# *ReViNE*: Reallocation of Virtual Network Embedding to Eliminate Substrate Bottleneck

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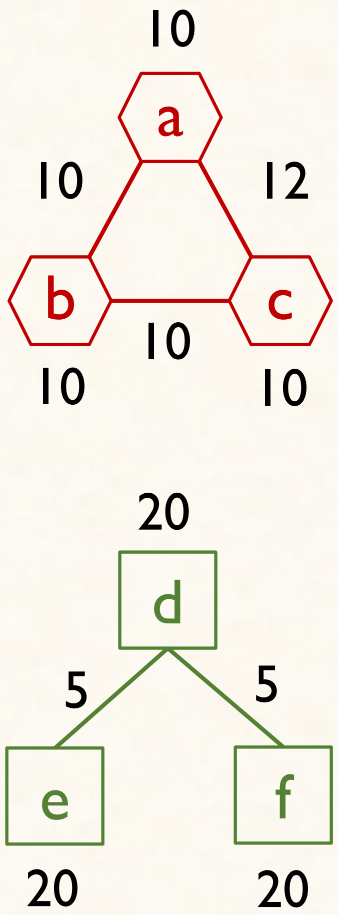
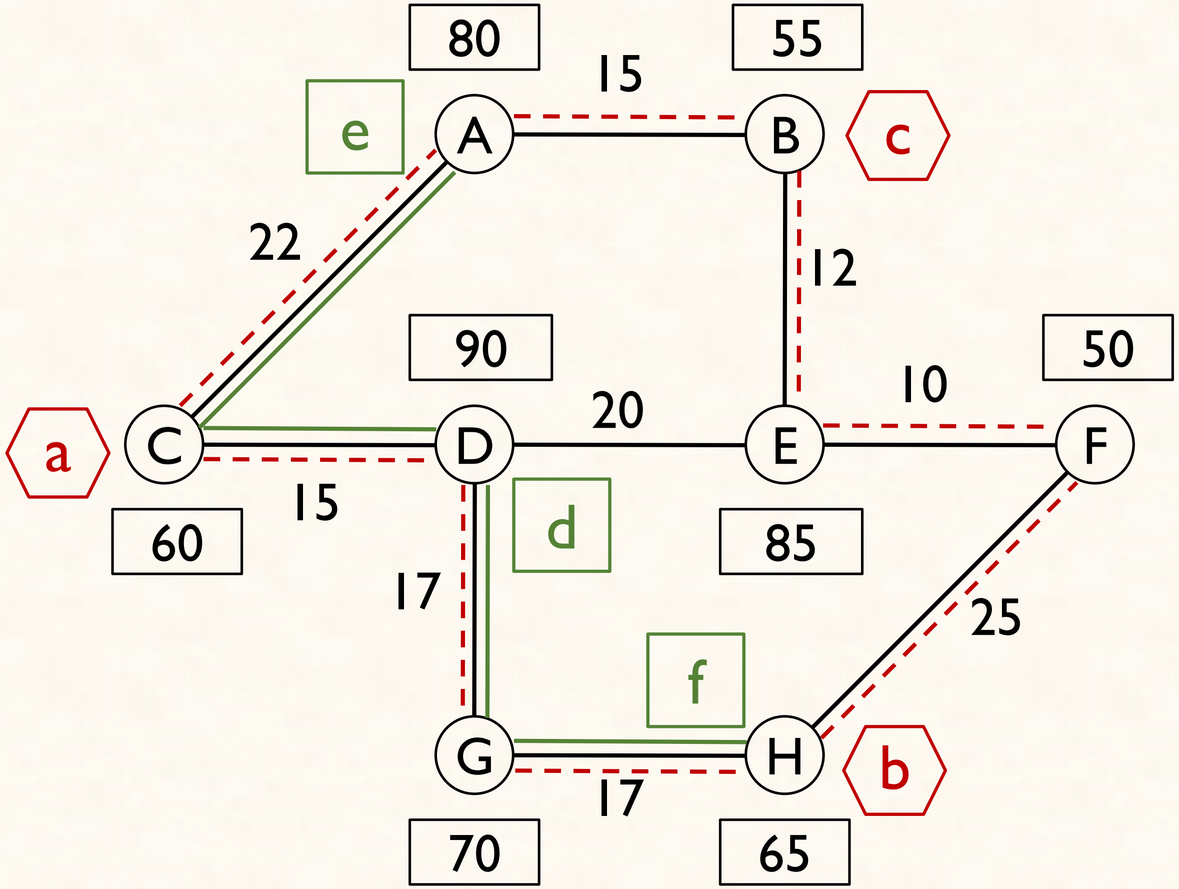
# Virtual Network Embedding (VNE)





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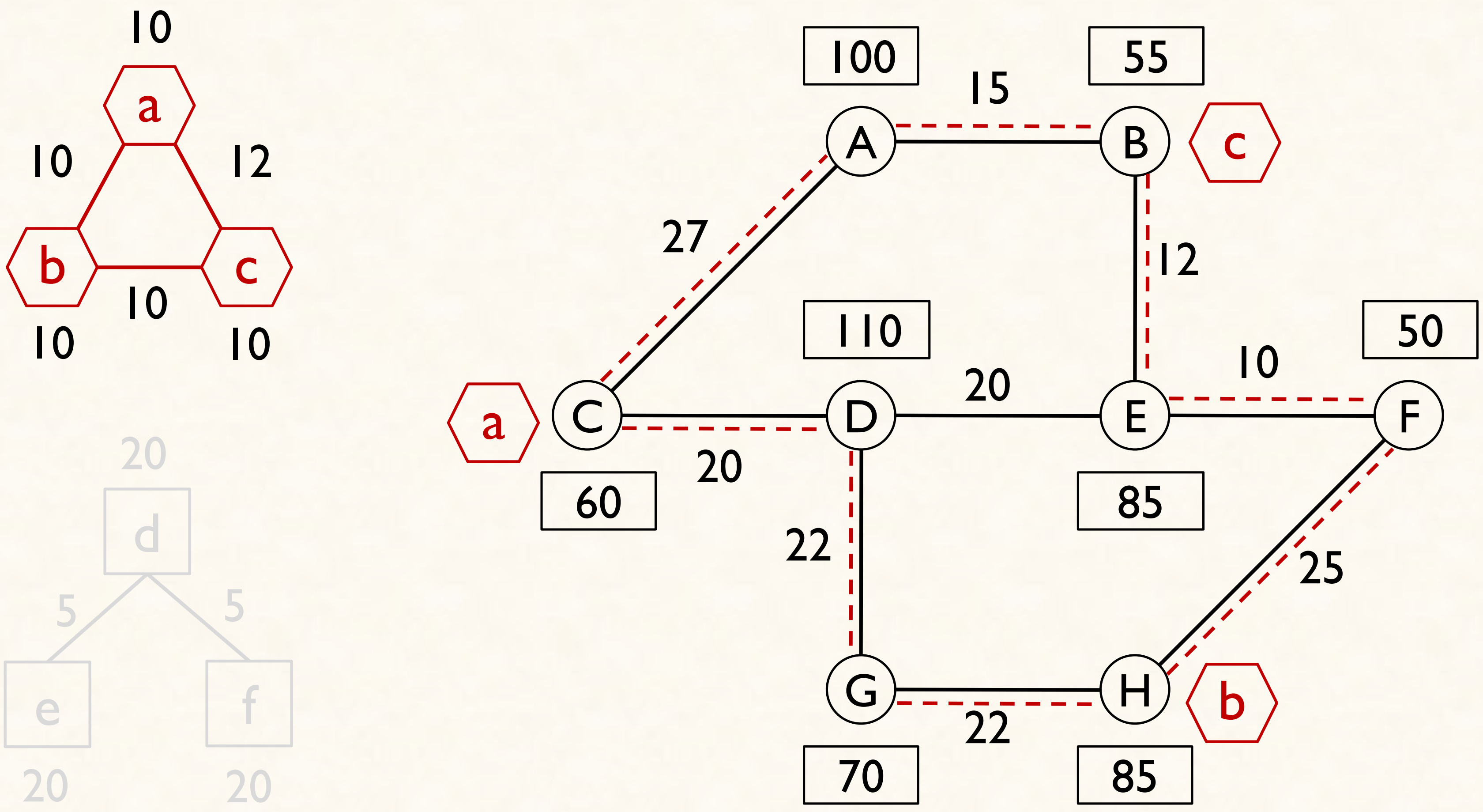

# Impact of Dynamicity: An Empirical Study

*300+* SNodes, *900+* SLinks. (*AS6461*), *4 – 8* VNodes/VN (*50%* conn. pr.)

Poisson Arrival (*10VNs/100 T.U.*), Exponential Lifetime (*1000 T.U.*)

Optimal embedding that minimizes total bandwidth consumption

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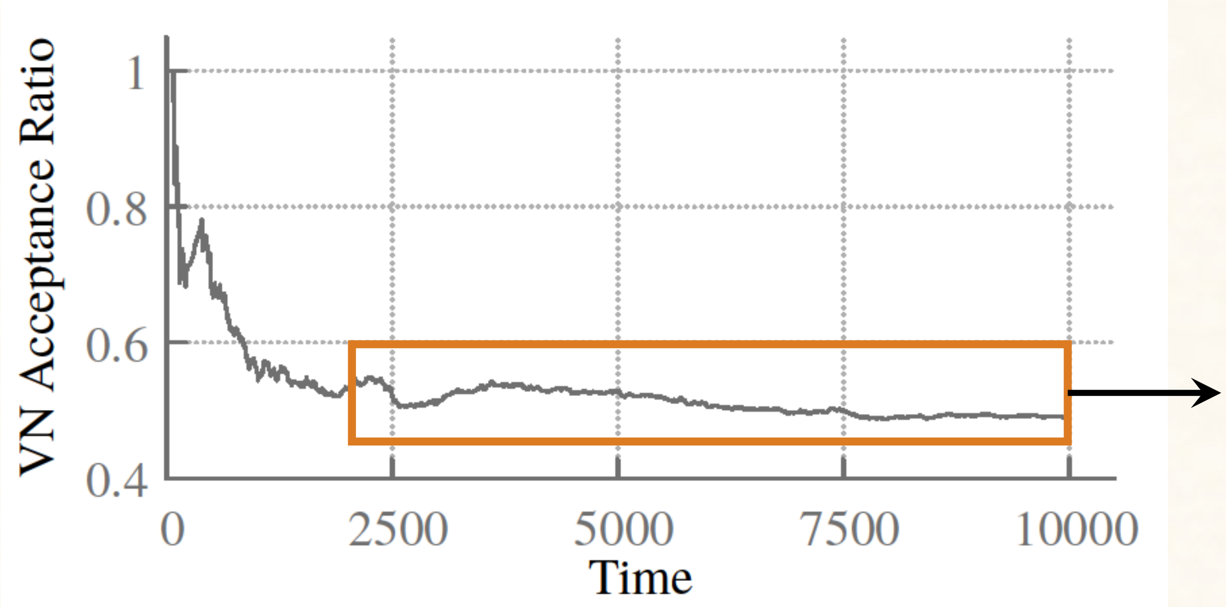

*Acceptance Ratio capped at ~50%*

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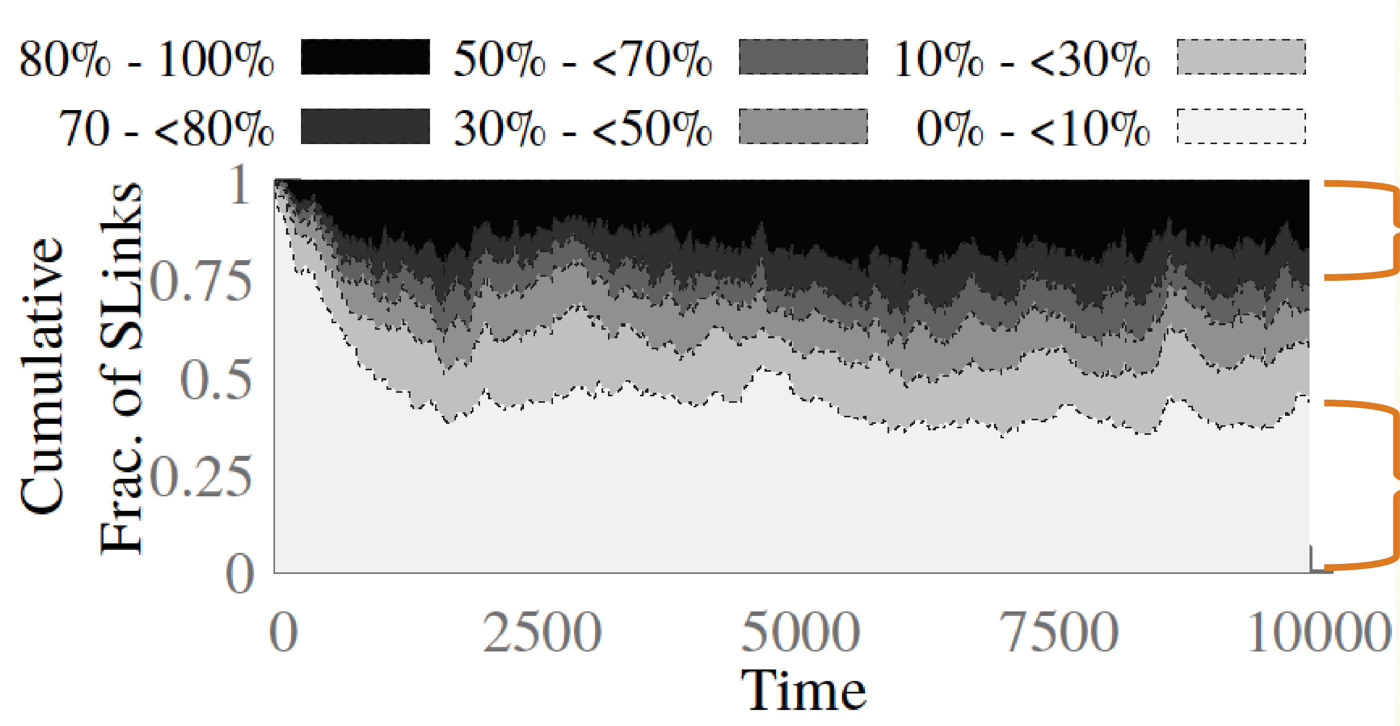

*~30% links utilized >= 70%*

*~40% links utilized <= 10%*

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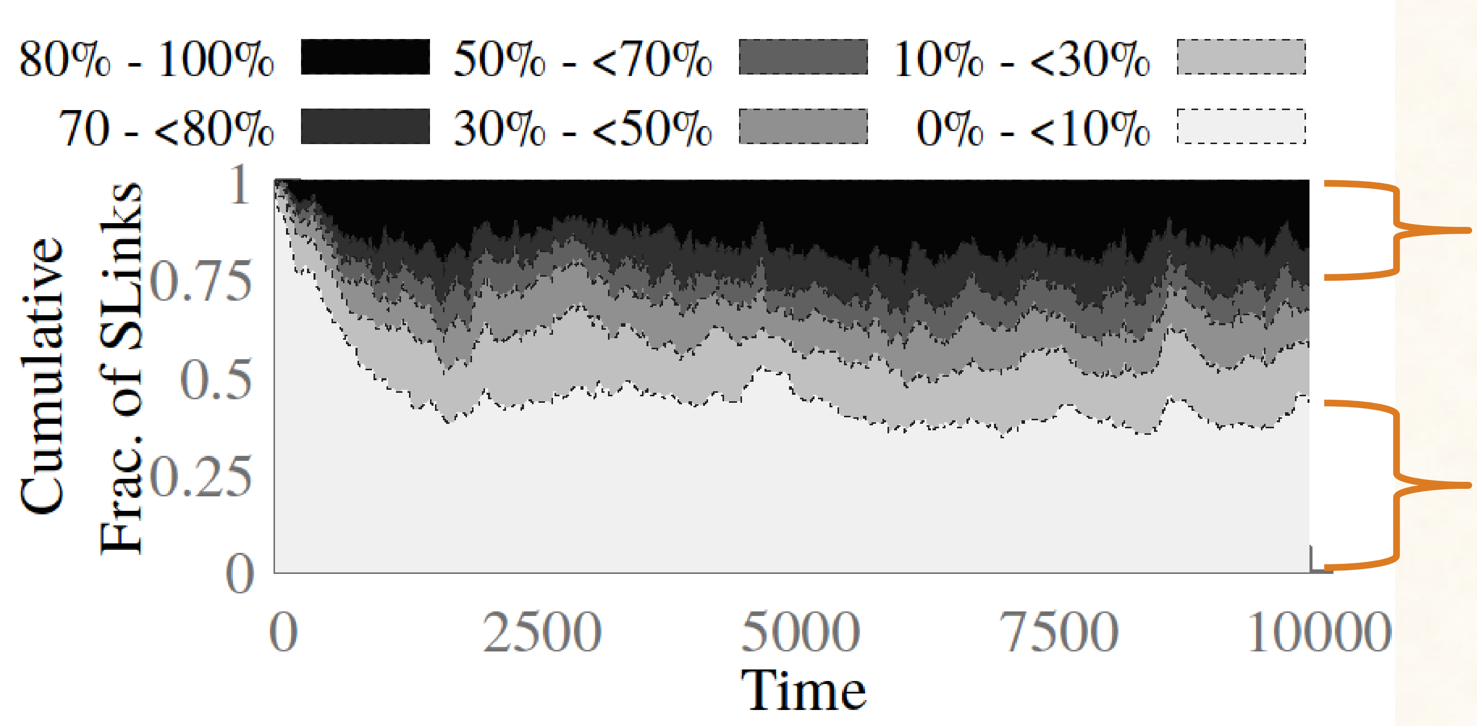

*~30% links utilized >= 70%*

*~40% links utilized <= 10%*

*Skewed Substrate Link Utilization* impacts *Acceptance Ratio* !!

## Key Question:

How to cope with the dynamicity in Network Virtualization when little or no information about the future is available?

## (One Possible) Answer:

Periodically adjust the embedding to eliminate “*bottlenecks*” and “*optimize resource usage*”

# The Problem

Reallocation of Virtual Network Embedding (ReViNE)

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Objective: Eliminate Substrate Bottlenecks* and Minimize Resource Usage**

* Links with utilization >= θ%

** In our case, bandwidth consumed by virtual links

# Our Proposal

A suit of solutions to ReViNE

ReViNE-OPT

ILP-based optimal solution*
(NP-Hard)

ReViNE-FAST

Simulated Annealing-based
heuristic

* Details is in the paper

# Do We Need A Heuristic?

## Computing Optimal Solution is Very Expensive

*H/W Configuration:* 8x10 Core Intel Xeon E5 CPU, 1TB RAM

*Observed limits for ILP*: 50 – 100 Node SN with < 60VNs took several hours and several 10s of GB RAM

## ILP Can Yield Impractical Solutions

- A practical solution contains a sequence of operations to reach the re-optimized state (also satisfy *make-before-break* constraint)
- Not possible to model in ILP. Final state obtained from ILP can be unreachable without violating *make-before-break* constraint.

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# Heuristic Design

## Our Objectives are Conflicting

Minimize Bottleneck Links

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CONFLICT !!

Instead of an one-shot algorithm, *use a meta-heuristic (Simulated Annealing)* to explore the solution space and find a balance.

# Simulated Annealing: Neighborhood Generation

## Bottleneck Substrate Link Reconfiguration

Select a bottleneck substrate link and reroute virtual links using that bottleneck link until it is no longer a bottleneck.

## Virtual Node Migration

Randomly select a VN and re-embed a random virtual node and incident virtual links.

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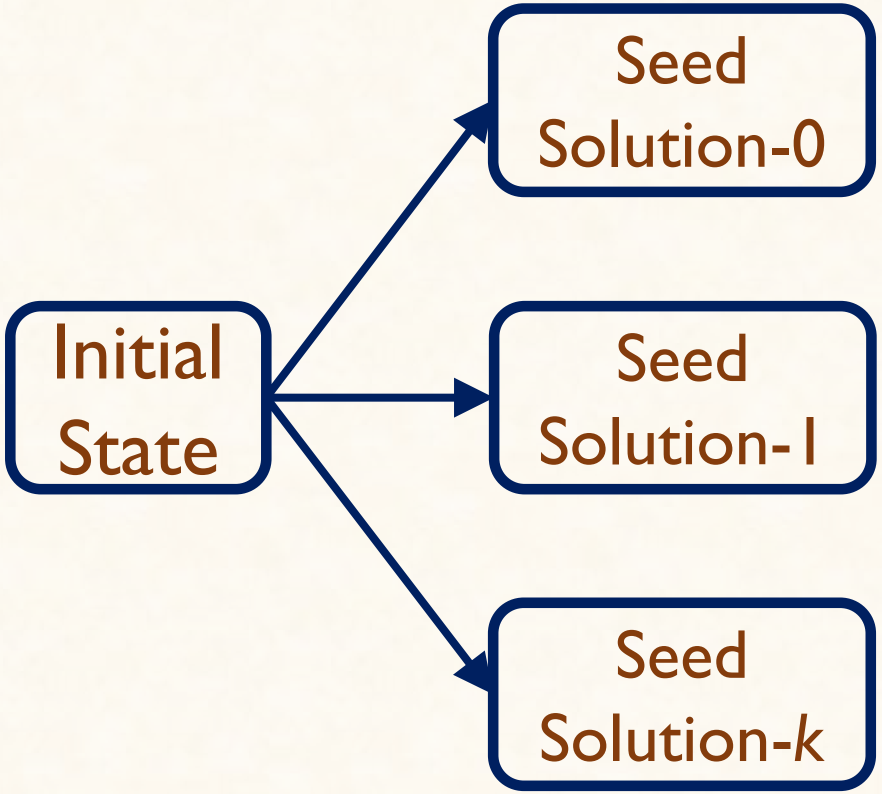
# Exploiting Multi-core CPU

## Parallel Simulated Annealing Searches



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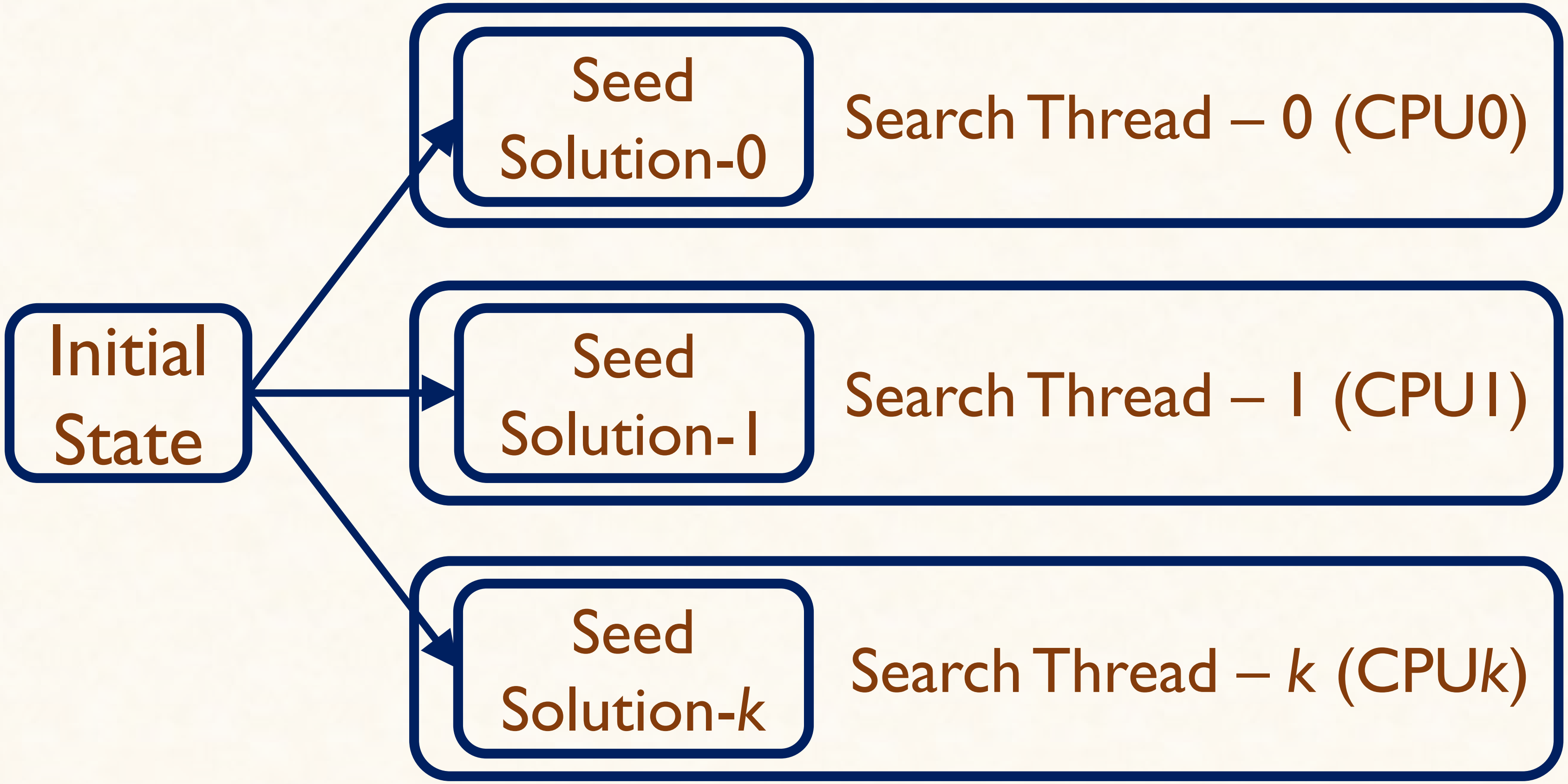

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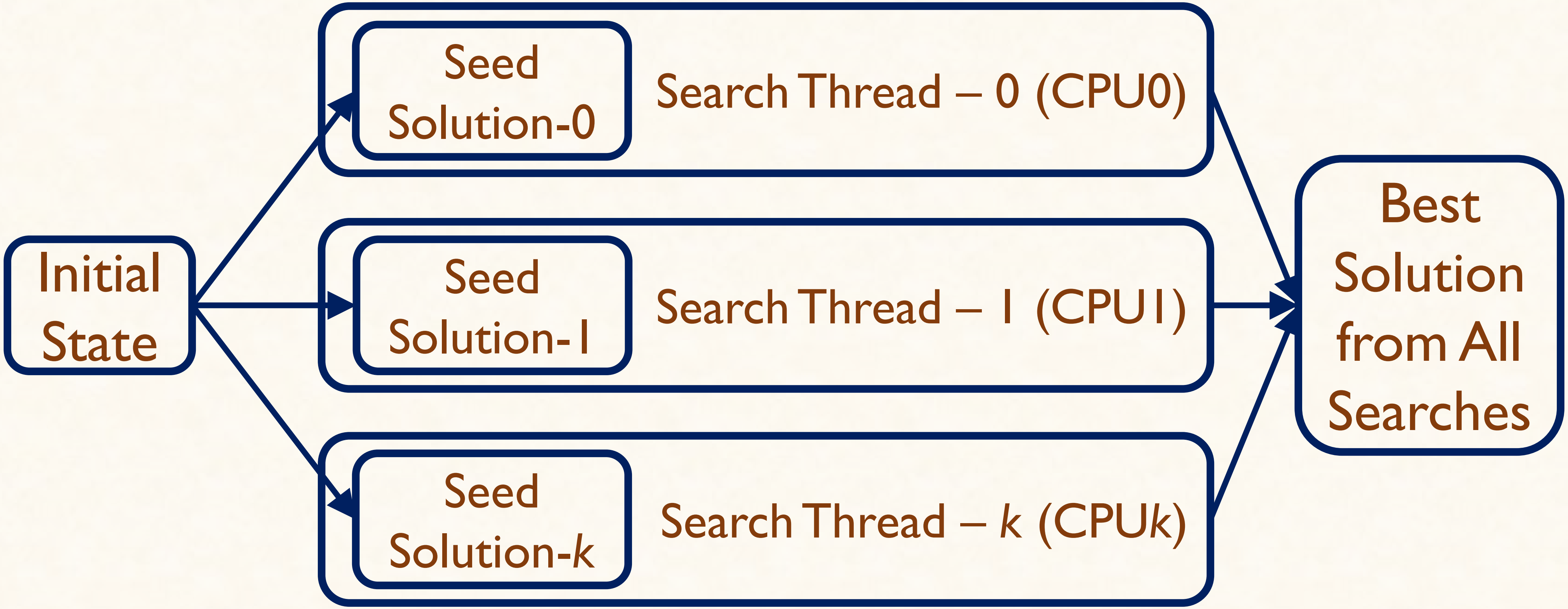


Initial State

Seed Solution-0

Search Thread – 0 (CPU0)

Seed Solution-1

Search Thread – 1 (CPU1)

Seed Solution-*k*

Search Thread – *k* (CPU*k*)

Best Solution from All Searches

# Evaluation: Setup

- ReViNE-FAST compared with ReViNE-OPT and SA-realloc*
- Parameters
  - 50 – 100 node synthetic substrate network
  - Larger test cases with 1000 node (heuristic only comparison)
  - Mean degree between 3.6 – 4
  - Mean substrate link utilization 60% - 80%
  - Bottleneck substrate link threshold 70% - 90%

* Masti, S,. *et al.* "Simulated Annealing Algorithm for Virtual Network Reconfiguration", *8th Euro-NGI Conference on Next Generation Internet*, IEEE, 2012, pp. 95-102.

# ReViNE-FAST Performance Highlights

Within ~*19% of optimal* (ReViNE-OPT) on avg.

~*3x less cost* compared to SA-realloc on avg.

~*5% more VNs accepted* on avg. when combined with optimal VN embedding algorithm

# Summary

ReViNE is one possible way to address the dynamicity in VN arrival/departure

ReViNE-FAST, a simulated annealing based heuristic performs ~*19% within the optimal* (empirically evaluated)

ReViNE-FAST performs ~*3x better* than S.O.A Simulated Annealing-based heuristic

# Questions?

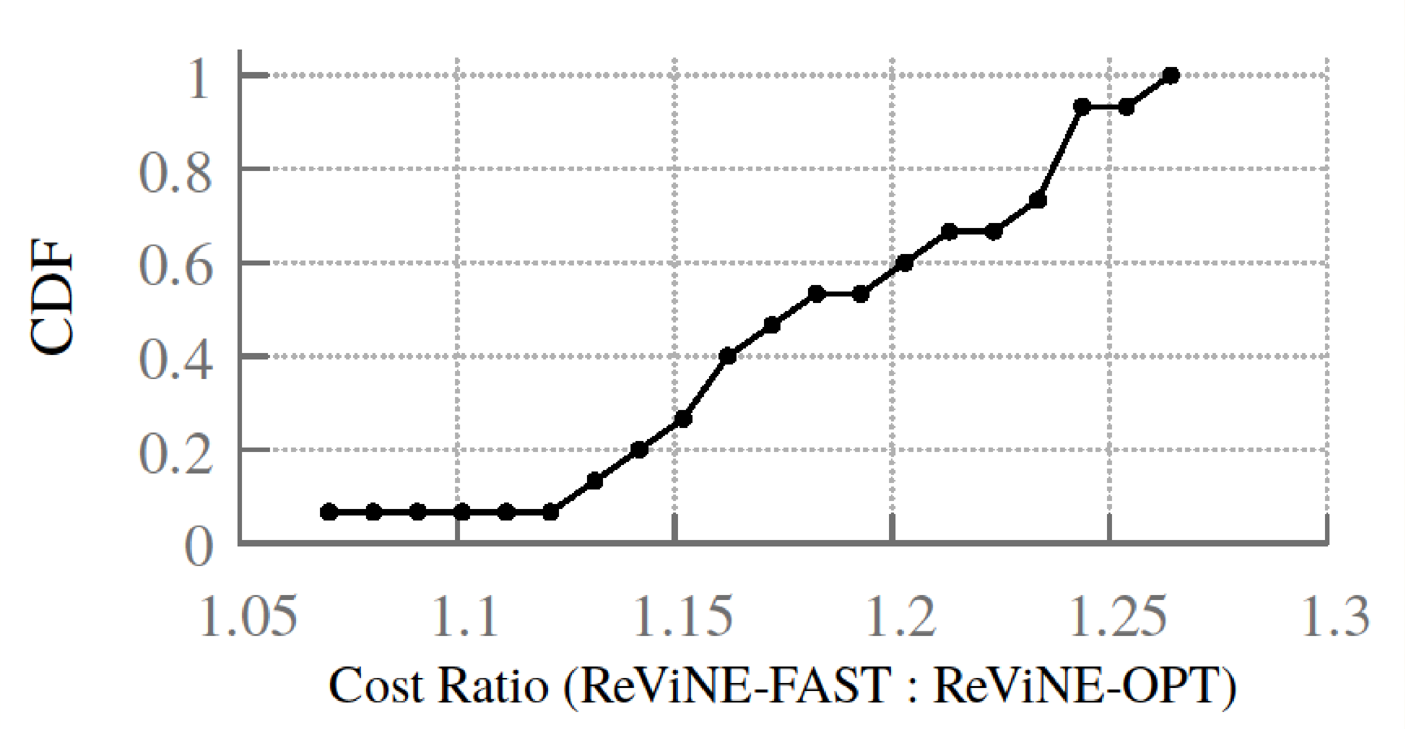
Source Code

CPLEX: https://github.com/srcvirus/vne-reallocation-cplex

Simulated Annealing: https://github.com/srcvirus/vne-reallocation-sa

# Backup

# ReViNE-FAST vs ReViNE-OPT



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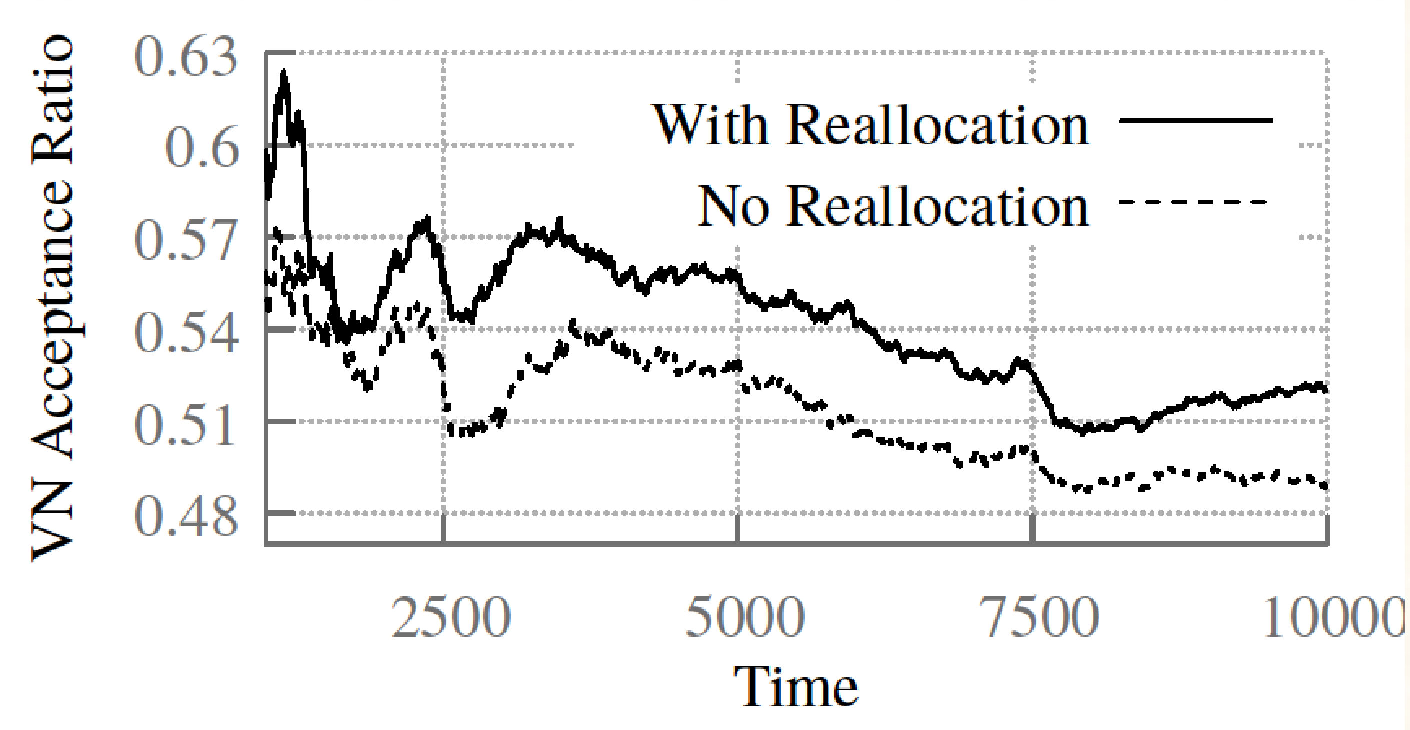
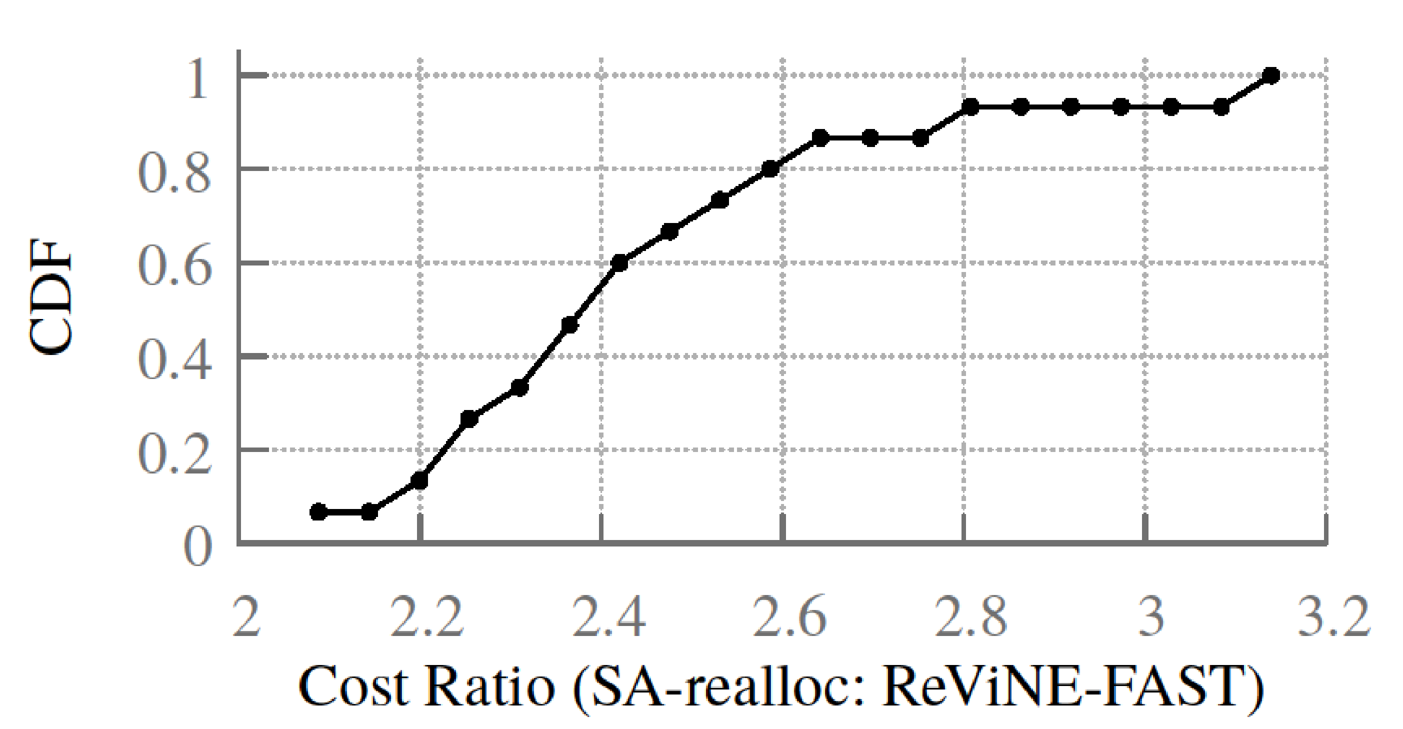
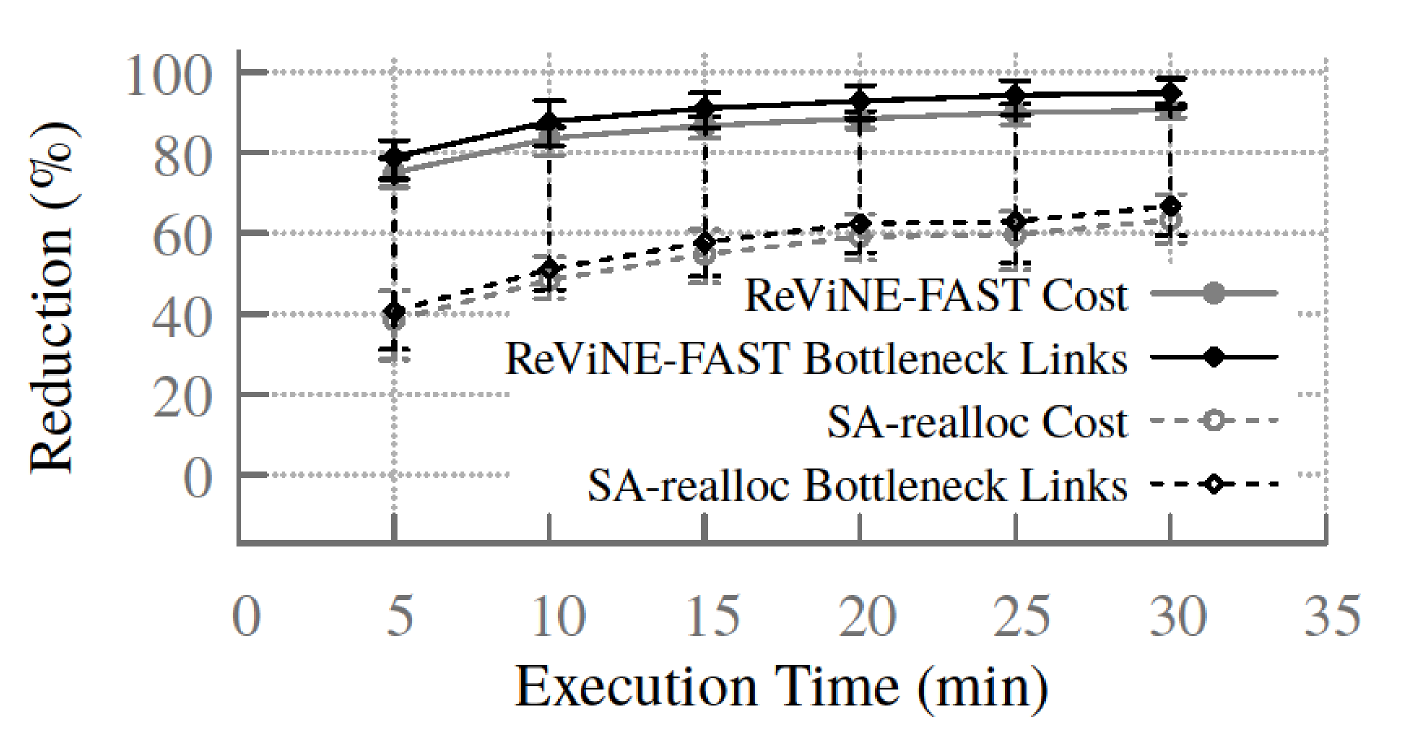


# ReViNE-FAST vs SA-Realloc (Large Cases)



# ReViNE-FAST Convergence (Large Cases)



# State-of-the-art

*Reactive One-shot Approaches*: Reallocate VNs when a new VN cannot be embedded [1][2]

*Proactive One-shot Approaches*: Periodically reallocate VNs [3][4]

*Meta-heuristic Approaches*: Simulated Annealing [5], Particle Swarm Optimization [6]

[1] Y. Zhu *et al.*, "Algorithms for assigning substrate network resources to virtual network components", IEEE INFOCOM, 2006.

[2] M. Yu, *et al.* "Rethinking virtual network embedding: substrate support for path splitting and migration", ACM SIGCOMM CCR, 38(2), 2008, pp. 17–29.

[3] N. F. Butt, *et al.* "Topology-awareness and reoptimization mechanism for virtual network embedding", Int. Conf. on Research in Networking 2010.

[4] P. N. Tran, et al., "Optimal mapping of virtual networks considering reactive reconfiguration," IEEE CloudNet, 2012.

[5] S. Masti, *et al.* "Simulated Annealing Algorithm for Virtual Network Reconfiguration", 8th Euro-NGI Conf. on Next Generation Internet, IEEE, 2012.

[6] Y. Yuan, *et al.* ,"Discrete particle swarm optimization algorithm for virtual network reconfiguration," Int. Conf. in Swarm Intelligence, 2013.