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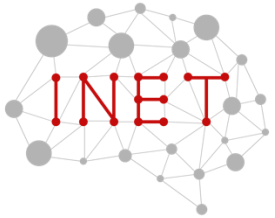

Demand-Aware Multi-Source IP-Multicast

Minimal Congestion via Link Weight Optimization

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https://www.tu.berlin/eninet

Motivation

- Multicast can improve efficiency in distributed systems
- Multicast senders often have fixed bandwidth requirements
  - Often known in advance
  - E.g., CCTV cameras have certain bitrate, IoT sensors, etc.
- Existing methods are demand-oblivious
- Leads to congestion and suboptimal resource usage
- New focus: Demand-aware link weight optimization

Contributions

- Formalize demand-aware multicast problem
- Prove it is NP-hard under several restrictions
- Propose a MILP formulation for optimal solutions
- Design two fast heuristics: DA-Picky & DA-Hybrid
- Empirical validation on real and synthetic topologies

Complexity Results

- Demand aware Multicast is NP-hard:
  - Even with only two link weights
  - Even with a single receiver
  - Even on planar graphs with small degrees

Heuristics

- Oblivious baseline: Link weight = 1 / capacity
- DA-Picky:
  - Prioritizes high-demand sources
  - Adds links incrementally
- DA-Hybrid:
  - Builds max bottleneck spanning trees
  - Assigns weights based on demand

Evaluation Setup

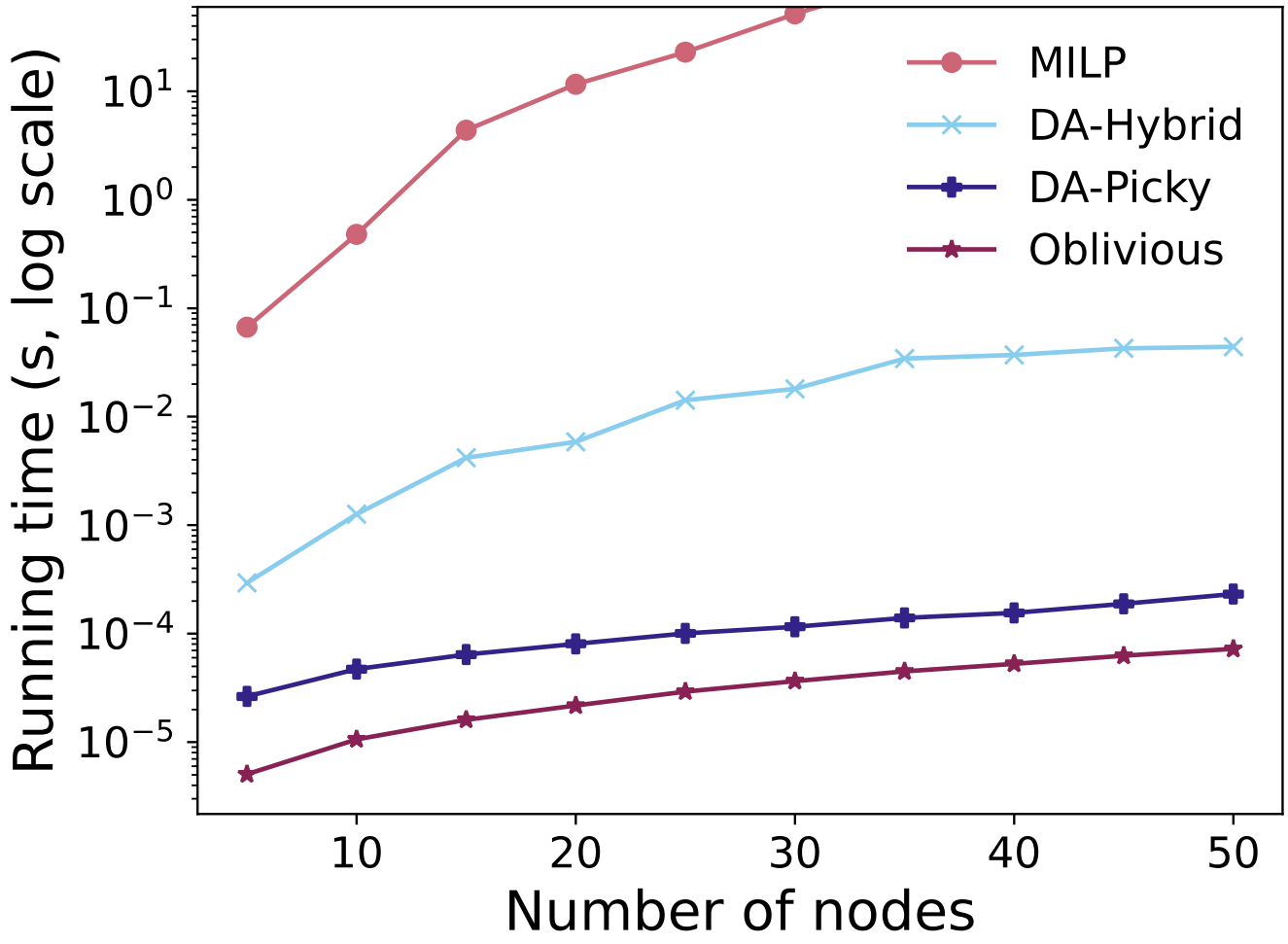
- Topologies:
  - Topology Zoo
  - IGen synthetic
  - Campus mesh
  - National ISP
- Demands/Capacities:
  - Uniform random
  - Gravity model

Key Results

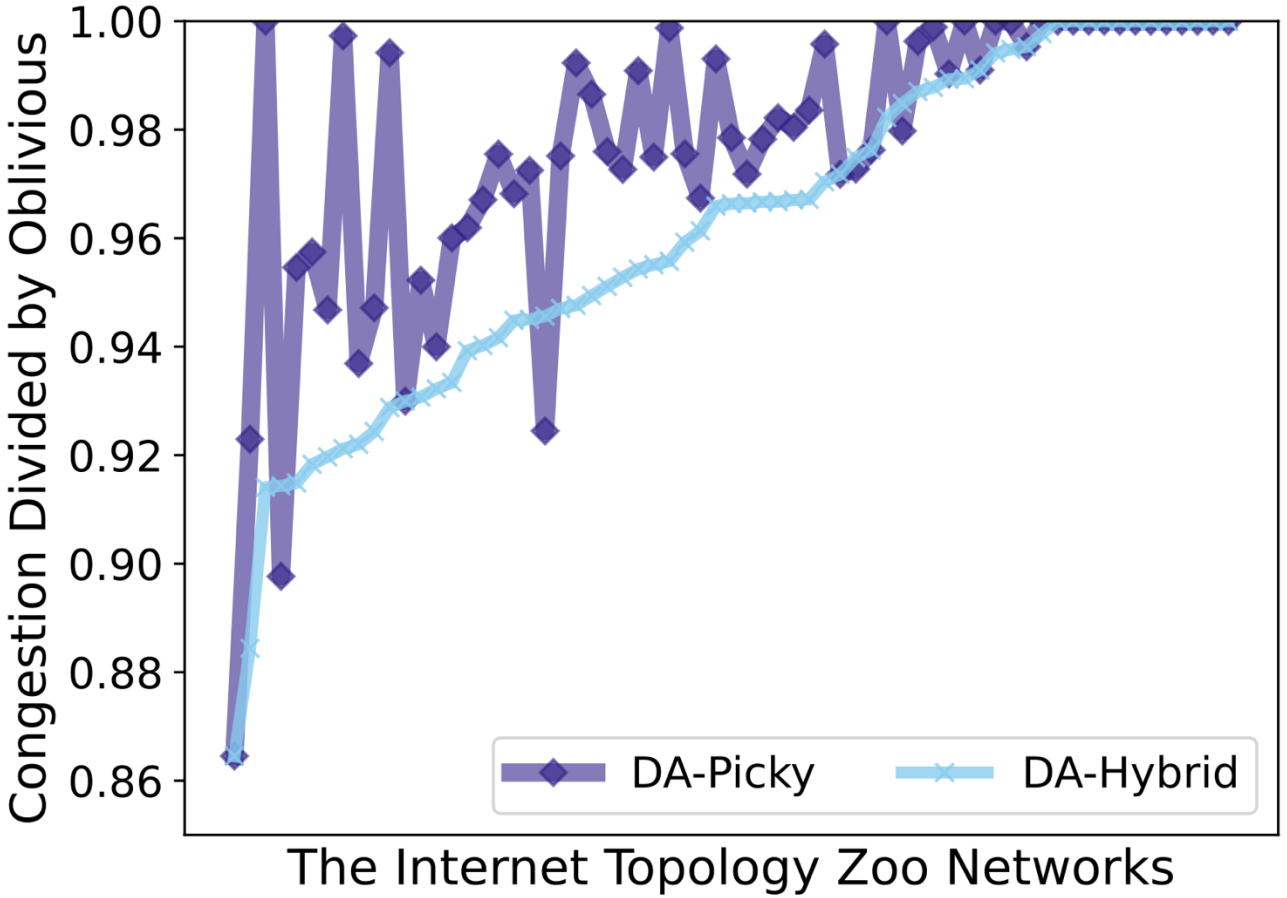
- DA algorithms outperform oblivious:
  - Lower congestion
  - DA-Hybrid slightly better than DA-Picky

- Running time:
  - MILP slow for large graphs
  - Heuristics scale well

Results


Running time (s, log scale)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10
20
30
40
50
Number of nodes
MILP
DA-Hybrid
DA-Picky
Oblivious

Results


Congestion Divided by Oblivious
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
DA-Picky
DA-Hybrid
The Internet Topology Zoo Networks

Conclusion

- Demand-aware multicast is computationally hard
- Practical heuristics offer good performance
- Significant congestion reduction over traditional methods
- Is there operational interest in these types of scenarios?
- Should we consider how possible protocol extensions could take bandwidth into account?

Our group's website:
tu.berlin/en/eninet