Improved Fast Rerouting Using Postprocessing

Klaus-Tycho Foerster (University of Vienna, Austria)

Andrzej Kamisiński (AGH University of Science and Technology in Kraków, Poland)

Yvonne-Anne Pignolet (DFINITY, Switzerland)

Stefan Schmid (University of Vienna, Austria)

Gilles Tredan (LAAS-CNRS, France)

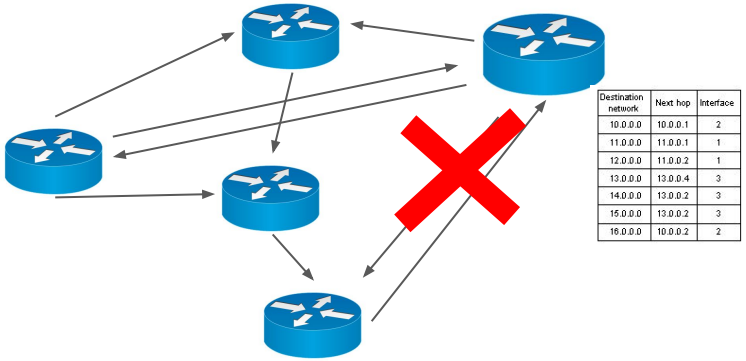
A tale of arborescences and donuts..

...and their connection to routing

Outline

1. Model and Objectives
2. Arborescence-based Fast Rerouting
3. Postprocessing Framework
4. Case Studies
5. Conclusion and Outlook

Motivation



Destination network	Next hop	Interface
10.0.0.0	10.0.0.1	2
11.0.0.0	11.0.0.1	1
12.0.0.0	11.0.0.2	1
13.0.0.0	13.0.0.4	3
14.0.0.0	13.0.0.2	3
15.0.0.0	13.0.0.2	3
16.0.0.0	10.0.0.2	2

Static Fast Rerouting (FRR)

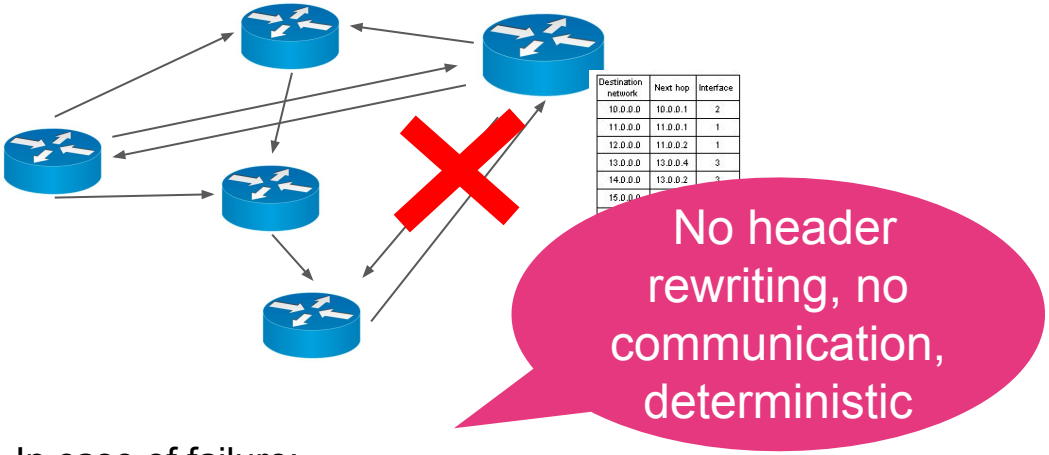
- Seamless failover
- Precomputed failover-routes

Approaches for maximal resilience are known [Chiesa et al. TON17]
=> What about stretch, load and other performance criteria?
[CCR18,Infocom19,DSN19]
=> Despite NP-hardness results and beyond special cases?

Model and Objectives

Model

Network: strongly r-connected di-graph



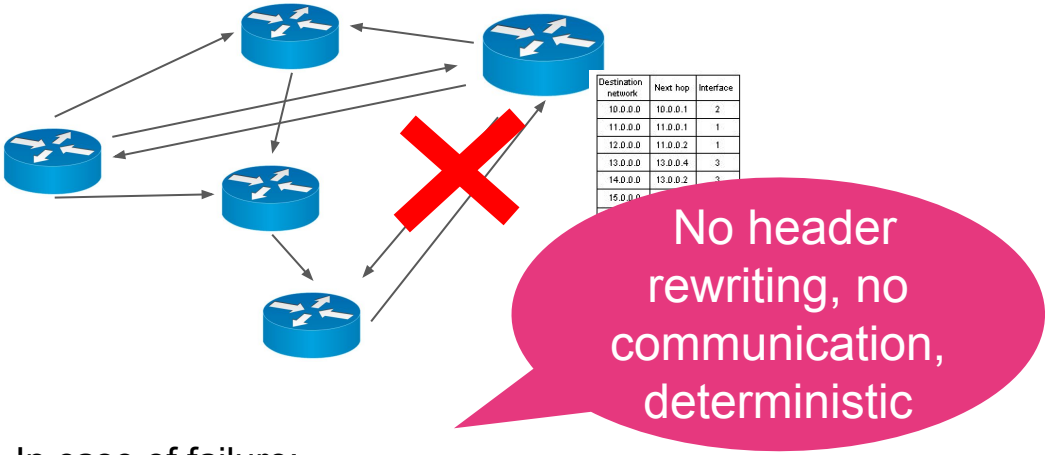
In case of failure:
static local re-routing based on

- SRC, DST, in-port
- incident failures

Model and Objectives

Model

Network: strongly r-connected di-graph



In case of failure:
static local re-routing based on

- SRC, DST, in-port
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Objectives

Load
Maximum additional link utilization due to rerouting

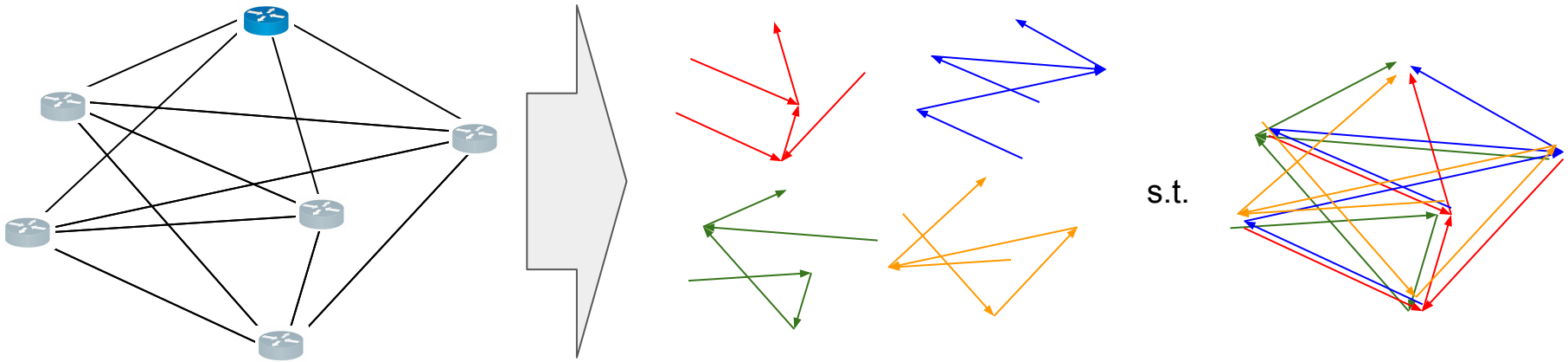
Stretch
Maximum additional hops due to rerouting

SRLG
Shared Risk Link Groups

Path independence
No shared intermediate nodes to destination

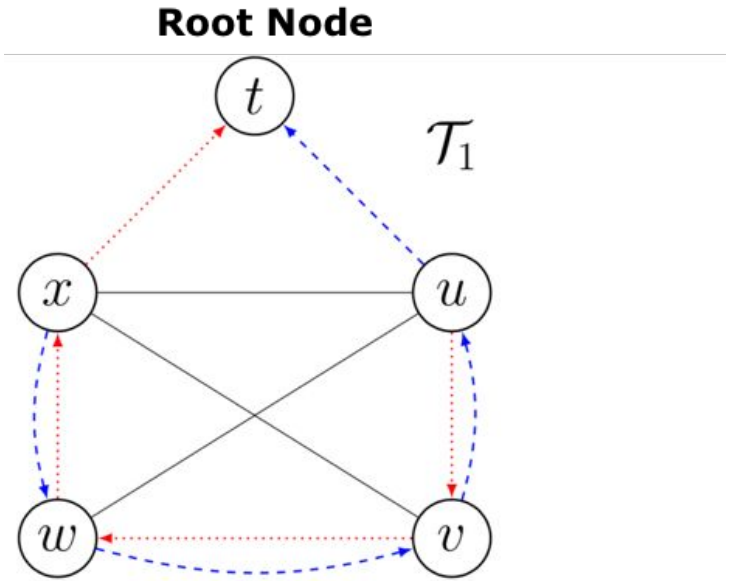
Arc-disjoint Arborescence Decomposition

- Arborescence = a rooted directed spanning tree
- Decomposition: union of r-arborescences uses each link at most once



Arborescence FRR

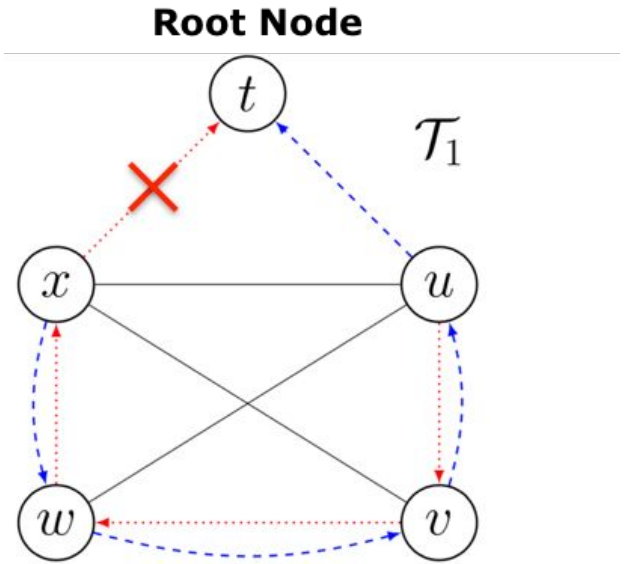
- Assign numbers to arborescences, pick arborescence 1
- Forward to next hop according to current arborescence

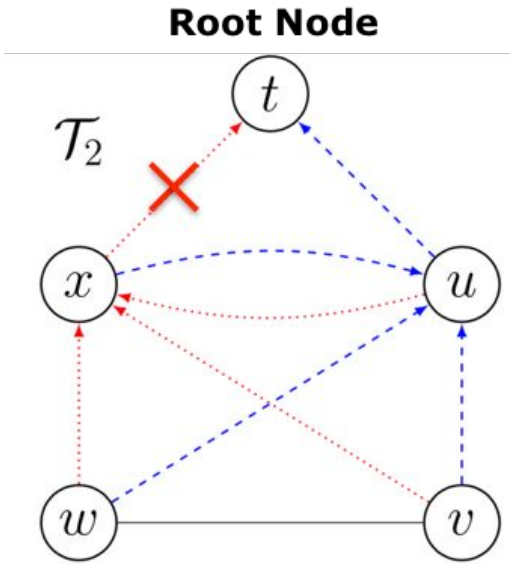


Arborescence FRR

Arborescence FRR

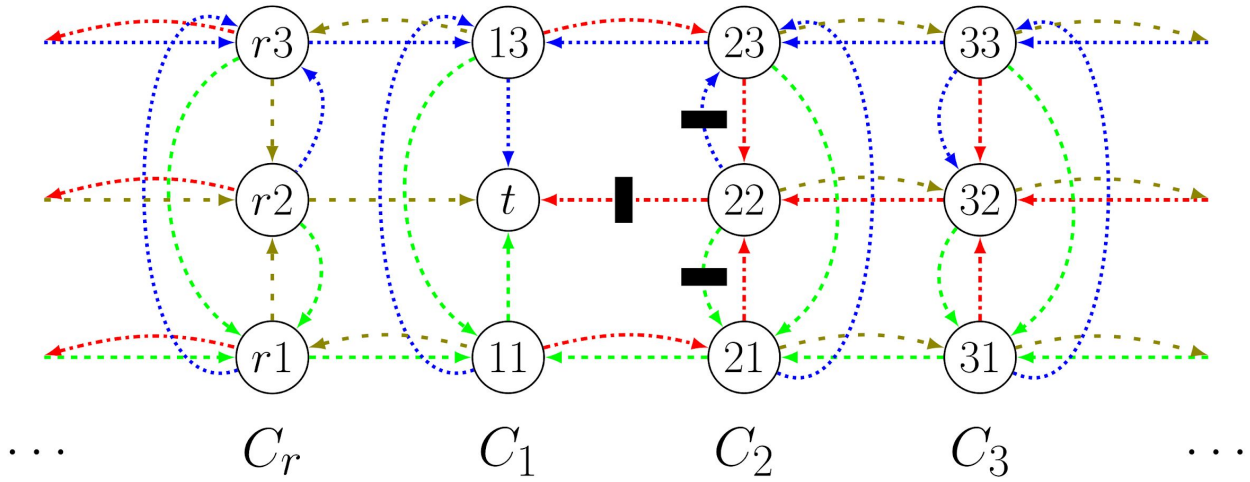
- Assign numbers to arborescences, pick arborescence 1
- Forward to next hop according to current arborescence
- If forwarding link is not available, use link of next arborescence





Decomposition influences length/load/..

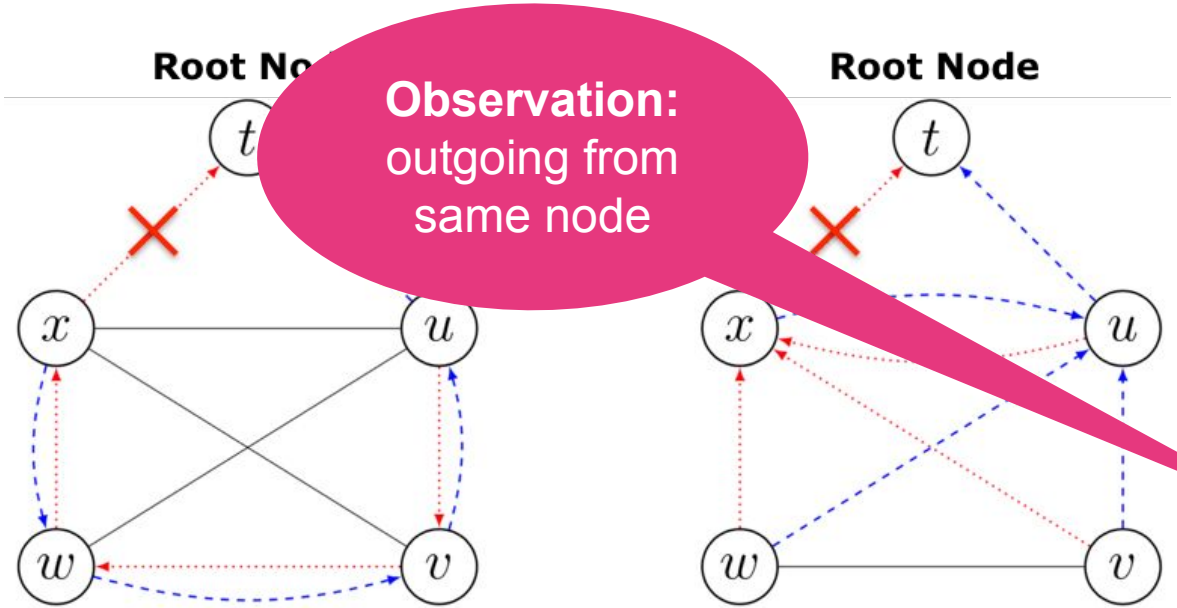
How good is Arborescence FRR?



Theorem 1: Deterministic local fast failover algorithms resilient to k − 1 failures, have competitive additive stretch of Ω(n/(k − 1))
(can be met by arborescence-based re-routing on donut graph).

Improve Decompositions

How to transform *T1* into *T2*?



Observation: outgoing from same node

(x,w) ↔ (x,u)

(u,v) ↔ (u,x)

…

Swapping Conditions

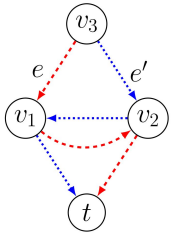
An arborescence swap *e=(u,v)* with *e'=(u,v')* is valid if

I. e ∈ Ti, e' ∈ Tj and
   - v′ is not on the path from v to the root in Tj
   - v is not on the path from v' to the root in Ti

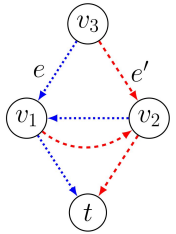
or

II. e ∈ Ti and e' not in any Tj and
   - v is not on the path from v' to the root in Ti

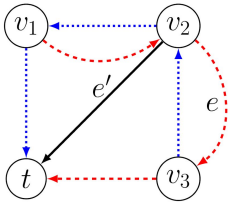
Observation: Validity computable in O(n)



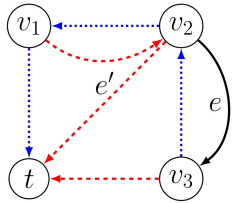
Before swapping



After swapping



Before swapping



After swapping

Post-Processing Algorithm

Decomposition

Objective function

Improved decomposition

Theorem 2.

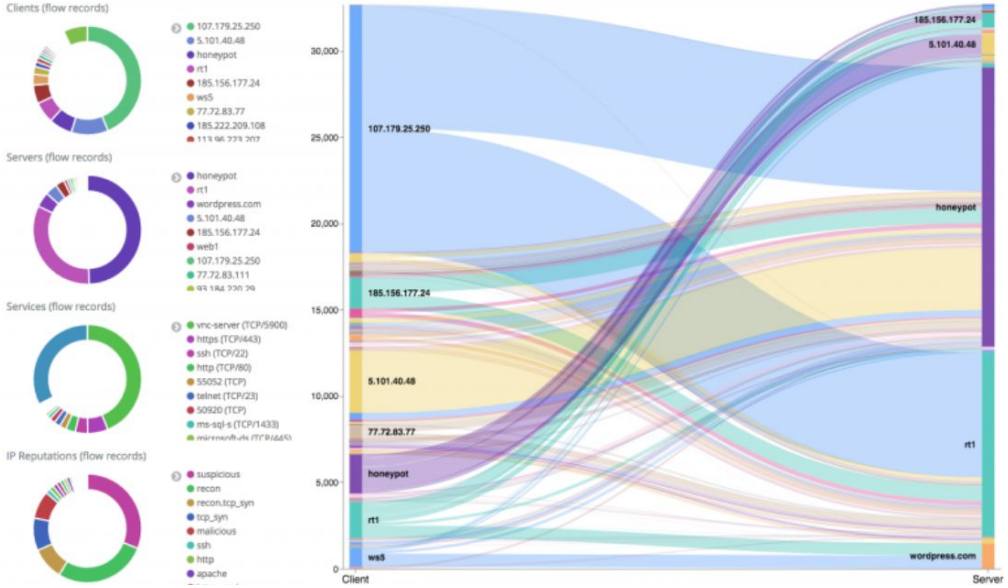
Post-processing algorithm never introduces cycles and always converges.

Case study 1

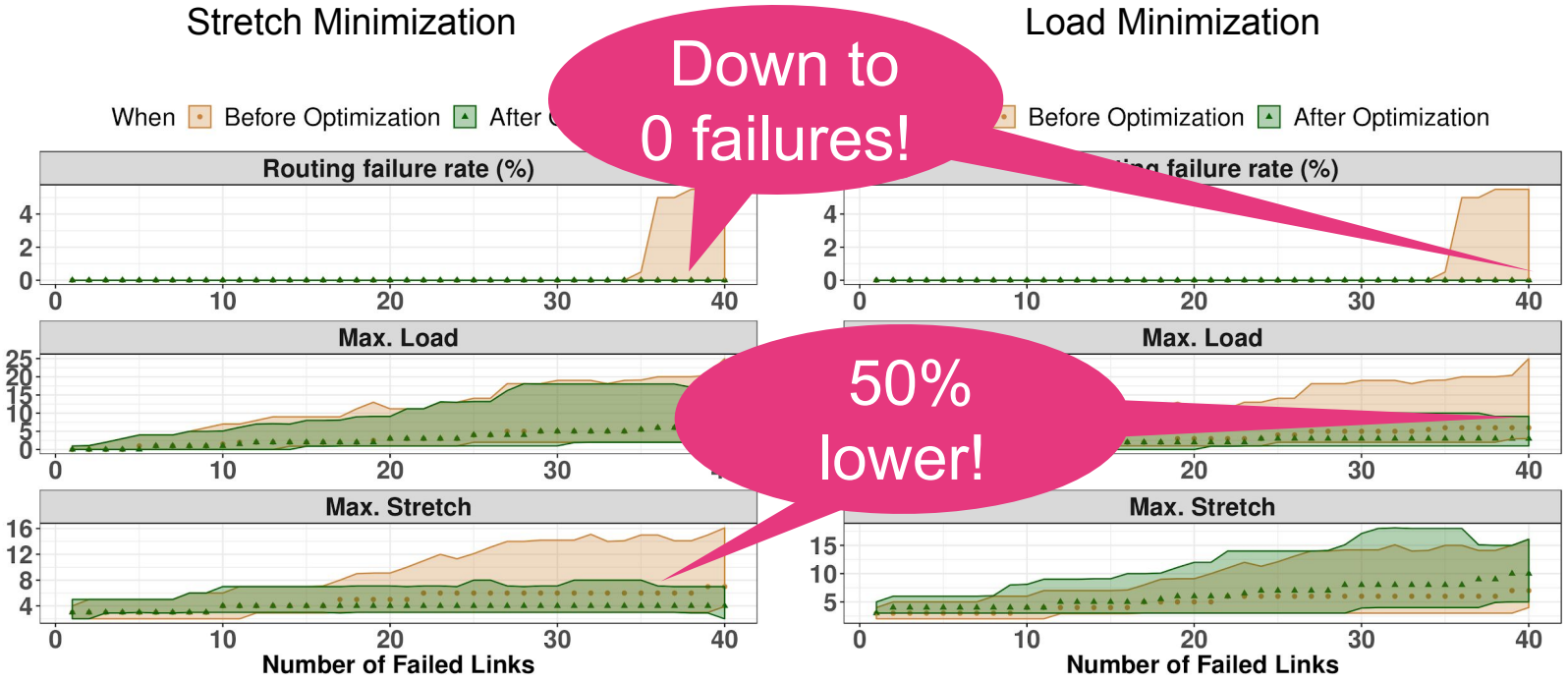
Traffic scenario optimization

- Flows differ in size and importance
- Links differ in failure probability

=> Minimize stretch/load of important flows given a failure model



Traffic Scenario



Case study 2

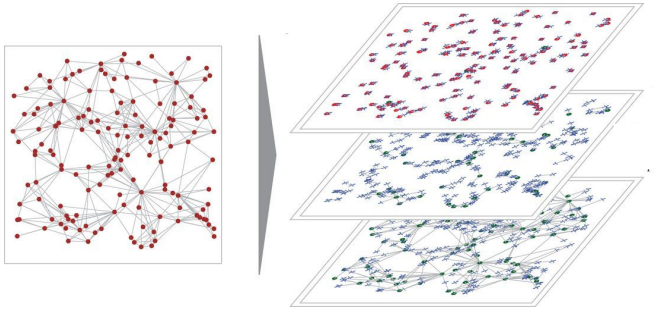
Direct decomposition optimization

- Shared Risk Link Groups (SRLG)

  => Links in SRLG in same arborescences

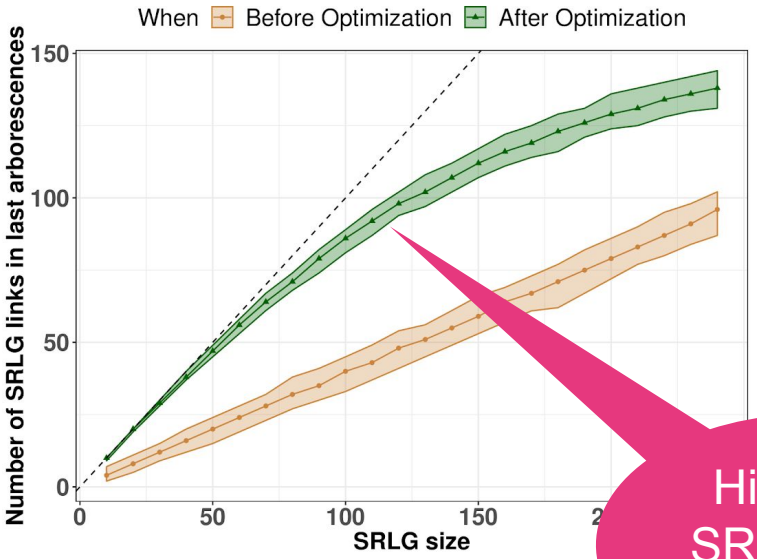
- Path independence

  => No shared intermediate nodes on routes to destination



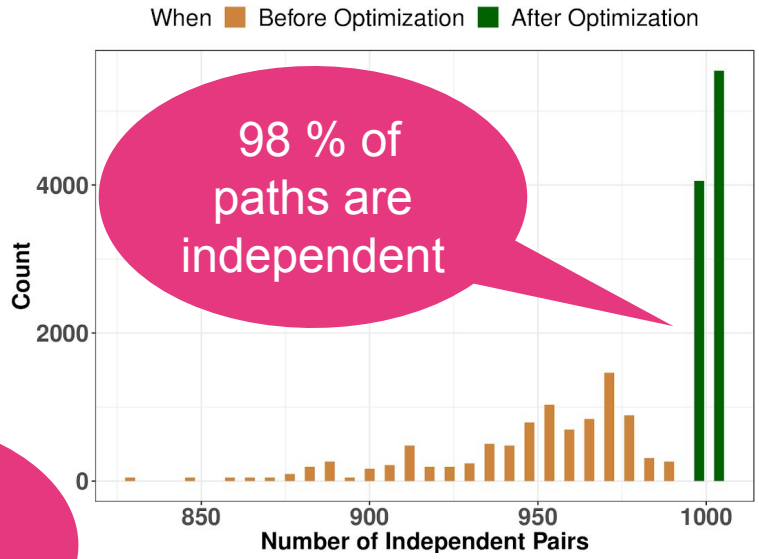
SLRG and Independence

SLRG



High % of SRLG links in last arbs

Independence



98 % of paths are independent

Conclusions

FRR to provide QoS in addition to basic connectivity

- FRR with arborescence decompositions can be asymptotically optimal wrt stretch
- Simple post-processing framework with convergence guarantee

  Case studies demonstrate applicability for stretch, load, independence, SRLG

Future work

- Bounds on improvement achieved
- Alternative post-processing strategies

Post-Processing Algorithm

```
Input: arborescence decomposition T, objective function
Output: improved decomposition

1.  improved := True
2.  while improved do
3.      improved := False
4.      for each node v do
5.          for all pairs of outgoing edges from v do
6.              if swapping condition met and objective function improves
7.                  swap edges in T
8.                  improved := True
```

Theorem 2.

Post-processing algorithm never introduces cycles and always converges.