Multicast Routing Under Optical Layer Constraints

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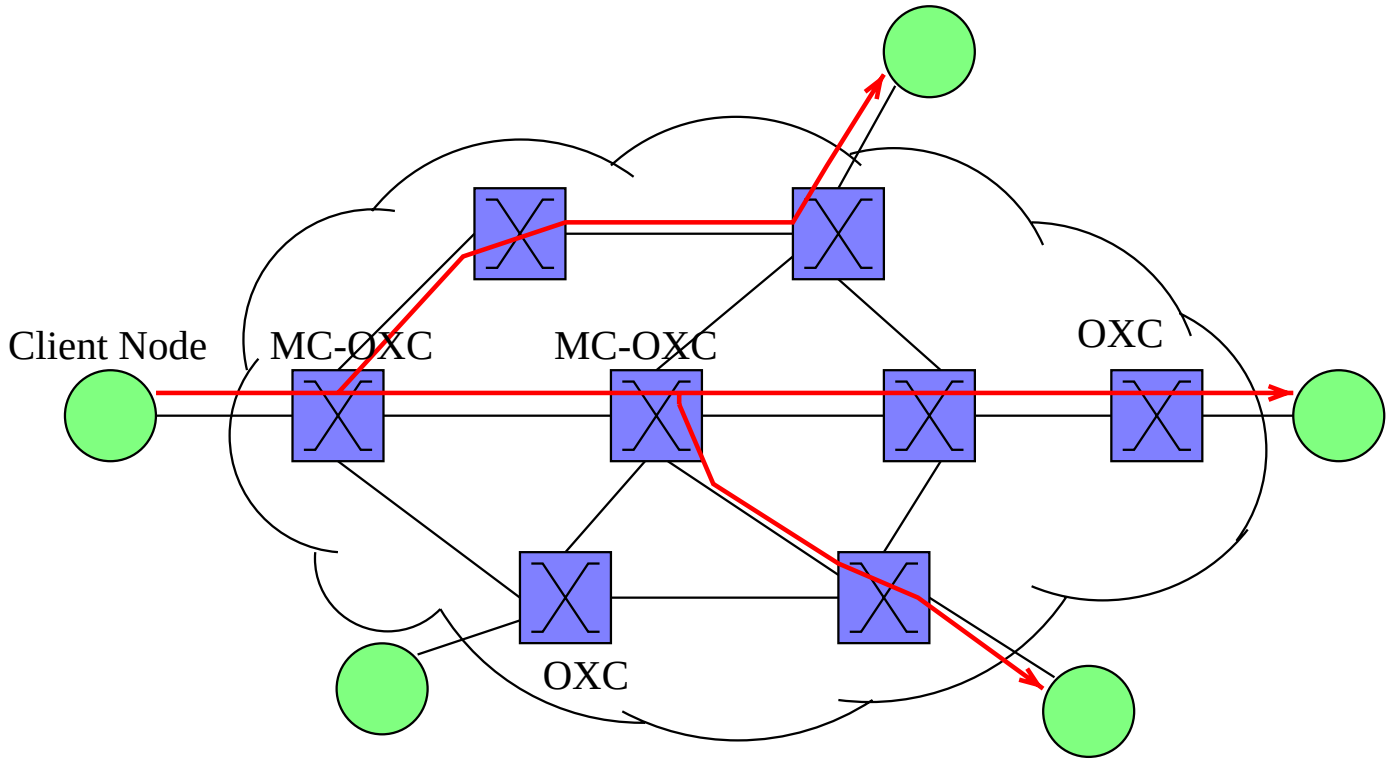
Outline

1. Concept and Applications of Light-Trees
2. Problem Statement
3. Balanced Light-Tree Algorithms
4. Results and Discussion

Light-Trees

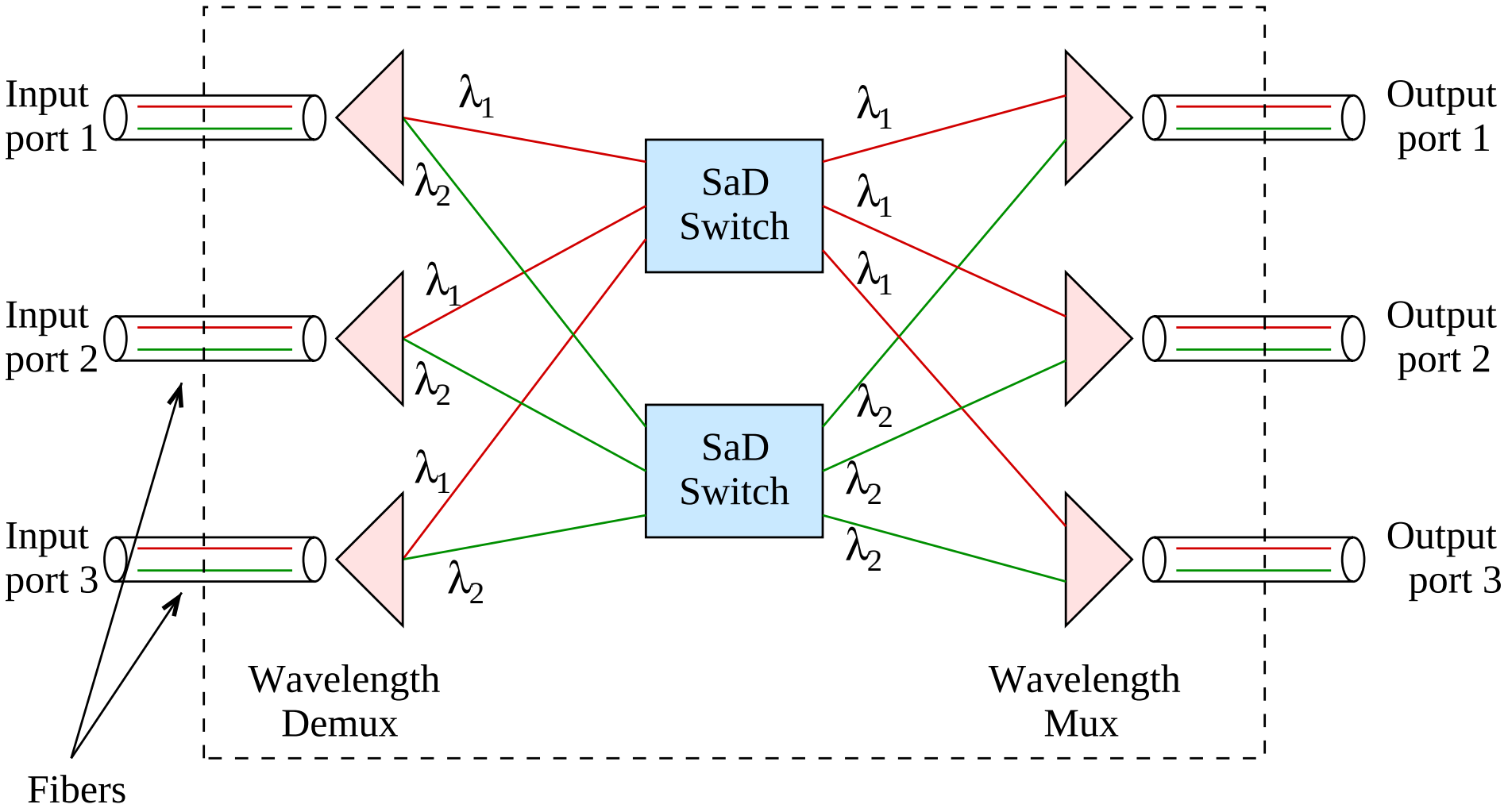
- Generalization of lightpath
- Implemented using power splitters



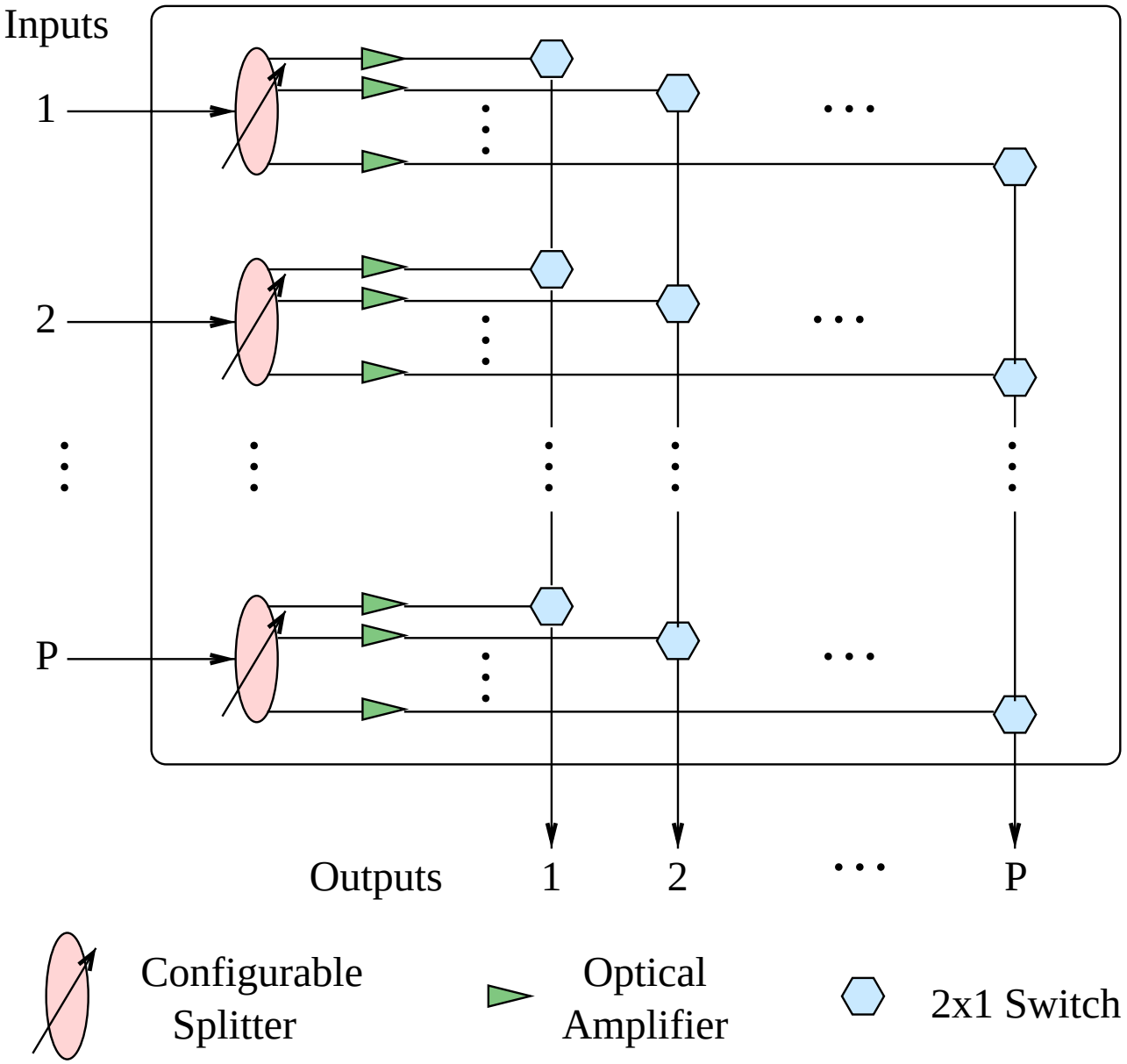
Applications

- Optical multicast
- Traffic grooming
- Enhanced virtual connectivity
- 1+1 optical layer protection
- Improved performance

MC-OXC


Input port 1
Input port 2
Input port 3
Fibers
Wavelength Demux
SaD Switch
SaD Switch
Wavelength Mux
Output port 1
Output port 2
Output port 3
λ1
λ2

Splitter-and-Delivery (SaD) Switch



Power Losses

- Power loss due to:
  1. signal attenuation along the fiber links
  2. light splitting at MC-OXCs
- Relative significance depends on network/destination set size
- Effects may be partially mitigated through optical amplification

Path Constraints

- Introduce two QoS parameters:
  1. source-destination loss tolerance $\rightarrow$ power budget
  2. inter-destination loss variation tolerance $\rightarrow$ fairness
- Power-constrained light-tree (PCLT) problem:
  - losses along all paths do not exceed the two tolerances
  - any feasible tree will do

Loss Due to Attenuation Only

- Neglect loss due to light splitting

  → large geographical span, small destination set

- Equivalent to delay- and delay variation-bounded multicast trees
  - NP-complete (Baldine/Rouskas, JSAC ’97)
  - reduction from PARTITION
  - heuristics can be applied to new context

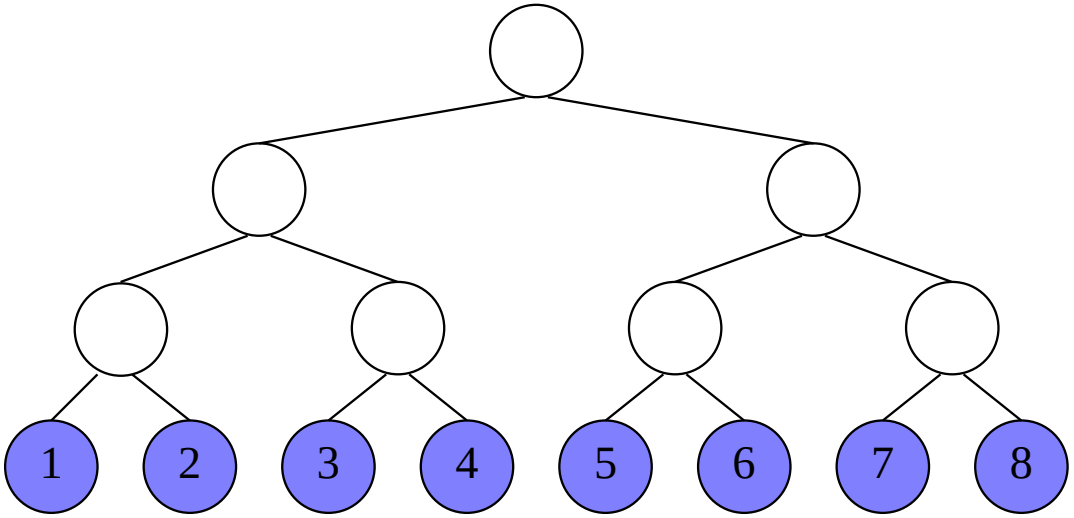
Loss Due to Light Splitting Only

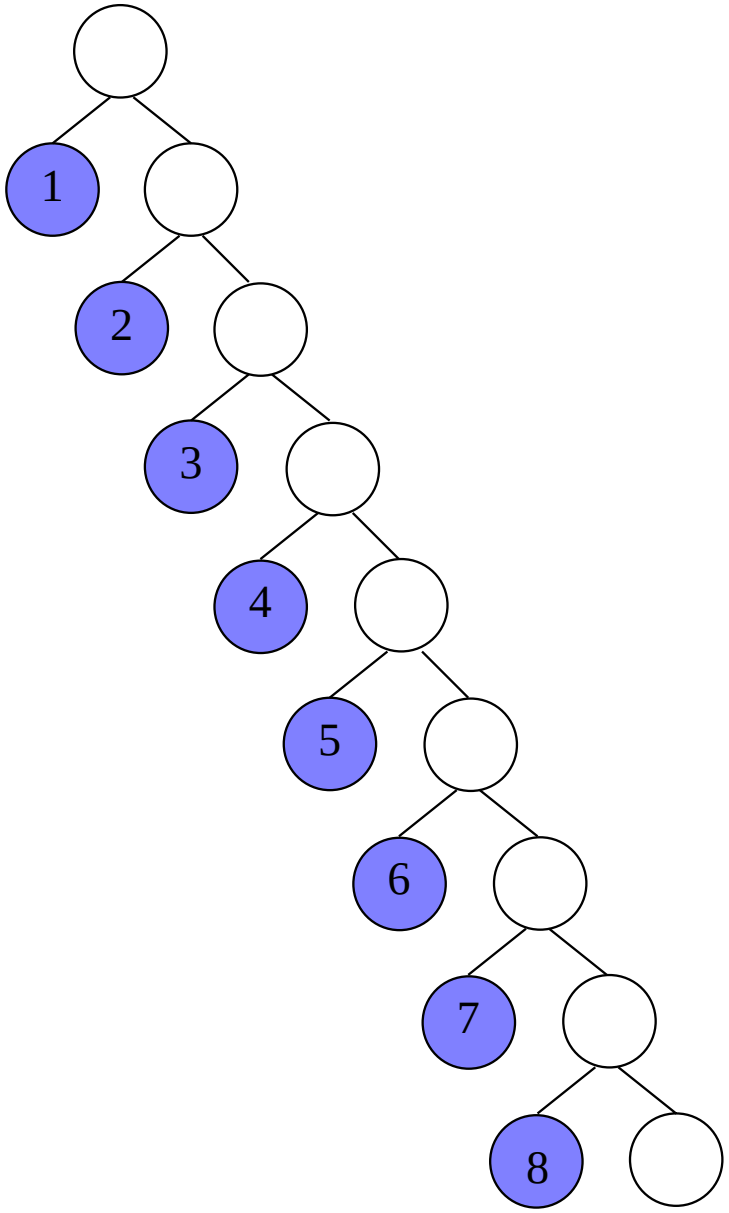
- Neglect signal attenuation

  $\rightarrow$ small geographical span, large destination set

- New multicast tree problem
  - NP-complete
  - reduction from Exact Cover by Three Sets
  - requires light-trees to be balanced

Why Balanced Trees?

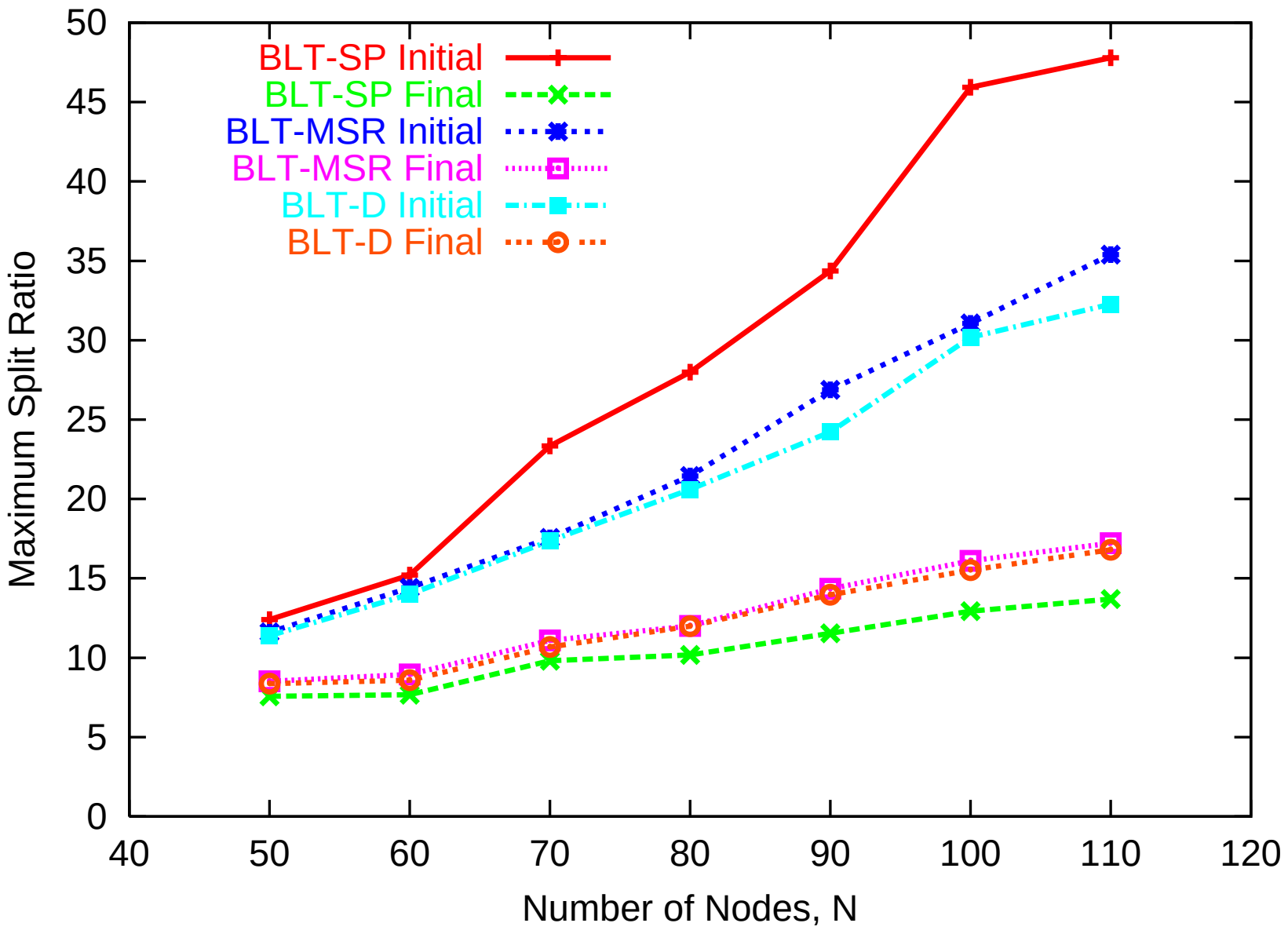




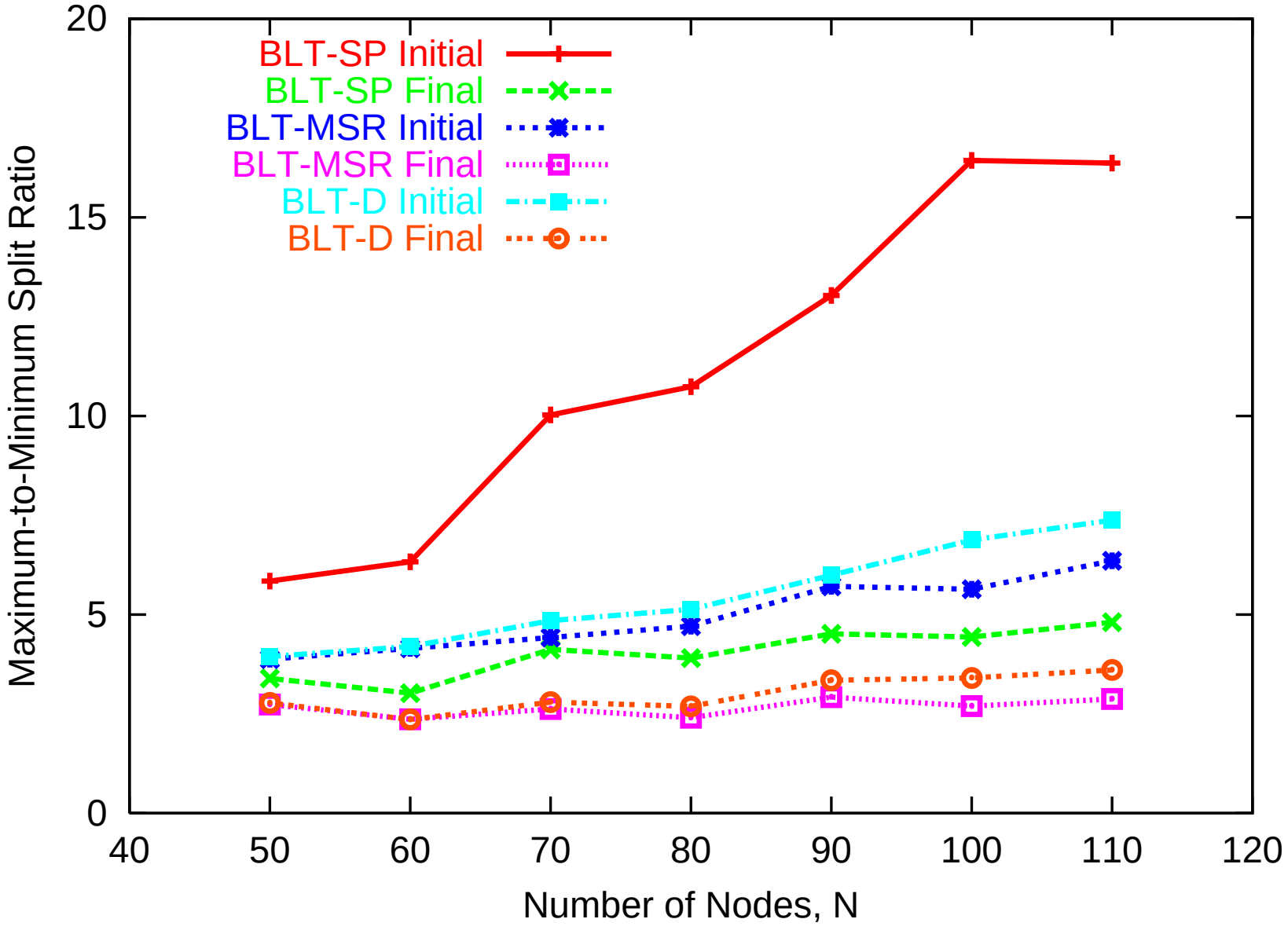
Balanced Light-Tree Algorithm

1. Start with initial tree spanning all destination nodes
2. $U \leftarrow$ leaf node incurring maximum signal splits
3. $V \leftarrow$ leaf node incurring minimum signal splits
4. Delete U from the tree
5. Add U to the path from the root to V
6. Repeat until no further improvement

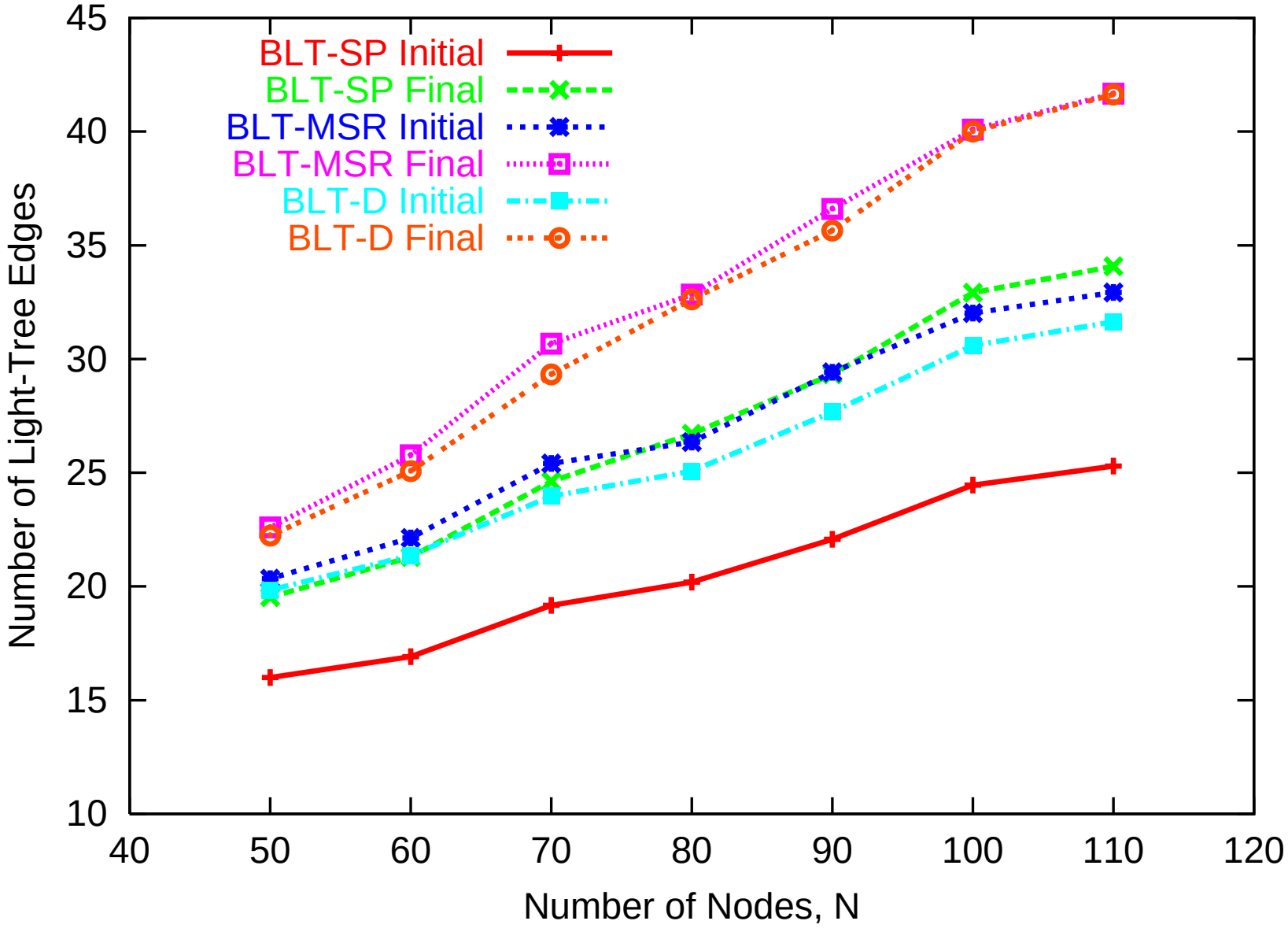
Results: Maximum Number of Splits



Results: Max-to-Min Number of Splits



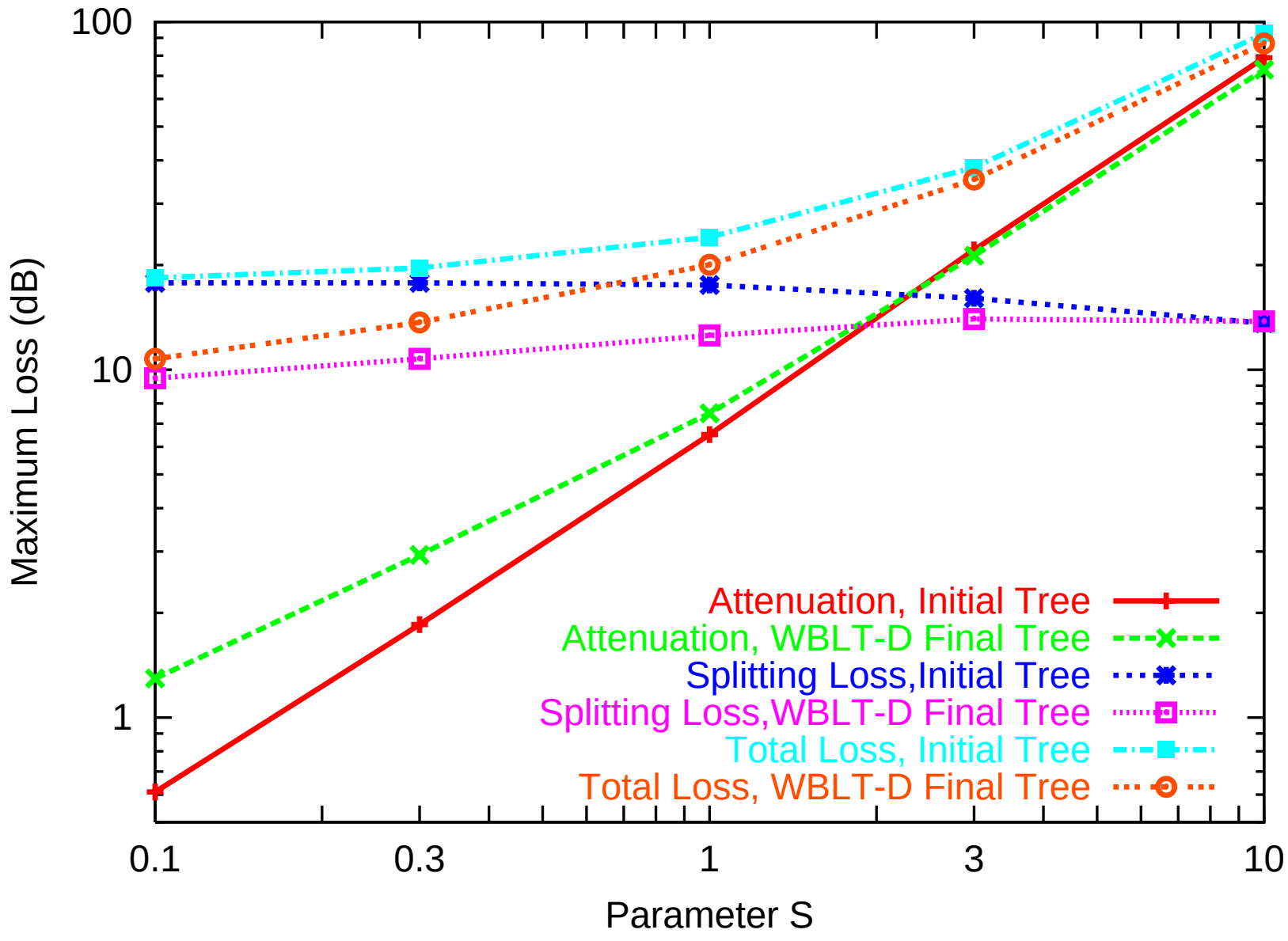
Results: Number of Tree Edges



The General PCLT Problem

- Obviously NP-complete
- Tradeoff: number of signal splits $\leftrightarrow$ distance signal travels
- Nodes physically distant from source must be logically close to it in the light-tree
- Light-trees must be distance-weighted balanced
- Use previous algorithm with small modification:
  - consider leaf node with highest total loss
  - move closer to source to reduce its splitting loss

Results: Maximum Loss



Summary

- Introduced constraints for quality of optical multicast signal
- Defined new constrained light-tree problem
- Developed algorithms to construct balanced trees