

DYNAMIC MULTICAST TRAFFIC GROOMING IN WDM NETWORKS

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Outlines

- Traffic Characteristics
- Emerging Multicast Applications
- Node Architecture
- Assumptions
- Resources and Network Topologies
- Provisioning Approaches
- Grooming Strategy
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Traffic Characteristics

- With the use of IP over WDM, MPLS over WDM, or with NGS, traffic sessions now tend to exhibit a dynamic nature
- Sessions arrive according to a certain arrival process, and they are characterized by holding times, which are taken from a certain distribution.
- Practically impossible to design optical networks such that they accommodate all such dynamic sessions
- Devising call acceptance, and session provisioning strategies that will try to reduce the session blocking probabilities.

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Emerging Multicast Applications

- Several new and emerging applications using high-performance networks are of the multicast traffic type
- Document distribution, on-demand video distribution, network news distribution, file distribution and caching
- Require transmission rates which are much less than those provided by lightpaths.
- Traffic grooming techniques can be applied.
- Unicast traffic grooming techniques may not be directly applicable to the treatment of multicast traffic.

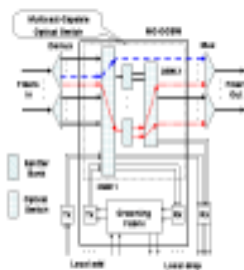
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Node Architecture

- OSW-1 provides all-optical bypass
- The LP/LT is dropped to the GF where traffic can be multiplexed.
- Upon grooming, the traffic is switched either to an output link (unicast), or to a splitter to duplicate the message and forward it to the OSW-2 to route the signals to their different output links.
- This will allow traffic to be forwarded from one LP/LT to another LP/LT to reach its ultimate destination(s)



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Assumptions

- Multicasting is always supported on a light-tree.
- In multi-hop grooming a node may groom unicast and multicast traffic demands on the same output channel
- Some destinations on the multicast tree may end-up receiving unintended unicast data, leading to a waste of network resources.
- Multi-hop grooming is constrained such that unicast traffic may not be groomed onto multicast traffic

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Resources & Network Topologies

- Physical topology and its associated available resources
- Logical topology and its associated available resources
- Combined physical and logical topologies (hybrid topology) and its associated available resources.

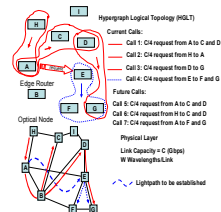
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Single-Hop Provisioning

- Existing light-tree
- Single-hop logical route.
- Same source and multicast destinations



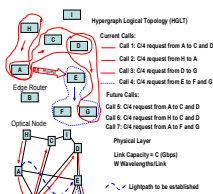
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Multi-Hop Provisioning

- More than one light-tree
- 2 hops are allowed
- Combination of existing light-tree (TDLT) and a light-path (FSLP).



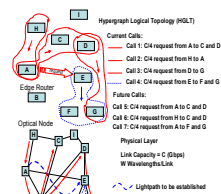
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Hybrid Provisioning

- Combination of existing TDLT and a newly created FSLP
- Physical routing is needed (FSLP)
- Optical layer must keep updated databases about the connectivity of both the logical and physical topologies as well as the resource utilization across both layers.



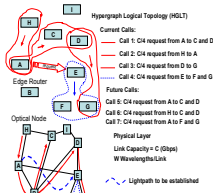
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Non-Restricted Multi-Hop Provisioning

- Allows light-trees to carry traffic destined to only a subset of the destinations of the light-tree
- This includes an empty subset, which corresponds to the case in which the light-tree is used as a first hop
- Unicast traffic may be groomed onto multicast traffic



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What is the problem?

- How to combine the multiple provisioning approaches to serve traffic demands as efficiently as possible?
- How the global network resources should be allocated to a given request if multiple routing schemes are available?
- Should a new request be accommodated using one or more existing lightpaths/light-trees first?
- Is it more appropriate to set up a new lightpath/light-tree first?
- Should the traffic session be accommodated using a combination of both in a sequential order similar to conventional sequential provisioning approaches used for unicast traffic grooming?

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- Existing sequential unicast grooming strategies and algorithms along with associated simulation results can't be taken as guidelines when considering multicast traffic.
- Conventional sequential routing/provisioning approaches used for unicast traffic grooming should be revisited (after being modified to tailor provisioning of multicast traffic) and thoroughly examined, to test its effectiveness for grooming multicast traffic as well.

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Grooming Strategy

- We devise a constraint-based grooming strategy that enable us to select the most appropriate blend of these multiple routing/provisioning schemes.
- In order to support dynamic traffic, once a multicast session is to be accommodated, one of four traffic grooming approaches may be used.

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Heuristics

- Sequential multicast grooming heuristics
- Interchanging the search space between the physical and logical layers.
- Augment the sequential grooming heuristics by a hybrid approach

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Logical-First Sequential Routing

- The network first tries to accommodate the traffic session on the logical topology making use of the already existing connections.
- if it fails, a new light-tree destined to all the multicast destinations is set-up on the physical topology.
- Logical-First Sequential Routing with Single-Hop grooming (LFSEQSH)
- Logical-First Sequential Routing with Multi-Hop grooming (LFSEQMH)

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Physical-First Sequential Routing

- Attempts to accommodate a session on the physical layer first.
- If the new light-tree is established successfully, a new logical/virtual route (light-tree) is created in the logical layer.
- If the physical routing fails. Routing on the logical topology
- Physical-First Sequential routing with Single-Hop grooming (PFSEQSH)
- Physical-First Sequential routing with Multi-Hop grooming (PFSEQMH)

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Hybrid Routing (LFHYB)

- Hybrid provisioning approach is combined with sequential provisioning approach
- Logical-First Sequential Routing is invoked to find an existing light-path to provision FSLP to deliver the traffic from the source of the session to the root of a TDLT that reaches the destinations.
- If this fails, a new light-path is created and used to reach the source of the TDLT.

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Non-Restricted Logical-First Sequential Routing

- Similar to Logical-First Sequential Routing
- A non-restricted multi-hop provisioning approach is used when Logical-First Sequential Routing fails.

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Performance Evaluation

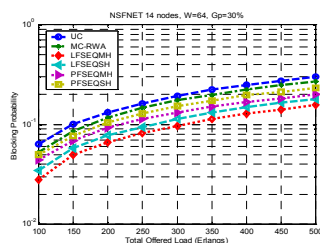
- A custom-built C++ simulator was used to evaluate the performance of the proposed multicast grooming routing algorithms on several network topologies that demonstrated similar conclusions.
- We present the results obtained using the "NSFNet", a network that consists of 14 nodes and 21 bi-directional physical links.
- Each physical link is assumed to carry 64 wavelengths.
- The multicast traffic is assumed to constitute 50% of the traffic.
- G_p represents the maximum percentage of the network nodes that could be destinations, we show the results when $G_p=30\%$.
- The sub-wavelength requests are 25% of the wavelength capacity.
- The blocking probability, and the performance gain are the evaluated metrics used to evaluate the network performance

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Blocking Probability of different used schemes



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Grooming Gain

$$G_{LFSEQMH} = \frac{BP_{MC-RWA} - BP_{LFSEQMH}}{BP_{MC-RWA}} \times 100$$

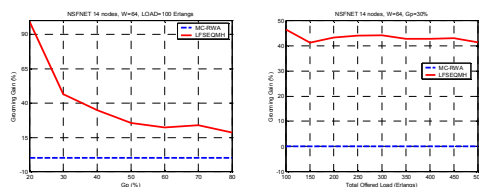
- "LFSEQMH" results in at least a 40% in network performance gain (grooming gain) when compared to a non-grooming scheme such as "MC-RWA"
- Note that the grooming gain is almost independent of the total network offered load since the gain is relative to "MC-RWA", and as the load increases, both schemes will have higher blocking probability.

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Grooming Performance Gain



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Multi-Hop Gain

$$MHG = \frac{BP_{SH} - BP_{MH}}{BP_{SH}} \times 100$$

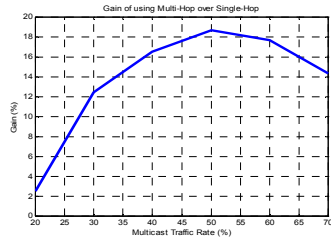
- with 20% multicast traffic, there is no significant advantage as most of the traffic is unicast.
- As the percentage of multicast traffic increases, the probability of finding a combination of existing lightpath/light-tree for multi-hop routing increases, resulting in a corresponding increase of the multi-hop gain, but up to a certain limit (percentage of multicast sessions are 50% or less).
- As the percentage of multicast sessions exceeds 50%, the gain decreases again. This is because with more multicast traffic, the probability of finding a single connection (single-hop lightpath) between the source of the multicast session and an intermediate source (the source of a TDLT) will decrease (less unicast traffic).

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Multi-Hop Gain



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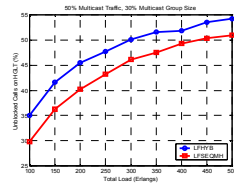
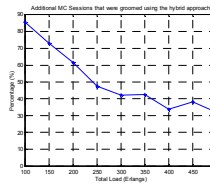
Impact of combining the hybrid and sequential approaches (LFHYB)

- The percentage of multicast sessions that are served using the hybrid scheme (LFHYB) is always greater than that of the sequential scheme (LFSEQMH).
- For instance, at low loads (100 Erlangs), the figure shows that the hybrid approach is able to groom almost 85% more multicast sessions than the logical sequential approach.
- This is very critical because blocking a unicast session is usually less expensive than blocking a multicast session.
- Hence, by allowing more multicast sessions to be served, we are improving the network performance.
- Note, however, as the load increases, the additional percentage of groomed multicast sessions decreases (down to almost 30%).
- This is because the hybrid approach uses both logical and physical resources to groom these additional multicast sessions. At high loads, physical resources are almost depleted and, therefore, the hybrid approach performance approaches that of the logical sequential approach (high loads means high logical connectivity and less available physical resources which are required for hybrid provisioning).

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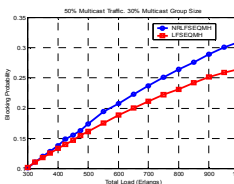
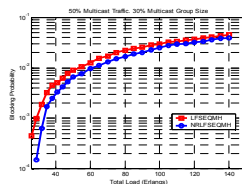
Non-Restricted

- We redefine the original restricted "LFSEQMH" scheme as a Non-Restricted Logical-First Sequential Routing (NRLFSEQMH) scheme.
- At low loads, the performance of the "NRLFSEQMH" scheme outperforms that of the original "LFSEQMH" scheme.
- This is because at low loads more resources are still available and the impact of wasting bandwidth (some destinations on the multicast tree end-up receiving unintended unicast data) is negligible.
- However, at higher loads, the performance of the original restricted grooming algorithm "LFSEQMH" outperforms that of the "NRLFSEQMH" scheme.
- This is because at higher loads, available resources are now scarce and the impact of wasting bandwidth has deleterious effect (increases blocking probability) on the overall network performance.

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Conclusions

- The proposed grooming approaches use the network resources more efficiently compared to the non-grooming and unicast approaches.
- The results have also shown that the percentage of multicast sessions that are served on the logical topology using the hybrid scheme is always greater than that of the sequential approaches.
- This is very important because blocking a unicast session is usually less expensive than blocking a multicast session.
- The hybrid approach increased the percentage of both unicast and multicast calls that were served purely on the logical topology
- Minimized the total cost of the network by maximizing the utilization of the existent logical resources.

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