelength;
qj (i)   // forward through any part as per RT;
increment j;
}
elseif (no route is available)
qj (i)   // forward through any part as per DRT;
increment j;
}
else if(neither wavelength nor free channel are available)
          send to Fiber delay lines(FDL);
                    elseif
          {
                    Discard the flow;
                    }
 }
```

Figure 3: b Flow routing

Due to the bursty nature of the traffic process and the irregular packet length, the contention resolution schemes deployed at optical routers cannot sufficiently maintain a reasonable low PLR under a high traffic load [8]. In order to achieve a much more efficient result for contention resolution [9], the concept of bulk flow TCP is introduced [12]. This also handles the diverse traffic patterns [13] to exploit the available electronic memory buffers at ingress edge routers to achieve an uniform traffic function, which enables the ingress edge routers to assemble optical flow at the network edge from client IP Flow of the same Forward Equivalent Class (FEC) to assemble optical flow from client Internet protocol (IP) flows [2]. This is done by ingress edge routers with the help of available electronic memories.

An edge router first sorts the incoming client packets into their corresponding assembly queues based on their destinations and common attributes such as QoS requirement. The edge router assembles an optical packet when the buffer occupancy of an assembly queue reaches a maximum payload size in mega bytes which sets an upper bound on the length of optical packets. Meanwhile, the assembly mechanism adopts a time-out period to avoid excessive queuing delay, after which an optical packet is also generated even if the FLOWmax value is not reached. This work sets the time-out period T and is written as

$$T = 2 \times D \quad (1)$$

where, d is average payload filltime with traffic arrival rate for a particular destination. From the Fig. 4, it is seen that the probability of occurring contention is less for flow than that of Packet or byte. Here, for a time of 1second, the percentage of probability of occurring contention at any node, for flow based routing the probability of contention resolution is 42%. But in the case of packet and byte based routing are 45% and 55% respectively. This is due to the less time taken by the flow during the routing and forwarding mechanism. In the case packet or bytes based transmission; the time taken is more than the flow based routing.

It is seen that the probability to occur contention through byte are very high than compared to packets and flows. A flow can have almost 27% probability to end up with contention and the same time the byte may have 34% probability for contention in a given time. The contention probability (CP) has been computed as

$$\text{Contention probability} = \frac{\text{No of Occured Contentions}}{\text{No of transit packets in one specific router}} \quad (2)$$

The packet loss rate (PLR) has been calculated as the number of packets (nt) successfully transferred through

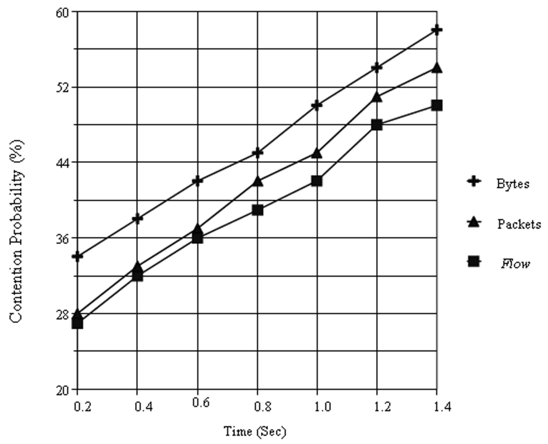

Figure 4: Contention probability through Bytes, Packets and Flow

the network to the number of packets discarded (nd) within the network and has been calculated using the relation

$$PLR = \frac{nt}{(nd + nt)} \quad (3)$$

Even though this multi-domain scheme resolves a large majority of contention, still there is packet loss in the network as per this simulated environment. Similarly the Flow Loss Rate (FLR) has been calculated for the bulk flow TCP is

$$FLR = \frac{Nt}{(Nd + Nt)} \quad (4)$$

where, N is the number of packet in a flow.

The packet loss rate or Flow loss rate can be calculated as per the equation (3) and (4) and the successfully transmitted data for both packets, fixed sized flow and Variable sized flow are referring to the node 1 in Fig.1. From Table.1, it is evident that the packet loss rate is higher than the fixed sized flow rate or variable sized flow rate.

Table 1.Data loss rate calculation for Packets (PLR), Fixed sized flow and Variable sized flow (FLR)

Sl. No	Successfully Transmitted Packets / Flows	Dropped Packets	Packet Loss Rate (%)	Dropped $Flows_{fixed}$	Flow Loss $Rate_{fixed}$ (%)	Dropped $Flows_{variable}$	Flow Loss $Rate_{variable}$ (%)
1	150	8	0.051	5	0.032	3	0.020
2	175	11	0.059	7	0.038	4	0.022
3	200	14	0.065	10	0.048	8	0.038
4	225	18	0.074	14	0.059	11	0.047
5	250	23	0.084	18	0.067	14	0.053
6	275	28	0.092	25	0.083	20	0.068
7	300	33	0.099	27	0.084	23	0.071
8	325	39	0.100	33	0.092	29	0.082

The FLR for variable sized flow is noticeably lesser (about 0.01%) than the fixed sized flow. This result is due to the fact that variable flow significantly increases the flow latency and jitter. The approximate average assembly delay of 100 micro sec is normally limited by the time out period. Moreover the unified contention resolution can be achieved by incorporating the flow based transmission method in the optical core routers.

4.2 Contention resolution through Bulk flow TCP for Wavelength domain

Fig. 5 illustrates the contribution of wavelength domain towards contention and it is proven that when the flow size increases then wavelength has to contribute nearly 97% for higher wavelengths to resolve contention. This is due to the fact that the higher wavelength has more capacity to hold data than the lower wavelength flows. Similarly when the flow length is minimum, then the wavelength contribution is less for lower wavelength networks at about 92%.

Previous literature [14] has shown that the magnitude of the average assembly delay is approximately 100s, primarily because the induced extra delay is explicitly limited by the time-out period. Furthermore, OPS network with a large number of wavelengths can achieve a considerably low FLR by incorporating the functions of edge routers with the optical core routers and also it is demonstrated that the effectiveness of the unified contention resolution scheme in reducing FLRs. The uniform traffic function exists for the simulated node and uses the network topology (Fig.1) to examine the impact of the uniform traffic on network performance

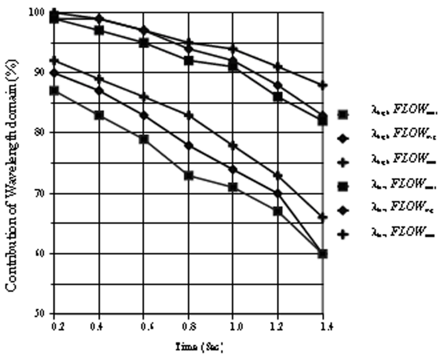

Figure 5: Contributions of the wavelength domain to contention resolution for different flow sizes

4.3 Contention Probability with respect to Bytes, Packets, Fixed sized Flow and Variable Sized Flow against transmitter load.

Contention probability is the ratio of number of occurred contention to the number of transmitter load (?) for bytes, packet, fixed sized flow and variable sized flow in one specific router. The contention probability measured at node 1 with reference to the Bytes, Packets, Fixed sized flow and Variable sized flow is depicted in Fig. 6. It is seen that for a transmitter load of 0.5, the probability to contention is 41% for byte based data transmission. The probability of occurring contention has been reduced to 37% when the data transmission is packet mode. However, for the same load Fixed sized flow exhibits 33% and 30% when the flow is variable one. The reduction in the contention resolution is due to less frequency and less number of flows contenting than the bytes or packets.

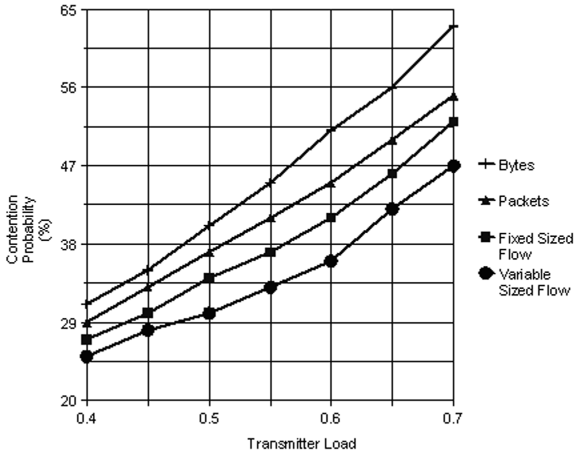

Figure 6: Contention Probabilities for different form of data transmission against transmitter load.

5 CONCLUSION

This paper presented a simulation of a flow based all-optical packet routing system supporting variable-sized packets with unified contention resolution in wavelength, time, and space domains in the core Optical Label Switched (OLS) router. The results evidently reveals that the probability for contention is very low that is only 27% when a flow form of packets are transmitted and it also reveals that the resolution for contention is to depend more on wavelength for maximum flow lengths of about 97%. The contention resolution yields about a maximum of 90% for the flow size of four under lower wavelength region. The simulation of unified contention reveals an effective all optical performance with multi-domain and especially in wavelength domain particularly both in core router and also in edge router.

This work can further be carried out for real-time performance monitoring based on the strong correlation between the BERs of the optical label and those of the data payload indicate its application in OTTL detection for loop mitigations. VLSI implementations of the flow based TCP routing may be carried out to study the performance of the probability of occurring contention resolution for the multi-domain.

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