Impairment-Aware Manycast Algorithms Over Optical Burst-Switched Networks

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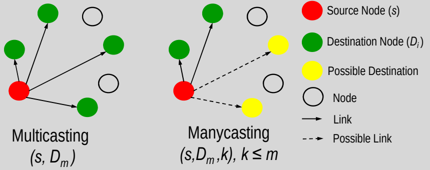
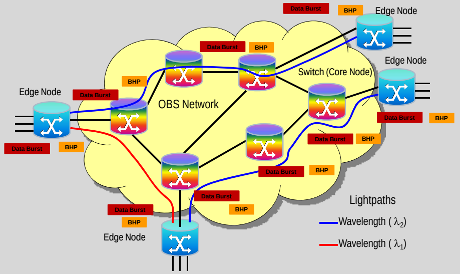
Introduction

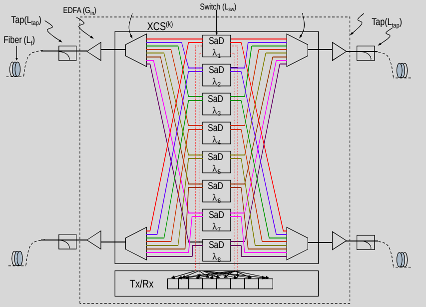
- ❑ Optical burst switched (OBS) network is a promising candidate to support high bandwidth Internet applications.
- ❑ Many distributed applications require high-bandwidth,
  - ✓ Grid Computing,
  - ✓ Content Distribution Networks (CDN), and
  - ✓ Storage Area Networks (SAN).
- ❑ These applications require multiple destinations to be co-ordinated with a single source.



- ❑ Given a network $G(V,E)$, with V nodes and E edges, edge cost function is given by $g: E \to R^+$, an integer k, a source s and candidate destination set D_m where $|D_m| = m$.
- ❑ Data Loss:
  - ✓ *Contention*: Occurs when burst contended for the same wavelength.
  - ✓ *Signal quality:* Occurs due to the lossy fiber medium (optical impairments).
- ❑ We develop policies that implement manycasting considering both *burst contention and optical impairments*.

Problem Statement





MC-OXC based on Splitter-and-Delivery (SaD) Architecture

Calculation of BER on per hop basics

- $L_{sp}(n) = 1/k(n)$ is a loss due to splitter.
- $L_{att}(n) = e^{-\alpha l}$, where α is the fiber attenuation in $(km)^{-1}$, 'l' is the length of the fiber in *km*.
- L_d, L_m, and L_t are defined as de-multiplexer, multiplexer and tap losses, respectively.
- L_{ins} is insertion loss of the SaD switch.
- G_{in} and G_{out}, are gains of the input and the output EDFA, respectively.
- $\overline{G}$ is the saturated gain of the in-line EDFA. This gain is set to compensate the fiber loss between consecutive amplifiers given by $\overline{G} = e^{\alpha l}$.
- $P(n)$, $P_{ase}(n)$ are the signal and amplified spontaneous emission (ASE) noise, power output at the nth node, respectively.

$$P(n) = P(n-1)G_{in}G_{out}L_dL_mL_t^2L_{ins}L_{att}(n)L_{sp}(n-1) \quad \text{.........(1)}$$

$$P_{ase}(n) = P_{ase}(n-1)G_{in}G_{out}L_dL_mL_t^2L_{ins}L_{att}(n)L_{sp}(n-1) + P_nL_dL_mL_tL_{ins}L_{att}(n)[G_{in}-1] + P_nL_t[G_{in}-1] + P_n[\overline{G}-1]a_n \quad \text{......(2)}$$

where a_n is the number of amplifiers placed between nodes n and $n-1$.

$$OSNR(n) = \frac{P(n)}{P_{ase}(n)} \quad \text{.........(3)}$$

where $OSNR(n)$ is the optical signal-to-noise ratio.

- Relationship between OSNR and q-factor (also called Quality factor) is given by

$$q(n) = \frac{2\sqrt{\frac{B_O}{B_e}}OSNR(n)}{1 + \sqrt{1 + 4 \times OSNR(n)}} \quad \text{..........(4)}$$

where B_O, B_e are optical and electrical bandwidths.

- q-factor is related to BER by the following equation,

$$BER(n) = 2erfc\left(\frac{q(n)}{\sqrt{2}}\right) \quad \text{..........(5)}$$

Parameters used for computation of q-factor

Parameter	**Value**
Channel bit rate *(B)*	10 Gb/s
Optical Bandwidth (B_O)	70 GHz
Electrical Bandwidth (B_e)	0.7 × B
Input power of the signal	1 mW (0 dBm)
Loss of Multiplexer/De-multiplexer	4 dB
Switch element insertion loss	1 dB
Waveguide fiber coupling loss	1 dB
Tap loss	1 dB
Fiber Attenuation Coefficient	0.3 dB/km
Gain of EDFA in MC-OXC (G_{in}, G_{out})	22 dB, 16 dB
ASE factor (n_{sp})	1.5
Planks Constant h	6.63×10^{-34} J-s
Carrier frequency f_c	193.55 THz
P_n in Eq. (4)	$2n_{sp}hf_cB_O$
Spacing between the amplifiers *(l)*	70 kms
q_{th} (q-factor threshold)	6.5
Number of fibers/link *(N)*	2 (bi-directional)

Impairment-Aware Manycasting Algorithms

- ❑ We consider three different algorithms to reduce the burst loss due contention and signal quality.
  1. Impairment-Aware Shortest Path Tree (IA-SPT),
  2. Impairment-Aware Static Over Provisioning (IA-SOP),
  3. Impairment-Aware Dynamic Membership (IA-DM).
- ❑ In all the algorithms considered, we have
  1. *Input:* The manycast request (u, D_u, k_u) arrives at the source node with a candidate destination set D_u, along with k_u intended destinations. The power inputs for this manycast request are $(P(u), P_{ase}(u))$. Hence we have $(u, D_u, k_u, P(u), P_{ase}(u))$.
  1. *Output:* Manycast request to the next-hop node after satisfying the BER constraint.
  3. *Initialization:* At the source node, the manycast request is of the form $(s, D_s, k_s, P(s), P_{ase}(s))$. For every new burst entering the network, this manycast request is tagged to it. All other sets are initialized to null.

Impairment Aware Shortest Path Tree (IA-SPT) Algorithm

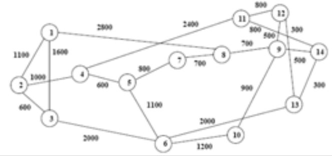
```
if $u \in D'_u$
  ▷ Update $D_u$ and $k_u$
  $D'_u \leftarrow D'_u \setminus \{d'_j\}$
  $k_u \leftarrow k_u - 1$
  ▷ Destination set $D'_u$ is the non-decreasing order of
   the hop distance
else
  for $j \leftarrow 1$ to $k_u$
    $n_j \leftarrow SPT[u, d'_j]$
     ▷ Next hope node or child node is obtained from
     shortest path tree
    $N = N \cup \{n_j\}$
  end
  for $i \leftarrow 1$ to $|N|$
   if $(\langle u, n_i \rangle = FREE)$
    $P(n_i) \leftarrow POW\_SIGNAL(P(u), |N|)$
    $P_{ase}(n_i) \leftarrow ASE\_SIGNAL(P_{ase}(u))$
    $q(n_i) \leftarrow Q\_FACTOR(P(v_i), P_{ase}(v_i))$
    if $(q(n_i) > q_{th})$
     $D_{n_i} \leftarrow D_{n_i} \cup \{S_D(n_i)\}$
     ▷ $S_D(n_i)$ is the set of all destinations ($\subseteq \{d'_1, \ldots, d'_{k_u}\}$) that
     can be reached through child node $n_i$. $|S_D(n_i)| \le k_u$
     Output: Manycast request to the next hop node will be
     $(n_i, D_{n_j}, |S_D(n_i)|, P(n_i), P_{ase}(n_i))$
     $\mathbb{D} \leftarrow \mathbb{D} \cup S_D(n_i)$
    else
    end
   else
   end
  end
```

Note: In case of IA-SOP, burst is sent to extra k' destinations. Thus in IA-SPT k is replaced *with* $k+k'$ $(\le m)$.

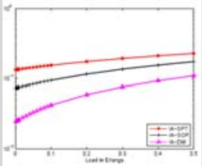
Impairment Aware Dynamic Membership (IA-DM) Algorithm

```
if $u \in D'_u$
▷ Update $D_u$ and $k_u$
  $D'_u \leftarrow D'_u \setminus \{d'_j\}$
  $k_u \leftarrow k_u - 1$
  ▷ Destination set $D'_u$ is the non-decreasing
   order of the hop distance
else
  for $j \leftarrow 1$ to $|D'_u|$
        $n_j \leftarrow UNI\_CAST[u, d'_j]$
        if $(\langle u, n_j \rangle = FREE)$
            $\mathbb{V} \leftarrow \mathbb{V} \cup \{n_j\}$
            for $i \leftarrow 1$ to $|\mathbb{V}|$
                $P(v_i) \leftarrow POW\_SIGNAL(P(u), |\mathbb{V}|)$
                $P_{ase}(v_i) \leftarrow ASE\_SIGNAL(P_{ase}(u))$
                $q(v_i) \leftarrow Q\_FACTOR(P(u), P_{ase}(u))$
                  if $(q(v_i) > q_{th})$
                     $D_{v_i} \leftarrow D_{v_i} \cup \{d(v_i)\}$
                     ▷ $d(v_i)$ is the destination to be
                     reached through child node $v_i$
                  else
                     $D_{v_j} \leftarrow D_{v_j} \setminus \{d(v_i)\}$
                     $\mathbb{Q}_L \leftarrow \mathbb{Q}_L \cup \{d(v_i)\}$
                  end
            end
            while $\sum_{k=1}^{j} k_{n_k} < k_u$
            do $k_{n_j} \leftarrow k_{n_j} + 1$
        else
        $\mathbb{C}_L \leftarrow \mathbb{C}_L \cup \{d_j\}$
        end
  end
end
```

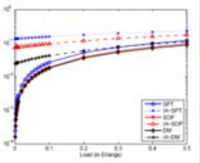
Numerical Results



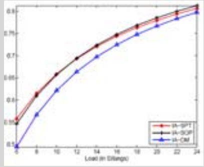
National Science Foundation network, with 14 nodes and 21 bi-directional links. The numbers on the links indicate the distance between the nodes in kilometers. These links consists of in-line EDFAs (not shown in the figure for clarity)



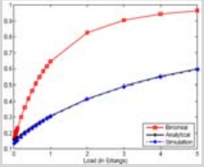
Comparison of algorithms with impairment awareness



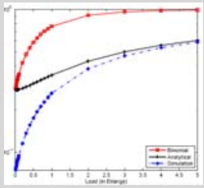
Comparison of algorithms with and without impairment awareness



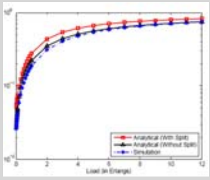
The blocking performance comparison between IA-SPT, IA-SOP and IA-DM for manycast configuration 7/4 under High load



Comparison of Binomial, Analytical and Simulation results for overall blocking probability for IA-SPT under low load



Comparison of Binomial, Analytical and Simulation results for overall blocking probability for IA-SOP under low load



Comparison of Binomial, Analytical and Simulation results for overall blocking probability for IA-DM under low load

Conclusion

- ✓ We discuss issues of impairment-aware manycasting service over OBS networks.
- ✓ Supporting manycasting over OBS improves the network performance.
- ✓ We indicate that BER based signaling using BHP has significant impact in calculating data loss in OBS networks.
- ✓ We propose three impairment-aware algorithms IA-SPT, IA-SOP and IA-DM.
- ✓ Through extensive simulation and numerical analysis, we show that IA-DM has better performance for supporting manycasting over OBS.

Acknowledgements

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