Light-hierarchy: an efficient structure for multicast routing in WDM mesh networks

Fen Zhou, Miklós Molnár, Bernard Cousin (IRISA)

Contribution

A novel multicast routing structure, i.e. **light-hierarchy**, is introduced instead of the traditional light-tree for Wavelength Division Multiplexing (WDM) networks with sparse light splitting. The light-hierarchy accepts cycles by benefiting from the **Cross Pair Switching** phenomenon explained at right.

Model

In WDM mesh neworks, we consider a multicast session $ms(s, D)$, which requests for setting up a set of multicast distribution light-structures (e.g., light-trees) from the source s to a group of destinations D simultaneously under (i) Wavelength Continuity Constraint, (ii) Distinct Wavelength Constraint, (iii) Sparse light splitting Constraint.

Assume k light-structures $LS_i(s, D_i)$ are built for $ms(s, D)$, where $i \in [1, k]$, and $1 \leq k \leq |D|$. Regarding the optimization of network resources,

- **Total Cost** should be minimized which is calculated by the sum of cost in all the light-structures built for $ms(s, D)$.

$$\min\left\{c\big(ms(s,D)\big) = \sum_{i=1}^{k}\sum_{e\in LS_i(s,D_i)} c(e)\right\}$$

- **Link Stress** should also be minimized which equals to the number of built light-structures, i.e., $\min\{k\}$

Sparse Light Splitting Constrain

In a WDM network, the ratio of the multicast capable nodes (**MC**) is generally below 50% while the rest are MI nodes. The following figure illustrates the function difference between the MI and the MC nodes.

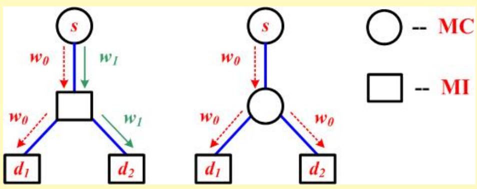

Fig. 1 The function difference between MI and MC nodes

Cross Pair Switching

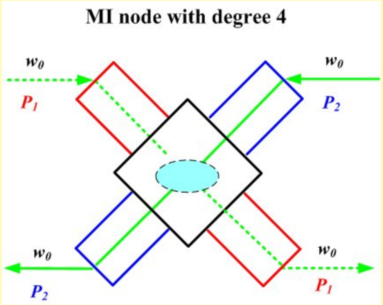

Fig. 2 Cross Pair Switching Phenomenon

Based on the assumption that multicast incapable (MI) nodes could not be traversed twice on the same wavelength, the light-tree structure was always thought to be optimal. In fact, as shown in Fig. 2, an MI node with a degree at least of 4 could be crosswise visited more than once to switch the light-signal towards two destinations in the same multicast session on the same wavelength by employing different input and output pairs. This is called **Cross Pair Switching**.

Light-hierarchy vs Light-tree

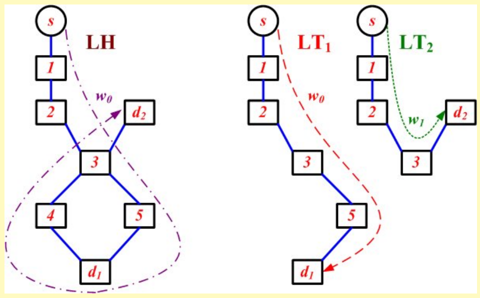

Fig. 3 An example (a) Light-hierarchy (b) Light-trees

Consider the network topology in Fig. 3 (a) (solid line), a multicast session $ms(s,(d_1,d_2))$ arrives. The optimal light-trees solution (i.e., a set of light-trees) is shown in Fig. 3(b): $LT_1 = \{s-1-2-3-5(or4)-d_1\}$ and $LT_2 = \{s-1-2-3-d_2\}$. The total cost of the optimal light-trees is 9. However, by noticing node 3 with 4 ports, a light-hierarchy (dash-dot line in Fig. 3(a)) could be found out: $LH = \{s-1-2-3-5-d_1-4-3-d_2\}$. As we can see, one light-hierarchy is enough to include the two destinations. The total cost of this hierarchy is just 8 and the link stress is 1. The light-hierarchy structure outperforms the light-tree structure.

Results

The backbone USA Longhaul Network (28 nodes, 7 nodes 4-degree and 1 node 5-degree) is employed as the simulation platform to evaluate the multicast routing performances of the light-hierarchy and the light-tree.

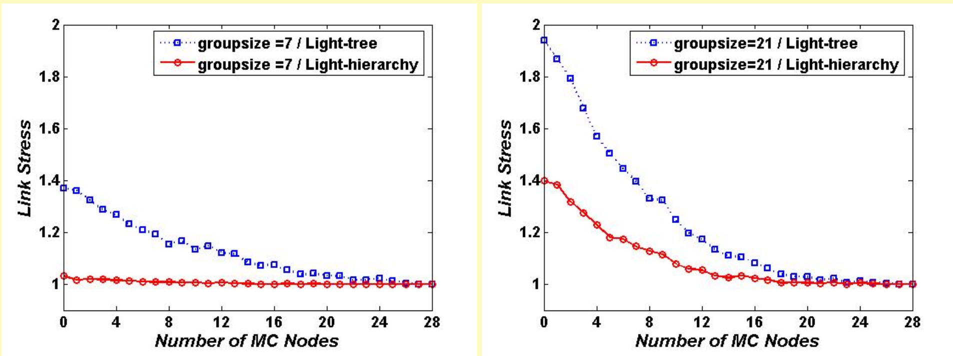

Fig. 4 Comparison of Link Stress against the number of MC nodes when the multicast (a) groupsize = 7, (b) groupsize = 21

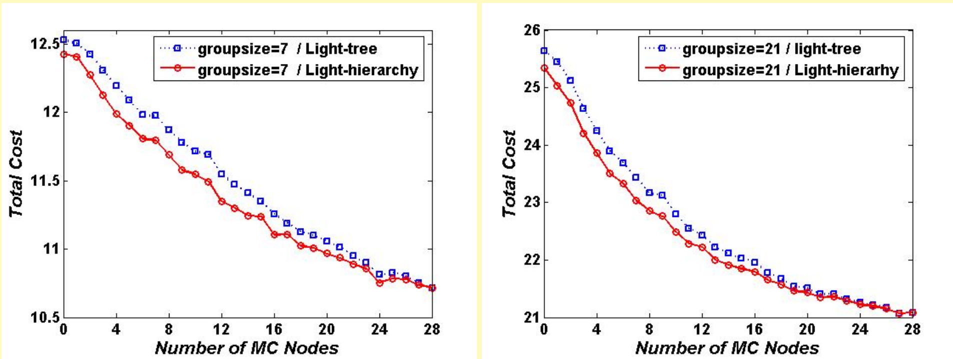

Fig. 5 Comparison of Total Cost against the number of MC nodes when the multicast (a) groupsize = 7, (b) groupsize = 21

As plotted in Fig. 4, the link stress is improved more and more by the light-hierarchy solution compared to the light-tree solution as the multicast group size grows (reduced up to 0.36 and 0.42 respectively for the group size of 7 and 21). Besides, the advantage of light-hierarchy is even more evident in the sparse light splitting case. As far as the total cost indicated in Fig.5, light-hierarchy achieves smaller value than the light-tree. Hence, the light-hierarchy structure is a better solution for multicast routing in sparse light splitting WDM networks.

References

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