Differentiated Services for Virtual Source Based Optical Burst Switched Multicast Traffic Routing

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Abstract. Virtual Source based multicast routing scheme for Optical Burst Switched Networks was dealt before. This scheme was based on consideration of specialized nodes called as Virtual Sources (VS). It aimed at exploiting the capabilities of VS nodes in order to reduce number of failed requests, thus reducing number of Burst retransmissions required. The architecture was proved good mathematically and well as through simulation experiments. The main drawback of the heuristic was the security threat on these specialized nodes. In this paper, multicast destinations were classified based on priority as Class S, Class A, Class B and Class C. While configuring the multicast tree, for all destinations belonging to the high priority class the VS must not be considered as these high priority nodes are comparatively much harder to secure.

Keywords: all-optical networks, multicasting, optical burst switching, wavelength division multiplexing.

1. Introduction

Internet users grow exponentially with increase in Real-Time and mission critical applications requiring huge bandwidth such as VoIP, telemedicine, remote learning, video conferencing, interactive simulations etc [1]. This phenomenal increase has motivated to replace the existing copper cables by optical fibers at the backbone. Also, an Optical fiber could support Terra Hertz bandwidth with extremely minimal losses as they are totally immune to electrical interferences and is almost impossible to tap. Data in an optical network is transmitted in the form of light waves. A light wave, which contains photons, has higher frequency than the electrons and hence shorter wavelengths thus allowing more bits of data to contain in an optic fiber than a copper cable.

To efficiently cater huge amount of data from unlikely applications with diverse characteristics there is a need for optical networks to perform wavelength and sub-wavelength switching [2]. Optical Burst Switching achieves the above said sub-wavelength switching by assembling data at the input ingress and routing all-optically towards output egress where the data is disassembled. An OBS

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2. Background

2.1 Burst contention and dropping

Burst Contention is a phenomenon in OBS when two or more incoming bursts contend to reserve a single wavelength at the same outgoing link and at the same time. When contentions occur between bursts, one of them successfully reserves the channel and the remaining drops. This is called as Burst Dropping. This occurs due to the absence of potential Optical buffers at the OBS Network as they traverse an all-optical path.

2.2 Contention resolution policies

Contention resolution can be achieved using policies like Wavelength Conversion, Fibre Delay Lines, Deflection Routing and Burst Segmentation. Assume, two Bursts contend for a single output wavelength and in such scenario, a wavelength converter can be used to route the contending burst from one wavelength to the other and thus contention is resolved. Here, the contention is resolved in spectral domain. In another similar contention scenario, the contending Burst can be delayed using resources like Fibre Delay Lines (FDLs), which has the ability to delay a Burst for a finite period of time i.e., a kilometre of fibre can delay a burst only 5 microseconds [3]. Here, the contention is resolved in time domain. The containing Burst may sometimes be deflected to some outgoing channel instead of intended one and this is called as Deflection Routing and this resolution take place in space domain. Burst segmentation may be employed in some architectures, where either the head of the contending burst or the tail of the contending burst is dropped known as head dropping and tail dropping schemes respectively.

These contention resolution policies suffer from demerits. Wavelength Conversion is immature and produces linear effects like noise; instead we may use Optical Tuneable Wavelength
Converter (OTWC) but is expensive [4]. FDLs are damn costly and Bursts of bigger lengths cannot be stored in FDLs [5]. For a tail dropping segmentation policy, the network suffers from Shadow Contention [6], i.e., the header contains the total burst length even if the tail is dropped. This causes the downstream nodes to be illiterate of Burst dimension due to truncation and make the sender resend the data thereby wasting network resources.

2.3 Service differentiation in OBS

In [9], differentiated scheduling scheme was designed to support OBS differentiated services. In [10,11] QoS with higher Offset time is assigned to high priority bursts when compared to the lower priority ones. This allows minimal or even no Burst dropping for the High Priority bursts when compared with to lower priority ones. But, this architecture would result in higher delays for higher priority bursts owing to higher Offset Periods. A priority based scheme was done in [12], where each node could not dynamically adjust loss probabilities for different classes.

2.4 Need of service differentiation to OBS destinations

All the works surveyed have considered only with priority on the data and not on the destinations. When multicasting communication paradigm is considered with a group of destinations then there is a vital need to prioritize the destinations. In practical perspective, the multicast source may be assumed as a file-hosting site such as rapid-share, files-tube etc., and the destination set may be assumed as customers/users with different subscription rates and thus must be served with different priorities when Data Burst is routed to them. This destination priority was not dealt before in OBS networks. So in order to describe an appropriate algorithm to model the above discussed issue a differentiated service to OBS multicast destination is considered with service classes of decreasing priorities. The remaining of this paper discusses these algorithms highlighting their merits and the simulation results of the proposal shows that the algorithm performs with better Burst throughput and minimized Burst delays.

3. Diff-Serv to Multicast Destination

Four service classes are considered in this proposal. These classes are Class $S$, Class $A$, Class $B$ and Class $C$. Separate multicast trees are generated for each service class. A collection of these trees is called as a multicast forest or simply forest, which is the objective of the proposal. The Differentiated Service algorithm is briefly given in Table 1.

For Class $S$ destination set, the multicast tree is configured by using all the Virtual source nodes that appear between the source destination-set pairs. Before defining a VS node, it is vital to know the classification of optical nodes (based on capability) present in the network. An optical node that is capable of forwarding or dropping an incoming optical data can be referred as a DoC (Drop or Continue) node. An optical node that is capable both forwarding and dropping an incoming optical data is a DaC (Drop and Continue) node. An optical node that can split an incoming optical data to more than one output can be referred as a light splitting node. The wavelength continuity constraint is an important property for optical communication and in situations the Burst passing through the cores gets dropped due to unavailability of same wavelength. Optical nodes called as Wavelength
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Table 1. Differentiated services to VS multicast destinations.

| Input: | Multicast Request = s, D, qF  
| Where, S→ Multicast Destination  
| D→ Multicast Destination  
| Destination Set = {Class S = (s₁, s₂, sₙ),  
| Class A = (a₁, a₂, aₙ),  
| Class B = (b₁, b₂, bₙ),  
| Class C = (c₁, c₂, cₙ)}  
| Output: | Differentiated Service to Multicast destination set.  
| BEGIN DiffServ  
| While (D = S)V(D = C) do  
| If (D = S) then  
| Select nodes for lightpath ∈ S  
| //All Class S destinations are secured as a part of their service//  
| END If  
| CALL MulticastVS ();  
| If VS Compromised then  
| Retransmit  
| END If  
| END While  
| END If  
| END While  
| While (D = A) do  
| CALL By—Pass heuristic ();  
| END While  
| END While  
| While (D = B) do  
| Generate (T)  
| Re-route to Any  
| If HCF > ‘THRESHOLD’ then  
| Re-route to S  
| END If  
| END If  
| END While  
| END Diff-Serv |

Conversion (WC) nodes can convert an incoming wavelength to a required wavelength. VS nodes are specialized nodes that are capable of both light splitting and wavelength conversion. A VS based heuristic was proposed in OBS (Table 2), which efficiently did result in overall delay reduction with good throughput mathematically [13] and through simulation results [14]. A demerit of the above work is the assumption for security on VS nodes. But, practically VS nodes are much hard to secure and the data transferred through it is affected by noise resulting in higher Bit Error Rates. In this proposal, Class S destinations are assumed to have subscribed for Premium services and thus are highly secured. Now these Class S destinations are connected to the multicast source either using a direct connection or by using one of these nodes that posses VS capability. This forms a light tree for Class S. This service is foolproof and can provide uninterrupted service to all Class S destinations effectively. For Class A destinations, a by-pass heuristic is considered as given in Table 3. For a source s and Class A destination set, all the intermediate hops are selected and are classified as either Multicast Capable (MC) nodes or Multicast Incapable (MI) nodes.
Table 2. Virtual source multicast heuristic.

<table>
<thead>
<tr>
<th><strong>Assume:</strong></th>
<th>obsVS → Virtual Source Nodes obsS → Splitting Nodes Q-factor threshold ($q_t = 6.5$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input:</strong></td>
<td>Multicast transmission with source nodes and destination set $D$ Where $D = {d_1, d_2, \ldots, d_n}$</td>
</tr>
<tr>
<td><strong>Output:</strong></td>
<td>Multicast Tree $T(s, D, qF)$</td>
</tr>
</tbody>
</table>

BEGIN MulticastVS($s, Ds, qF$)

Divide members ($N$) = \{obsMC, obsMI\}

obsVS $\in$ obsMC

For each ($s, D$) do

FIND obsVS $\in$ ROUTE ($s, D$)

obsVS = p-obsVS $\land$ s-obsVS

Connect $d_i \in D$ to p-obsVS

Generate ($T$)

CALCULATE $T(qF)$

If $qF < q_t$ then

Connect $d_i \in D$ to s-obsVS

Generate ($T$)

UPDATE $T(qF)$

End If

If $qF < q_t$ then

FIND obsS $\in$ ROUTE ($s, D$)

If $\lambda = \text{AVAILABLE}$ then

Connect $d_i \in D$ to obsS

Generate ($T$)

CALCULATE $T(qF)$

Else If $\lambda = \text{NOT AVAILABLE}$ then

SEGMENT BURSTS $\in d_i$

DEFLECT contending segment

End If

End If

End If

End For

END MulticastVS

The VS and light splitters are classified under MC nodes. Since, VS nodes are susceptible to security threat, the splitting nodes are considered for tree generation ($T$) to all Class A destinations. Now, the wavelength continuity constraint is considered and if an outgoing wavelength is not present then a segmentation policy is followed. To avoid shadow contention, a tail dropping scheme is used. A $q$-factor ($qF$) is calculated for every hop to determine the quality of the data and the resultant value is compared with a threshold value $q_{th}$ ($q_{th} = 6.5$). The value of $q_{th}$ was given in [15] and the
Table 3. By-pass heuristic.

<table>
<thead>
<tr>
<th>Input:</th>
<th>Multicast transmission with source nodes and destination set D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Where ( D = {d_1, d_2, \ldots, d_n} )</td>
</tr>
<tr>
<td>Output:</td>
<td>Multicast Tree ( T(s, D, qF) )</td>
</tr>
</tbody>
</table>

BEGIN Bypass \((s, D_s, qF)\) \(s, D_s, qF\) \(s, D_s, qF\)

Divide members \( N = \{\text{obsMC, obsMI}\} \)

For each \((s, D)\) do

FIND \( \text{obsS} \in \text{ROUTE}(s, D) \)

If \( \lambda = \text{AVAILABLE} \) then

Connect \( d_i \in D \) to \( \text{obsS} \)

Generate \((T)\)

CALCULATE \( T(qF) \)

Else If \( \lambda = \text{NOT AVAILABLE} \) then

SEGMENT BURSTS \( d_i \)

DEFLECT contending segment

End If

If \( qF < q_t \) then

[NOISE BLOCKING]

End If

End For

END Bypass

The relationship between BER and the \( q \)-th is given as

\[
\text{Bit Error Rate (BER)} = \text{erfc}\left(\frac{q}{2}\right) \quad [16].
\]

If the \( qF \) value is smaller than 6.5 then the request is blocked due to QoS constraints \([15]\) termed as Noise blocking.

For Class \( C \) destination set, the multicast tree is generated for source destination pairs. If Burst contention occurs, then Reroute to Any heuristic is applied. The data is directed to another link-disjoint path to the destination supporting the wavelength continuity constraint. But here the Burst may be deflected multiple times wasting network bandwidth. Thus a Hop Count Factor (HCF) is maintained and if this exceeds the network diameter value then Reroute to source heuristic is applied. For Class \( D \) destinations, the tree is configured considering the VS nodes as given in [14]. If the data does not reach the destination, which is primarily due to lack of security in VS, then a NACK is sent to TCP source for a retransmission.

4. Simulation Results

This section discusses the experimental results and analysis. The work is simulated in ns2 using nOBS patch, which is further modified to support multicast capability in OBS Networks. Simulation parameters are given in Figure 2. Simulations are carried out on a 14 optical node NSFNET topology with 17 optical links. Source and the destination set are selected randomly and they follow uniform distribution. Figure 3 and 4 shows the simulation results obtained from experiments done in ns2 using a modified nOBS for the proposed work. The Burst Loss Probability (BLP) is the probability of the Burst Losses at the intermediate nodes due to contention or insufficient QoS. Burst losses due to contention are termed as Contention blocking. Burst losses due to insufficient QoS are termed as
QoS blocking. BLP is the ratio between the Burst losses at the cores to the total Burst generated at the edges. Burst Throughput can be defined as the amount of transmitted Data Bursts in a given time interval. It denotes the variability of bandwidth usage over a given time.
5. Conclusion and Future Work

Optical Burst Switching has the potential to effectively utilize the vast bandwidth provided by the WDM Networks. Delivering Differentiated services to multicast destination was simulated successfully using ns2 with modified OBS patch by classifying the destinations based on priority. Several experiments were conducted and the results prove that differentiated services are achieved with higher throughput and minimum delay for destinations belonging to higher classes in comparison to lower class destinations.

The future work is primarily directed towards the nature of multicast tree generation in this algorithm and this nature may be static or dynamic. Also a quantification of number of destinations belonging to each service class is left for the future as an open issue.

References