UNIVERSITÄT OSNABRÜCK

Fast Reoptimization with only a few Changes: Enhancing Tactical Traffic Engineering with Segment Routing Midpoint Optimization

Alexander Brundiers, Timmy Schüller, Nils Aschenbruck

GI/ITG KuVS FG “Network Softwarization”
April 03–04, 2025

Quick Introduction - What is Traffic Engineering?

Traffic Engineering in one (simplified) sentence:

Control the paths of traffic flows in your network to achieve various objectives.

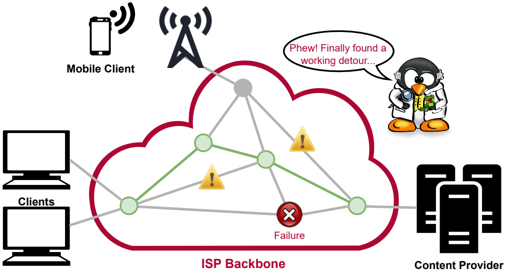

Image sources/credits in the appendix

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Possible Use Cases or Objectives:

- Reduce load of highly utilized links
- Reduce energy consumption (GreenTE)
- Deal with failures & traffic changes
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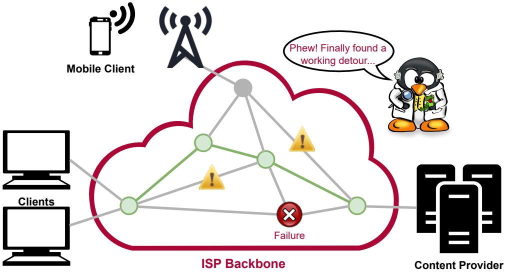

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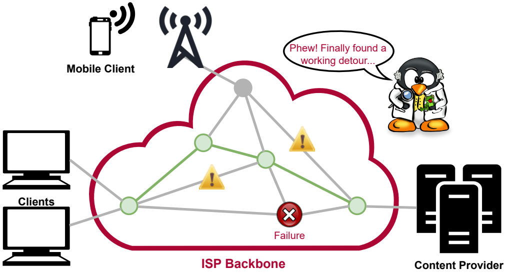

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Implemented via *Metric-Tuning*, *MPLS (with RSVP-TE)*, *Segment Routing*, ...

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Control a packet's path by defining **interim destinations/waypoints:**

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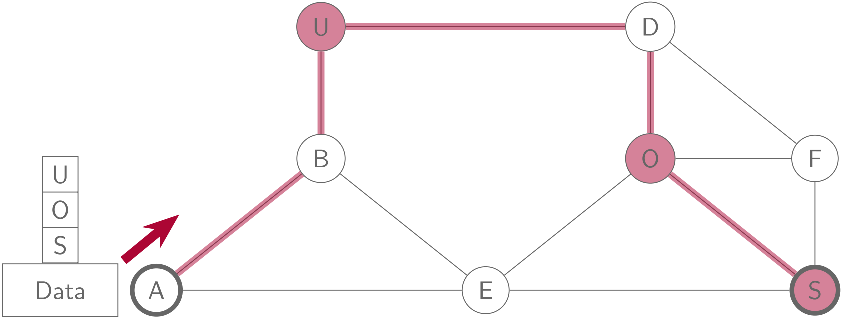

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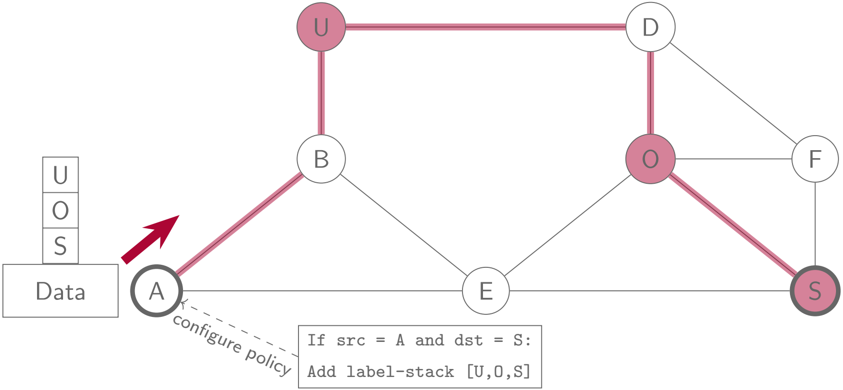
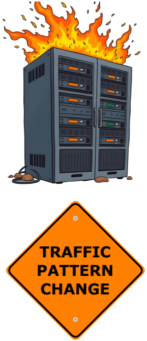


```
If src = A and dst = S:
Add label-stack [U,O,S]
```

Terminology:

SR Policy: "Rule" determining which segments to add to a packet

Common Operational Challenges: *“Mom, the Internet is broken!!!”*



Hardware Failures &
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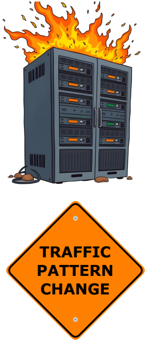

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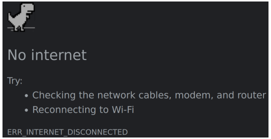

No internet

Try:

- Checking the network cables, modem, and router
- Reconnecting to Wi-Fi

ERR_INTERNET_DISCONNECTED

Service Deterioration
or Disruption

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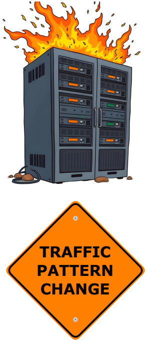

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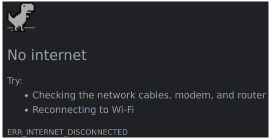

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Unhappy Customers

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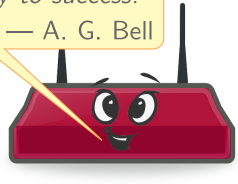
A) Proactive Protection

Idea: “**Hedge** *networks against said events so they don’t become a problem.*”

“Preparation is the key to success!”
— A. G. Bell



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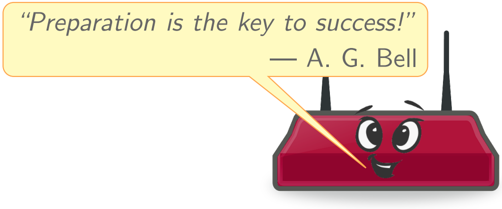

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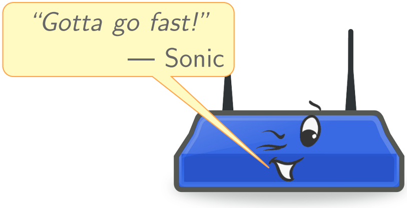

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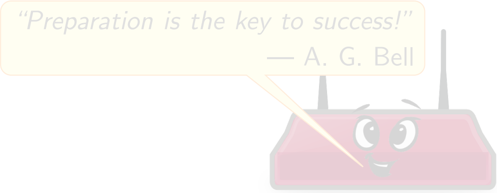

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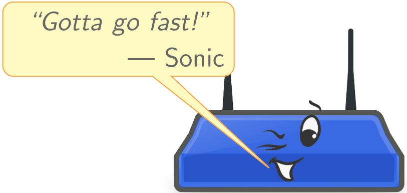

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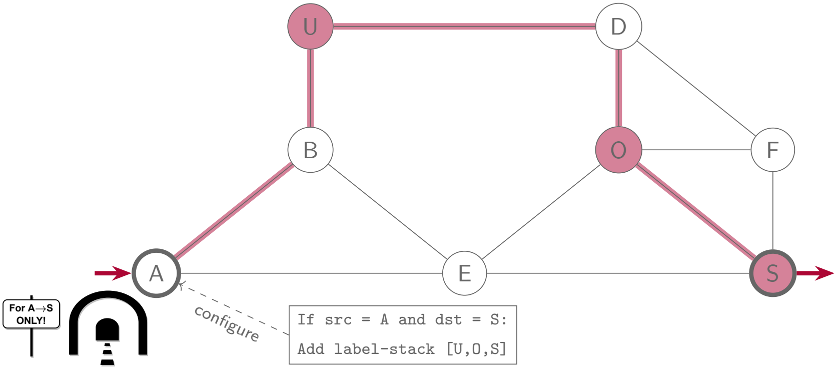

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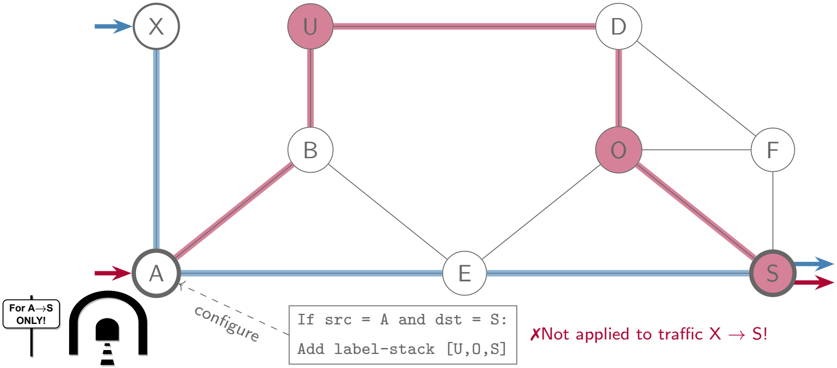

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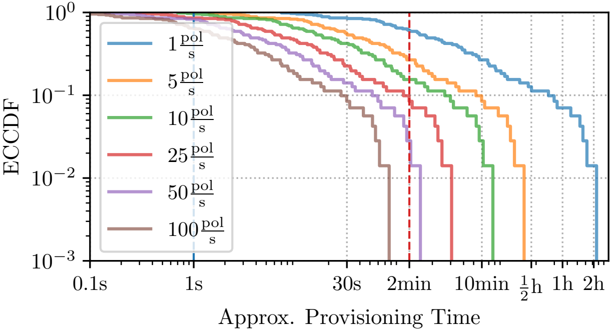

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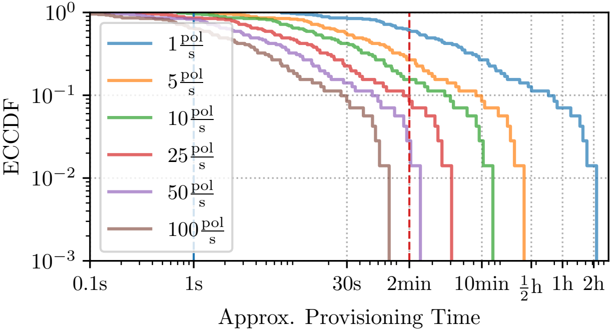
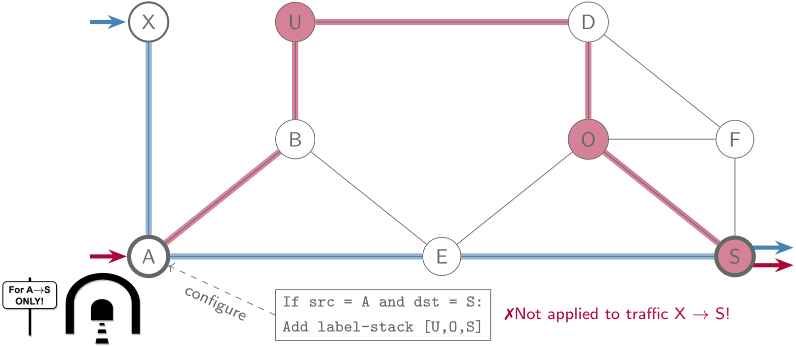


➔ **Limitations** regarding the practical usability of reactive restoration!

How to overcome these issues?

Problem: Dedicated *“demand-bound”* policies



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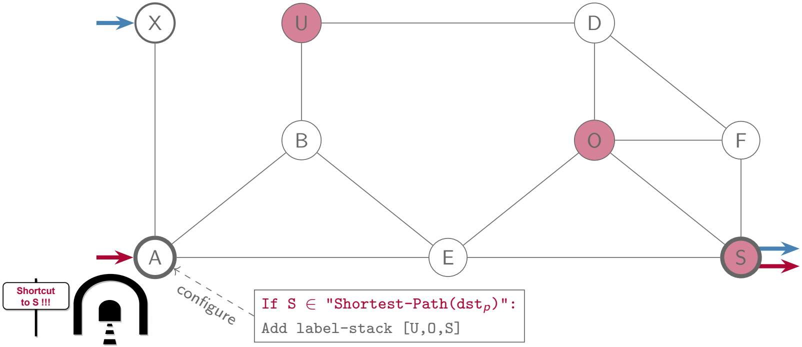

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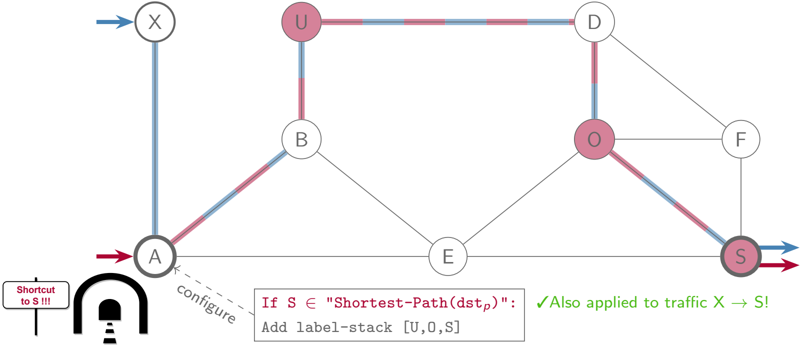

If S ∈ "Shortest-Path(dst_p)":
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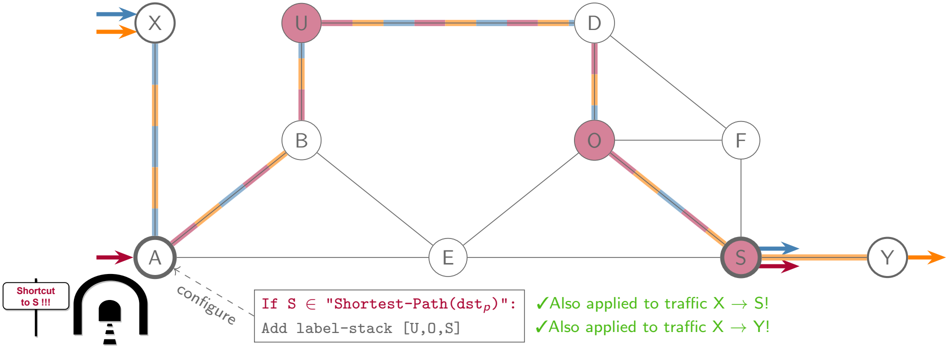

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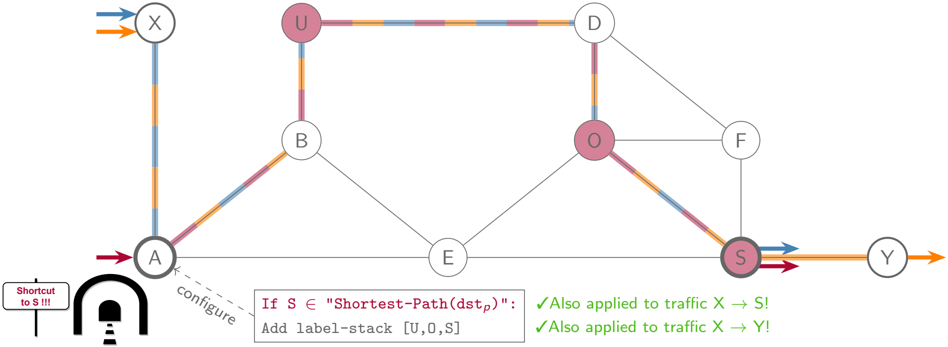

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→ Detouring of **multiple demands** with only **a single policy**!

How to compute suitable solutions fast?

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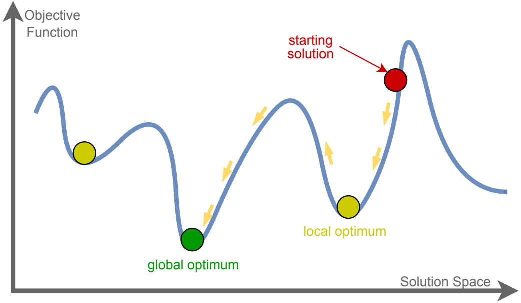
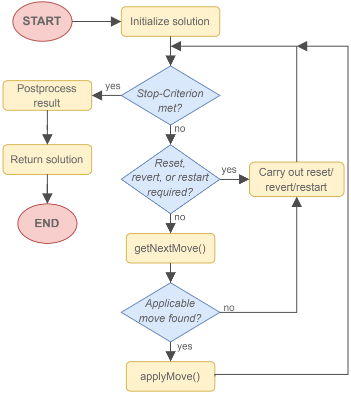
New algorithm: **Midpoint Optimization Local Search (MOLS)**





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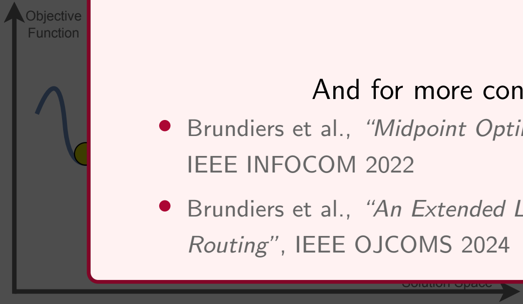

For more details, see our paper!

And for more context on SR MO, see:

- Brundiers et al., *"Midpoint Optimization for Segment Routing"*, IEEE INFOCOM 2022
- Brundiers et al., *"An Extended Look at Midpoint Optimization for Segment Routing"*, IEEE OJCOMS 2024

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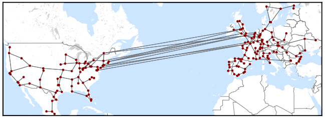
Evaluation Setup: (simulation based)



Topology Information

Source	Destination	Traffic
RTM	LAX	42
OS	RTM	5
...	...	...

Traffic Matrix

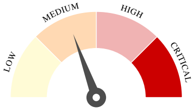
Input

Further Optional Requirements & Constraints

$$\begin{array}{lll} \min\ \theta & & \\ \text{s.t.} & \sum_{p \in P_d} x_d^p = 1 & \forall d \in D \\ & \sum_{d \in D} \sum_{p \in P_d} g_p(e)\, x_d^p\, t_d \leq \theta\, c_e & \forall e \in E \\ & x_d^p \geq 0 & \forall d \in D \\ & & \forall p \in P \end{array}$$

Optimization Model/Algorithm

Output



Objective Value

Required SR Policies
RTM → FRA → MAD
OS → RTM → LA
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TE Configuration

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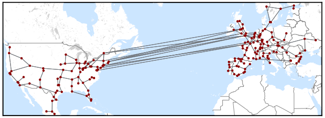

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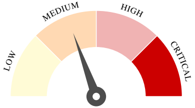

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TE Configuration

Data Sources:

- Semi-Artificial *Repetita*/*Topology Zoo* data
- Real-world data from a Tier-1 ISP backbone

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Our algorithm resolves **over 99%** of failure scenarios

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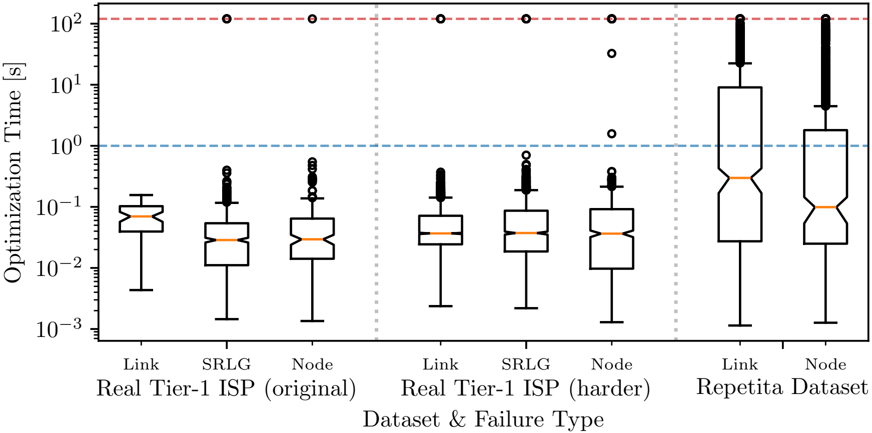

$<$ 2min

sub-second

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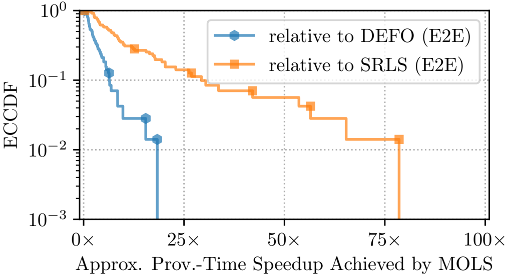

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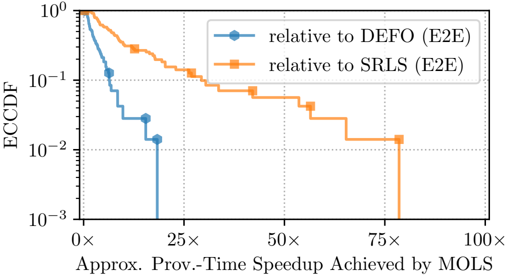
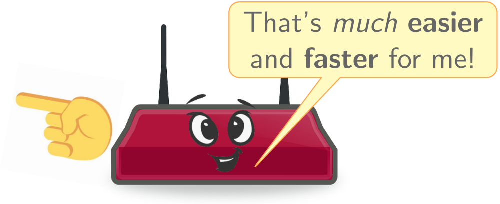
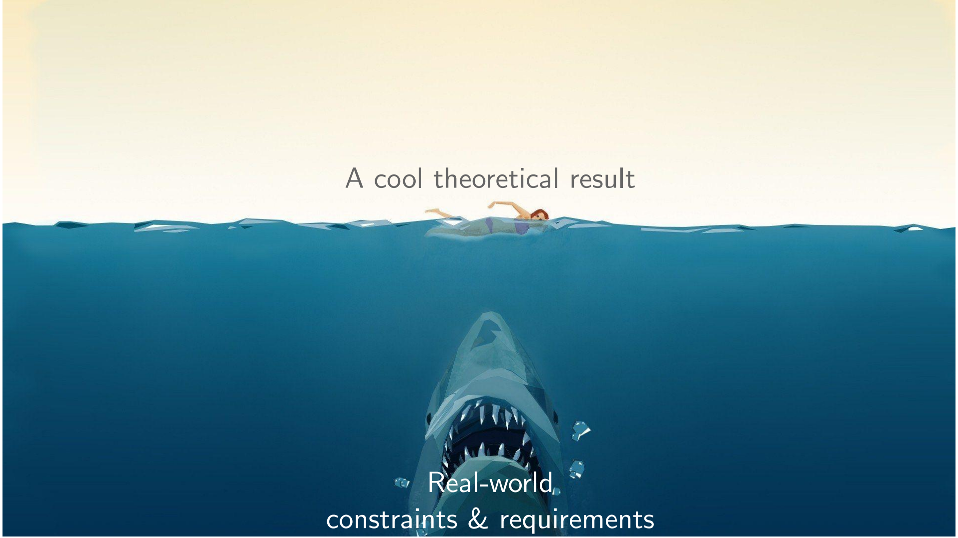




Fast computation, verification & provisioning

➔ Greatly improved "Time-to-Repair"!

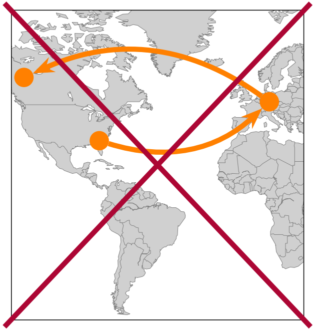
Bridging the Gap: Theory → Practice

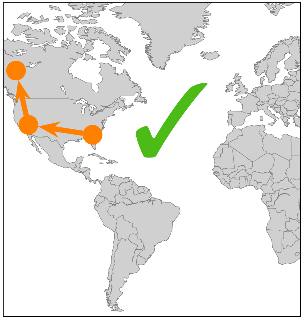


Source: wallpaperaccess.com

Important Constraints & Requirements

- Policy Numbers
- Routing Loops
- MSD Limits
- Traffic Splitting
- Latency Bounds
- ...





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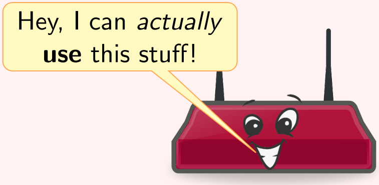
- Policy Numbers
- MSD Limits
- Latency Bounds

Our approach considers ALL these requirements!

Optimization Algorithm (+ Real-world Reqirements) + **Technical Implementations** (e.g., *Juniper* or *Cisco*) = **Practically usable results!**



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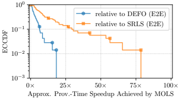

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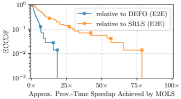

... and all that while even respecting **real-world constraints**!

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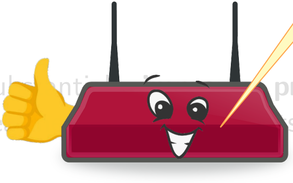
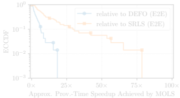


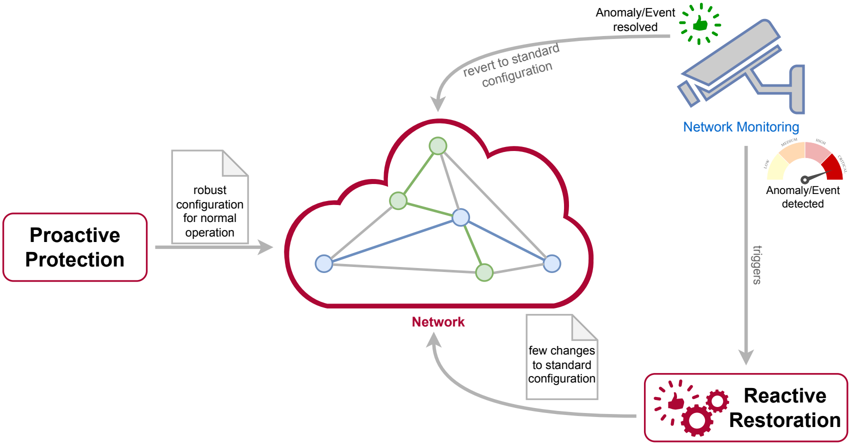
… which translates to su nti **provisioning times**
and, thus, a faster tre s,



… and all that while even respecting **real-world constraints**!

A sneak-peak into (potential) future work:

Combine MOLS with MO-based proactive protection approaches!



Anomaly/Event resolved

revert to standard configuration

Network Monitoring

Anomaly/Event detected

triggers

Proactive Protection

robust configuration for normal operation

Network

few changes to standard configuration

Reactive Restoration

Brundiers et al., "*Live Long and Prosper – On the Potential of Segment Routing Midpoint Optimization to Improve Network Robustness*", IEEE LCN, 2024

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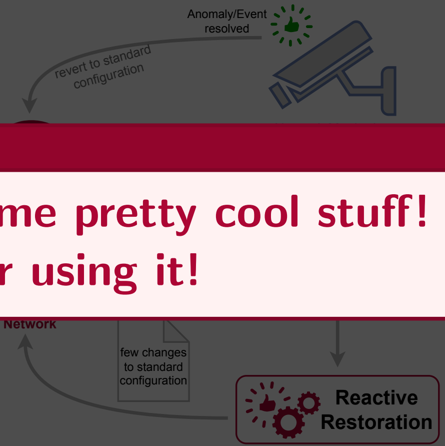
Anomaly/Event resolved
revert to standard configuration
Network
few changes to standard configuration
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The Final Takeaway:

SR MO enables some pretty cool stuff!

Consider using it!

Brundiers et al., "*Live Long and Prosper – On the Potential of Segment Routing Midpoint Optimization to Improve Network Robustness*", IEEE LCN, 2024

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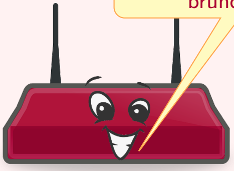

Time's up? Find me at
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or contact me directly:
brundiers@uos.de

Brundiers et al., "*Live Long and Prosper – On the Potential of Segment Routing Midpoint Optimization to Improve Network Robustness*", IEEE LCN, 2024

Appendix & Backup-Slides

Image Sources/Credits

- The “scientist tux” (penguin) on Slide 2 is taken from:
  M. Barbieri, 2010, “*Tux version of scientist Lazzaro Spallanzani*”, Wikimedia Commons.
  online: `https://commons.wikimedia.org/wiki/File:Tux_Spallanzani.svg`
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- Some of the illustrations on Slide 4 were created using the *AI Image Generator* of *DeepAI* (`https://deepai.org/machine-learning-model/text2img`)