Survivable Impairment-aware Traffic Grooming in WDM Rings

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Introduction

- There is an ever-increasing demand for network capacity
- Wavelength Division Multiplexing (WDM) optical networks are promising candidates for future networks:
  - Offer a large capacity (Tb/s)
  - Provide multiple, but independent wavelength channels (lightpaths)
  - Each lightpath can independently operate at high data rates

Issues in WDM networks

- **Survivable**:
  Link-disjoint primary and backup paths
  [*On-line Survivable Routing in WDM Networks*, Proc. of ITC, Sep. 2009]

- **Impairment-aware**:
  Regeneration at intermediate nodes
  [*Impairment-aware Path Selection and Regenerator Placement in Translucent Optical Networks*, Proc. of IEEE ICNP, Oct. 2010]

- **Traffic Grooming**:
  Aggregating independent traffic streams
  [*Survivable Impairment-aware Traffic Grooming*, Proc. of IEEE NOC, July. 2011]

Problem description

- **Given:**
  - A network *G(N,L)*
  - At each node, a transceiver = optical add/drop multiplexer (OADM) to selectively add/drop wavelengths + regenerator
  - A set of requests: each request *i* between a node pair has a demand $\delta(i)$

- **Problem**:
  - Minimize the number of transceivers (= dominant cost) such that
    - All traffic demands are accommodated
    - The capacity of each wavelength channel is not exceeded
    - All lightpaths are
      - *Feasible*: none of the segments of a lightpath should have an impairment value exceeding the impairment threshold
      - *Survivable*: all the lightpaths should be protected

Scenario

- Ring topology (e.g. SONET/SDH rings)
- Traffic scenarios:
  - Uniform Traffic (equal demand between each pair of nodes)
  - Non-Uniform Traffic (traffic between nodes is arbitrary)
- Two cases:
  - Impairment-agnostic: Survivability + traffic grooming
  - Impairment-aware: Survivability + traffic grooming + regeneration

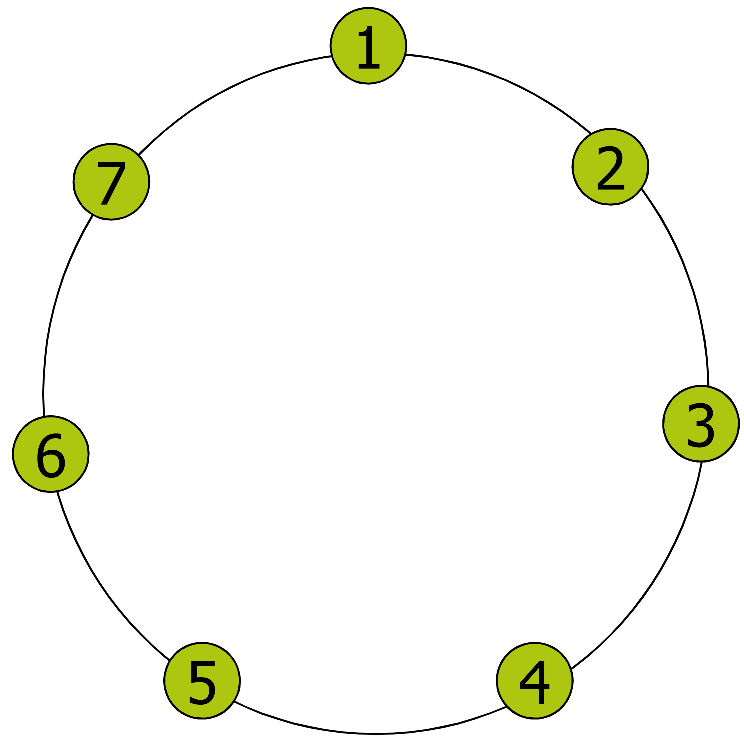
Solving the problem

- Problem is NP-hard (proof via reduction to bin packing problem)
- A-approximation: at most A-times worse than optimal
- Survivable traffic grooming:
  - Uniform traffic: 4-approximation algorithm (USGA = Unif. Traffic Surv. Grooming Algorithm)
  - Non-uniform traffic: heuristic algorithm (NSGA) with lower and upper bounds
- Survivable impairment-aware traffic grooming:
  - Uniform traffic: 20-approximation algorithm (USGA extended)
  - Non-uniform traffic: heuristic algorithm (extended NSGA) with lower and upper bounds

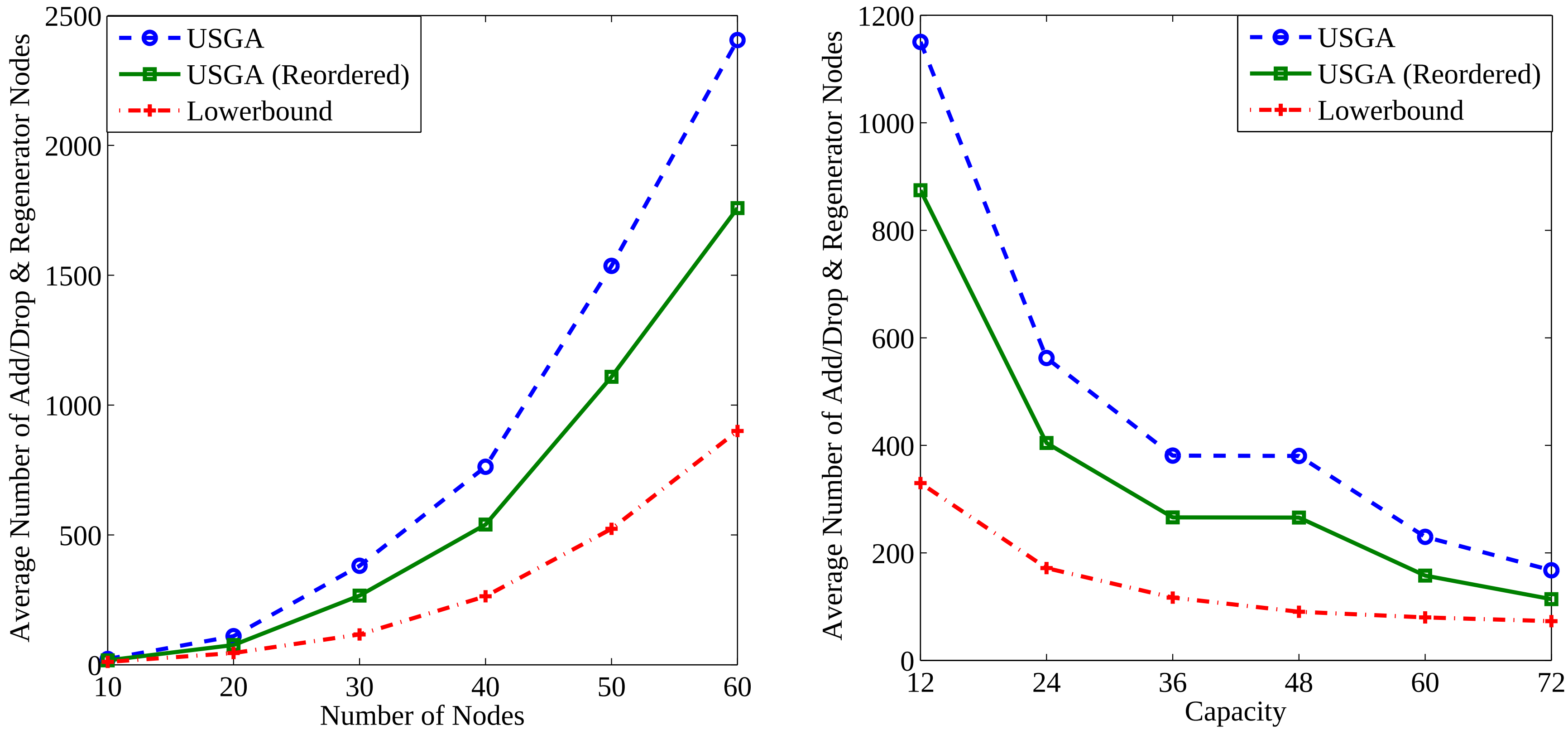
Uniform traffic: USGA example

For uniform traffic: Total number of transceivers $m \geq \left\lceil N(N-1)\sqrt{\frac{\delta}{2C}} \right\rceil$

- N = 7 nodes, wavelength capacity C = 9, demand δ = 1
- Place the nodes into sets of size $\left\lfloor \sqrt{\frac{C}{2\delta}} \right\rfloor = 2$: {1,2} {3,4} {5,6} {7}
- Combine sets in groups (each group has own wavelength ring): {1,2,3,4} {1,2,5,6} {1,2,7} {3,4,5,6} {3,4,7} {5,6,7}
- Total of 21 transceivers



Simulation results uniform traffic



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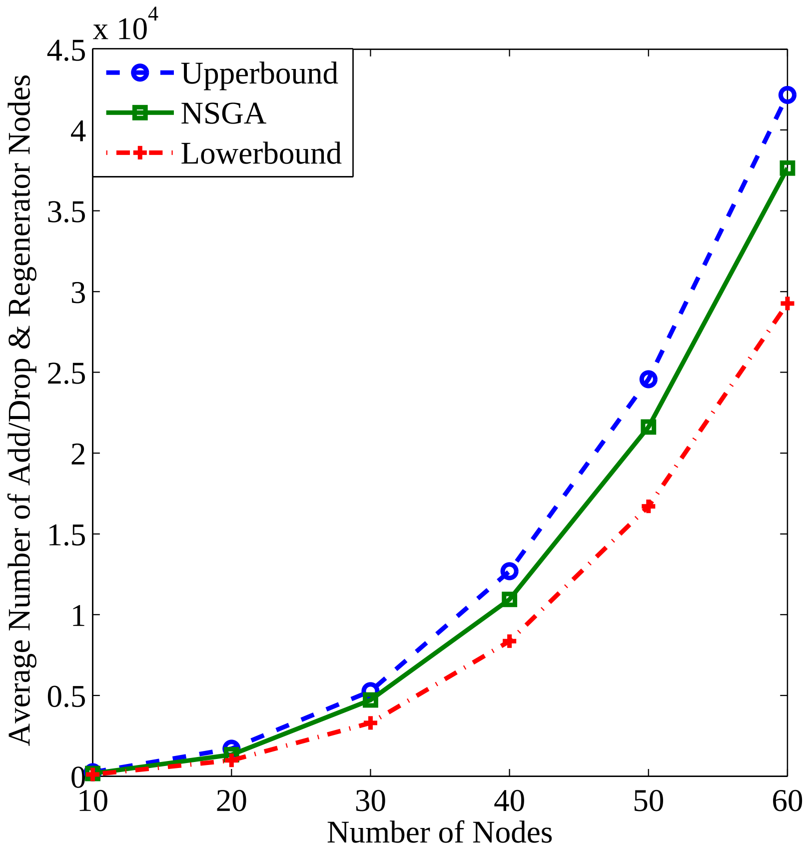
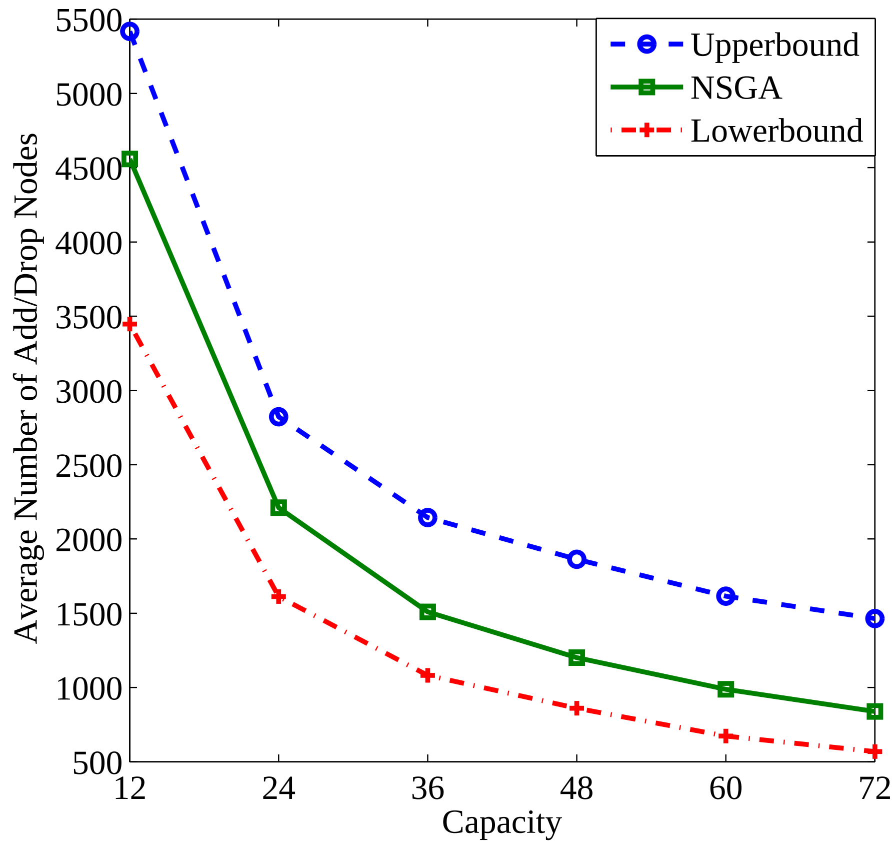
Results for non-uniform traffic





Conclusions

- Traffic grooming in WDM rings is NP-hard
- Approximation algorithms and bounds for uniform traffic
- Heuristic algorithms and bounds for non-uniform traffic
- Algorithms display good performance in simulations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