Simplifying Software-Defined Network Optimization Using SOL

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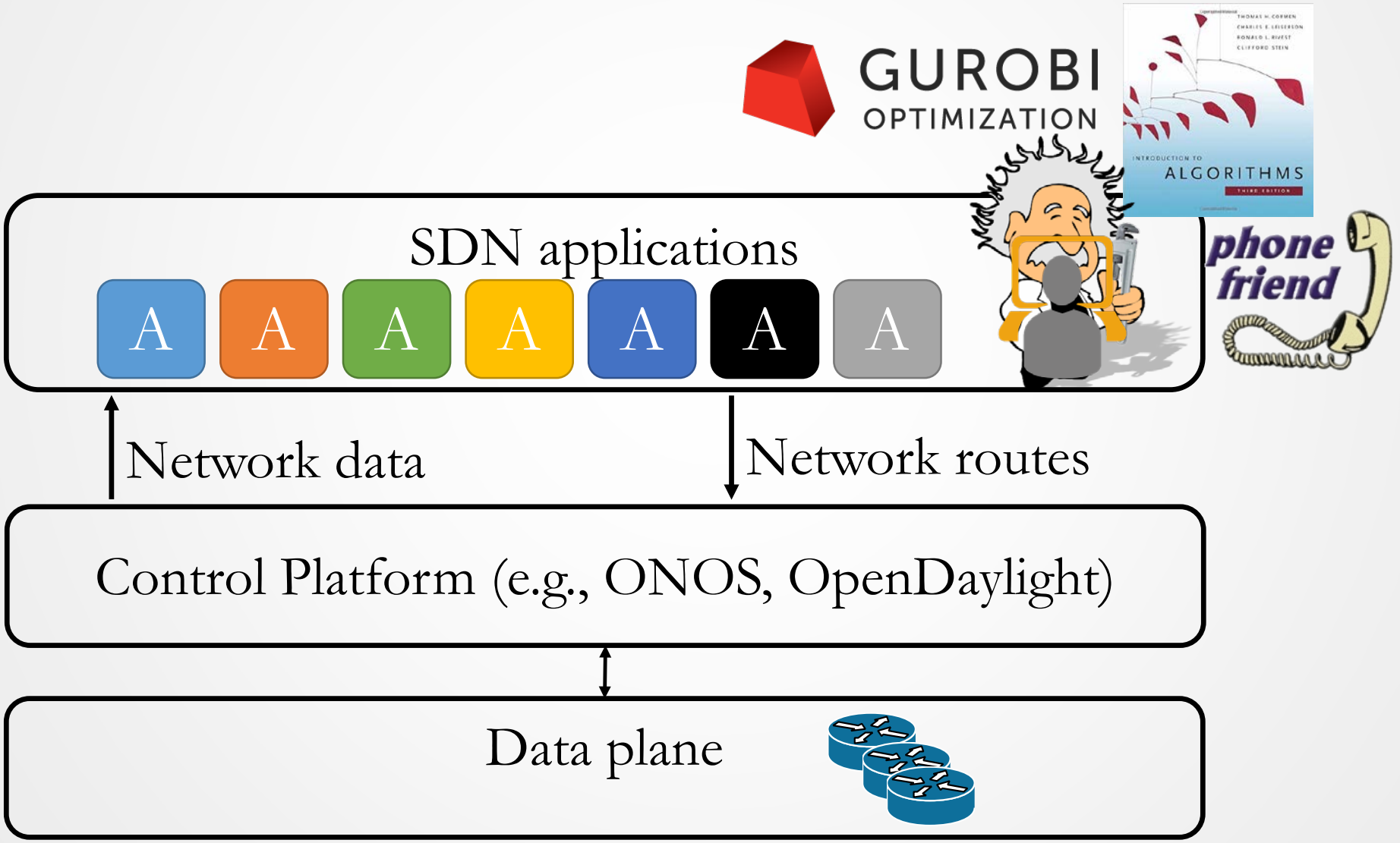
Overview: SDN



SDN Application Classes and Features

Classes	**Traffic engineering** SWAN (2013) B4 (2013)	**Service chaining** SIMPLE (2013) Panopticon (2014)	**Topology reconfiguration** ElasticTree (2010) Response (2011)
Classes	**Offloading** APLOMB (2012) SNIPS (2014)	**Dynamic service chaining** Bohatei (2015) FlowTags (2013)	**Network function virtualization** E2 (2015) Slick (2015)
Features	**Composition** Corybantic (2013) FlowVisor (2009)	**Fault tolerance** FatTire (2013)	…

Current Process

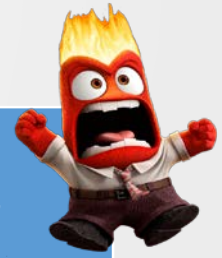
Take theory & optimization courses

Formulate the problem

Solve with a solver

Not fast enough

- NP hard?

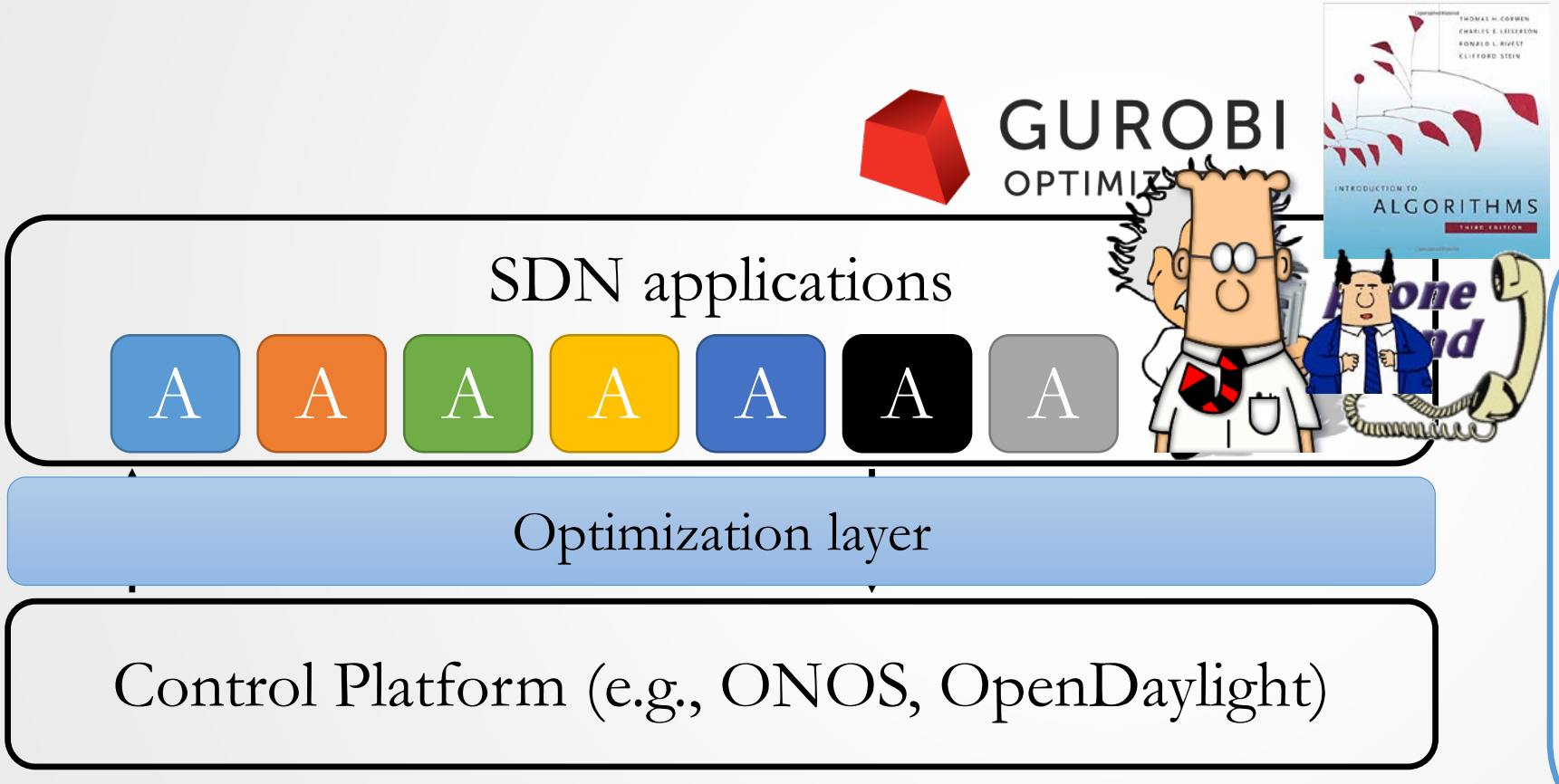


Develop heuristic

Parse solution

Deploy

Our Vision

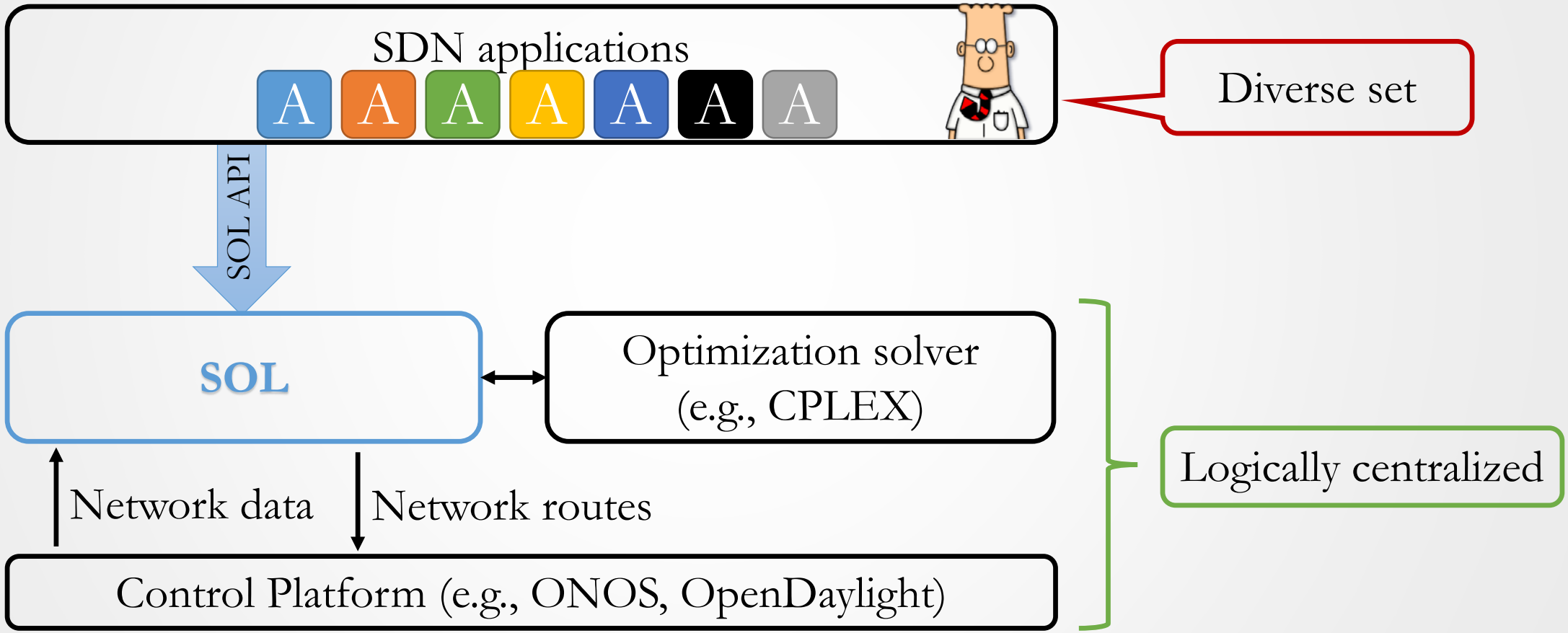


- No custom heuristics
- Focus on high-level network goals
- Rapid prototyping
- App = 20 lines of code

Challenge: Generality + Efficiency

Approach	Generality	Efficiency
Frameworks	✓	✗
Custom solutions	✗	✓
SOL	✓	✓

SOL: SDN Optimization Layer



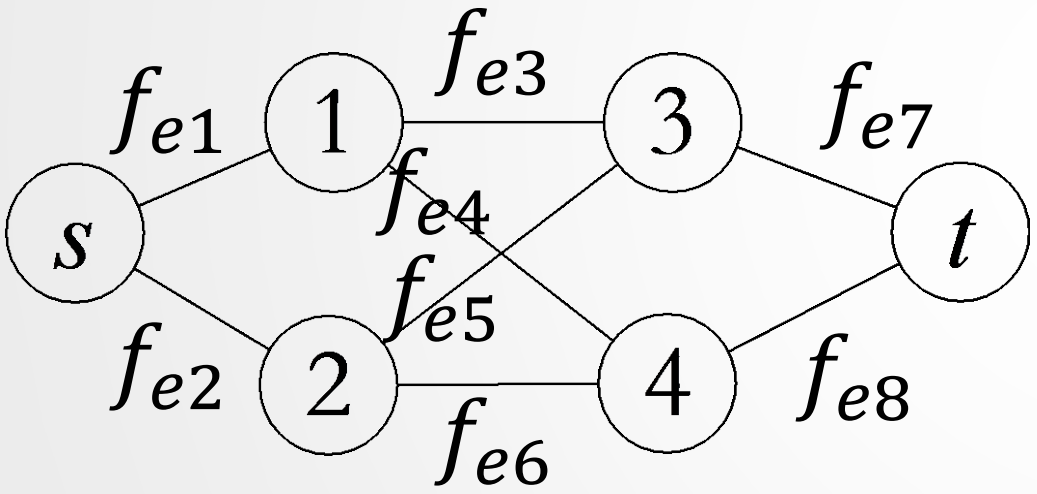
Insight: Path Abstraction

- Problems are *recast* to be **path-based**
- Policies are path predicates

Path-based Recasting: MaxFlow

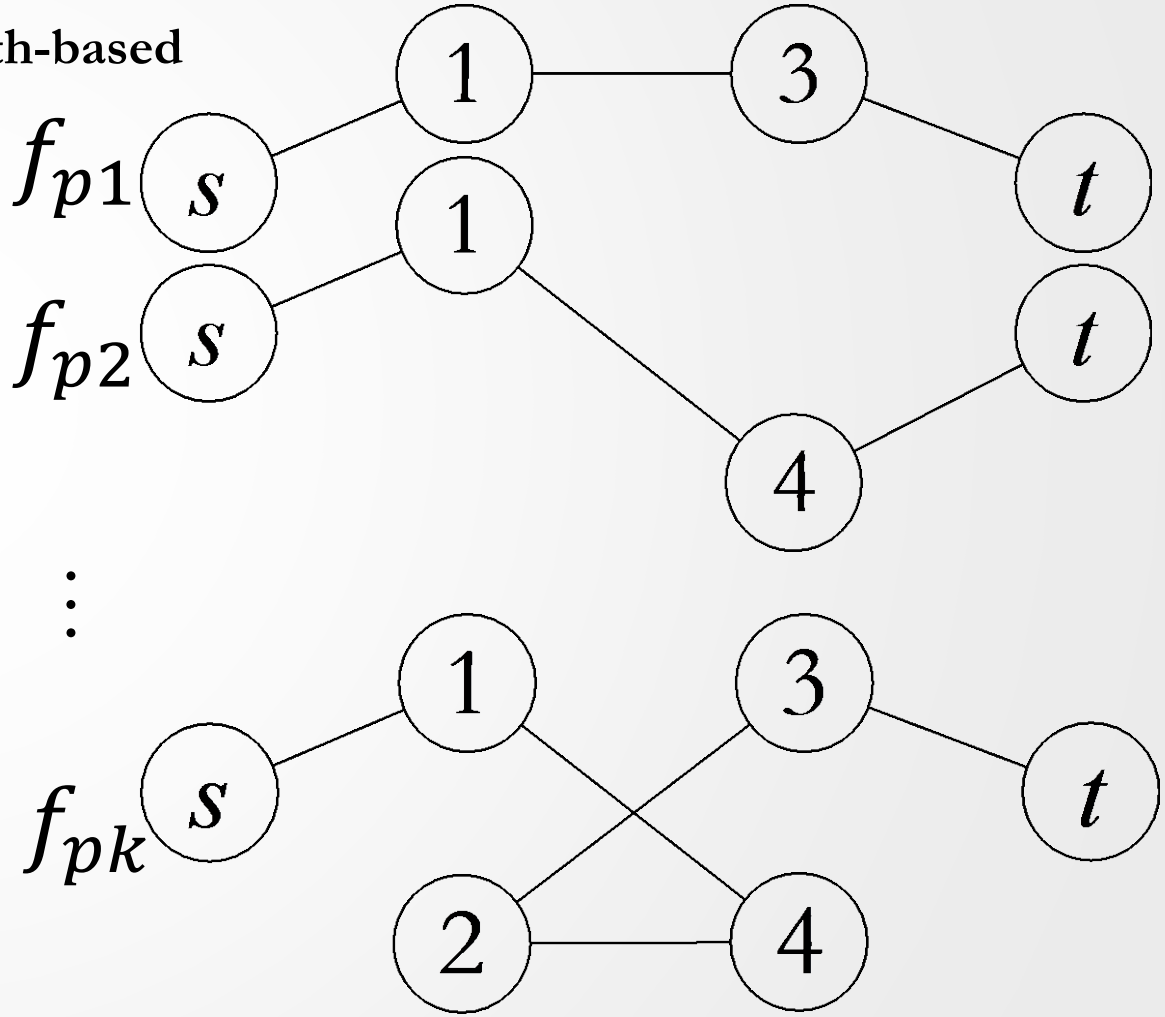
Edge-based

f: amount of flow



$$f_{e1} = f_{e3} + f_{e4}$$

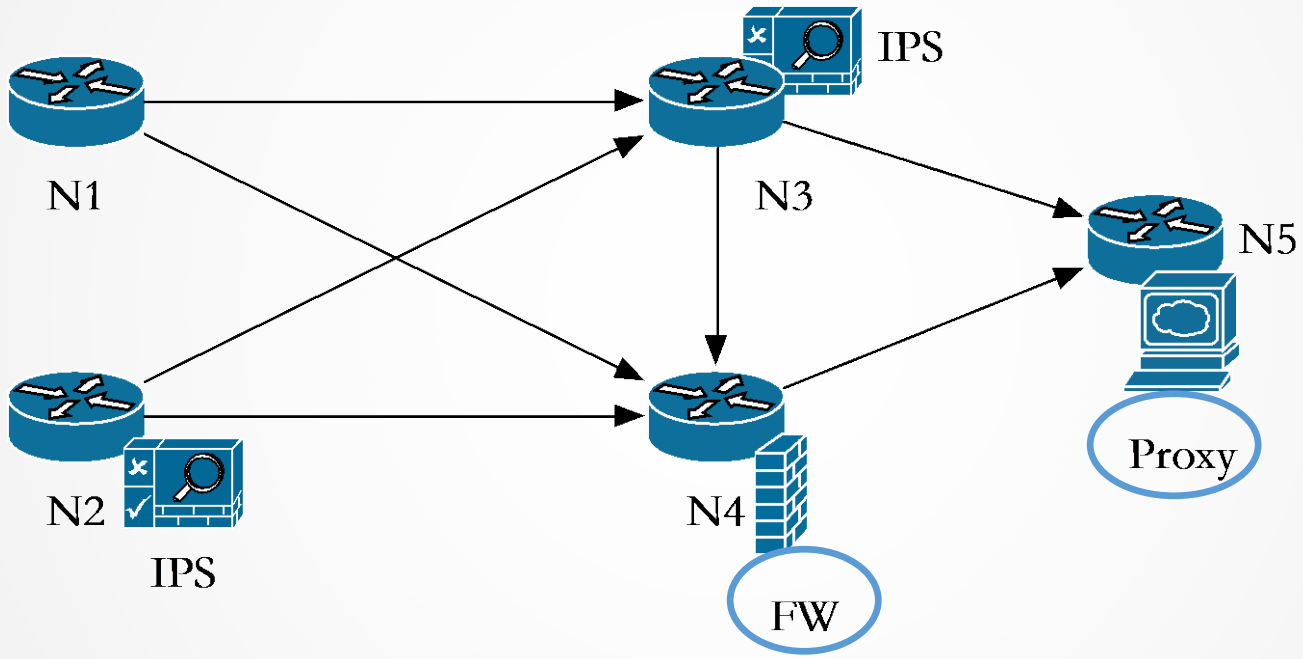
Path-based



$\sum_{i=1}^{k} f_{pi}$ = demand

Policies as Path Predicates

N1→N5
Web, 100 Mbps
FW→Proxy



Valid paths:

- N1-N4-N5
- N1-N3-N4-N5

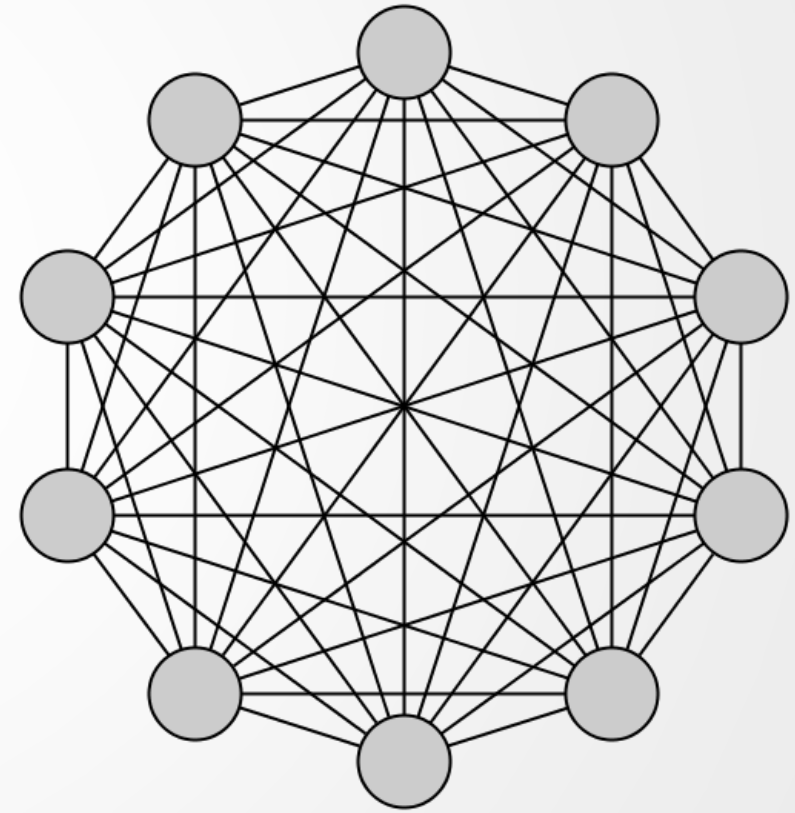
Invalid paths:

- N1-N3-N5

Generality

Path Challenge

Exponential number of paths



Large optimization size

Long run time = Bad efficiency

SOL Process

Path generation → Path selection → Optimization → Rule generation

1. Enumerate all simple paths
2. Keep valid paths (according to a predicate)

Offline step

Pick a subset of paths

This acts as a **heuristic**

1. Model resource usage and constraints
2. Solve

Use a controller to configure data plane paths

Efficiency

Implementation

- Python library; interfaces with CPLEX solver and ONOS controller
- Prototyped applications
  - MaxFlow, Traffic engineering, latency minimization
  - ElasticTree (Heller et al.), Panopticon (Levin et al.), SIMPLE (Qazi et al.)

Example: MaxFlow

Topology input

Path generation + selection

```
1. opt, pptc = initOptimization(topo, trafficClasses, nullPredicate, 'shortest', 5)
2. opt.allocateFlow(pptc)
3. linkcapfunc = lambda link, tc, path, resource: tc.volBytes
4. opt.capLinks(pptc, 'bandwidth', linkConstrCaps, linkcapfunc)
5. opt.maxFlow(pptc)
6. opt.solve()
```

Traffic flows

Resource consumption

Global goal (objective function)

Example: Traffic Engineering

```
1. opt, pptc = initOptimization(topo, trafficClasses, nullPredicate, 'shortest', 5)
2. opt.allocateFlow(pptc)
3. linkcapfunc = lambda link, tc, path, resource: tc.volBytes
4. opt.capLinks(pptc, 'bandwidth', linkConstrCaps, linkcapfunc)
5. opt.routeAll(pptc)
6. opt.minLinkLoad('bandwidth')
7. opt.solve()
```

Route all traffic
Minimize bandwidth load

Key Questions

- Does it reduce development effort for more complex applications?
- Is it faster than the original optimization?
- Is it any worse than optimal?

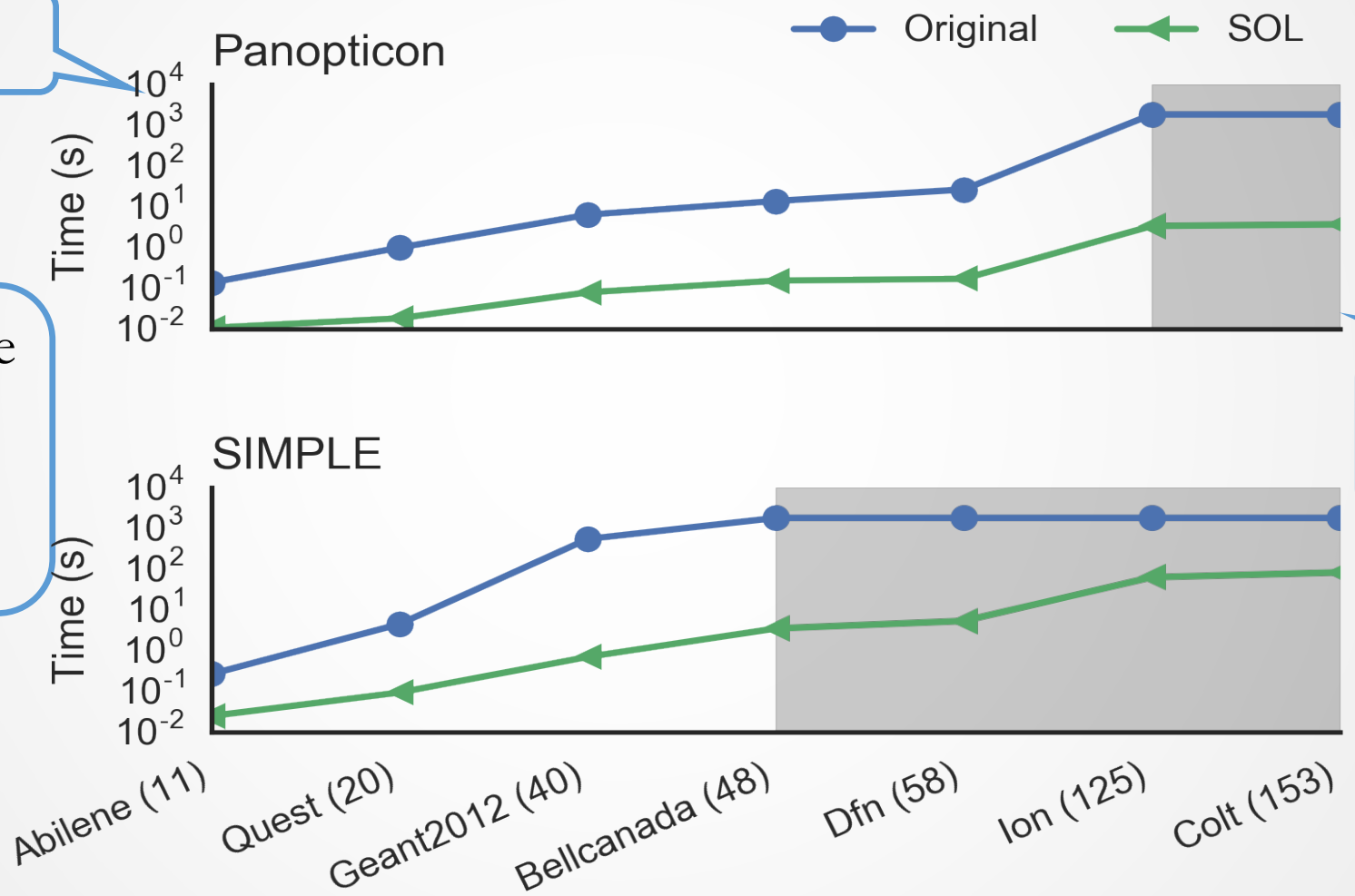
Development Effort

Application	SOL lines of code	Estimated improvement
ElasticTree (Heller et al.)	16	21.8×
Panoption (Levin et al.)	13	25.7×
SIMPLE (Qazi et al.)	21	18.6×

Optimization Runtime

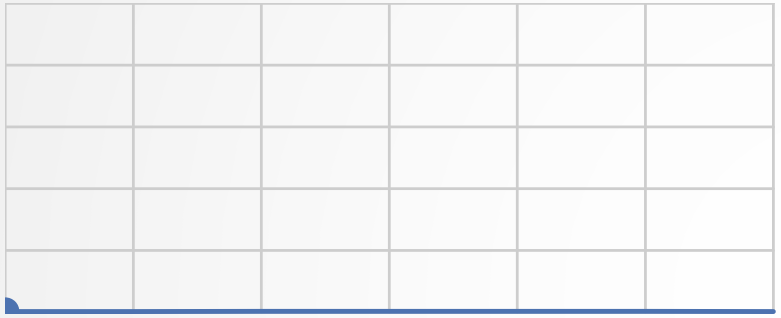
Log Scale

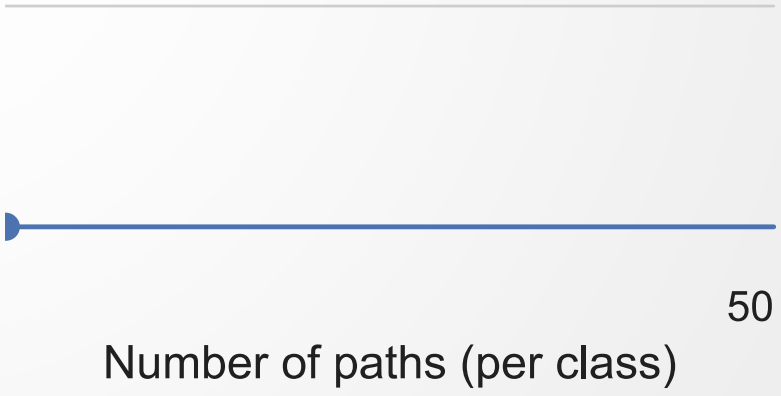
- Orders of magnitude **faster**
- Less than 1% away from **optimal**



Shaded: No solution by the original within 30 minutes

Runtime as Function of Number of Paths



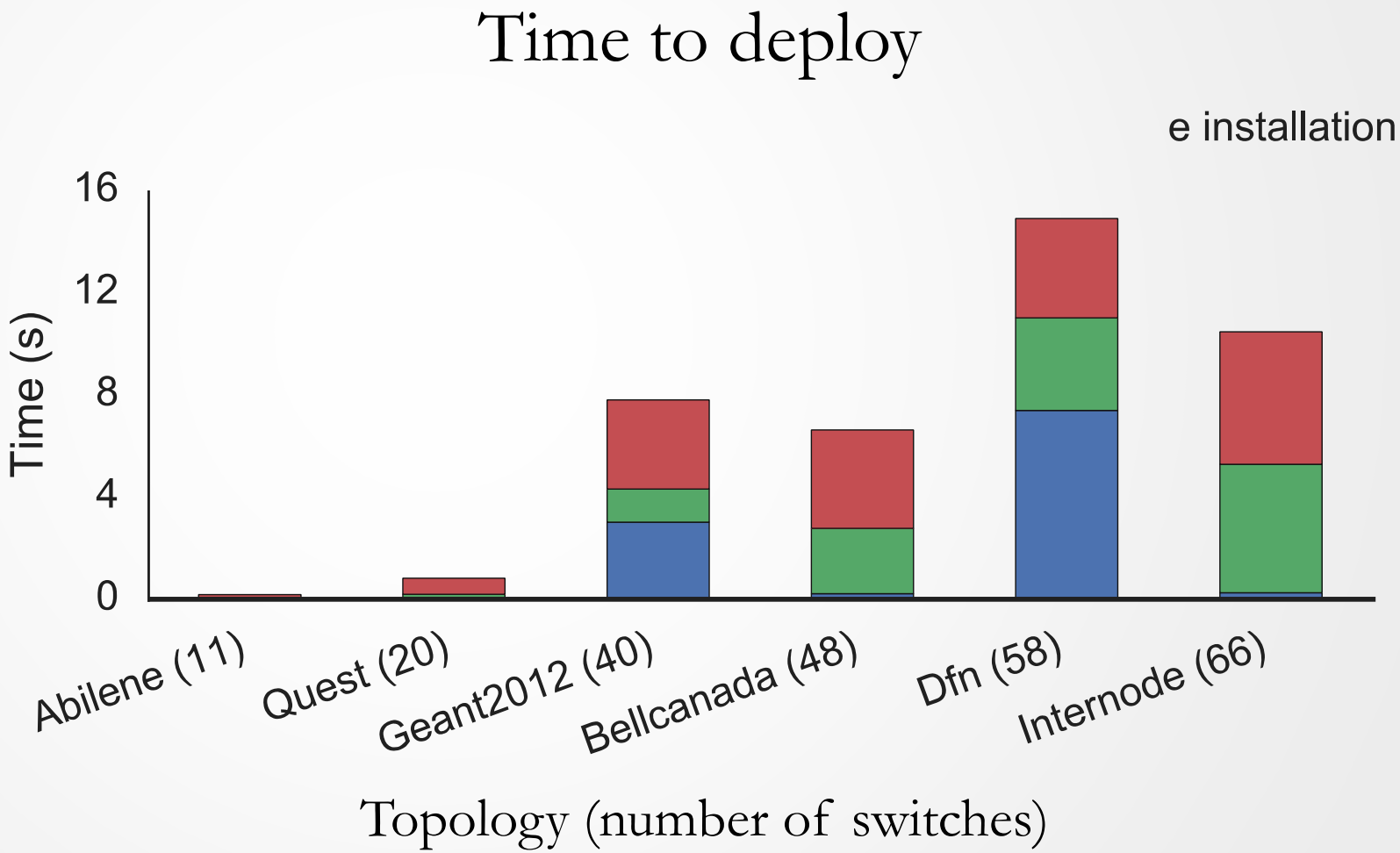


Mininet Tests

Setup:

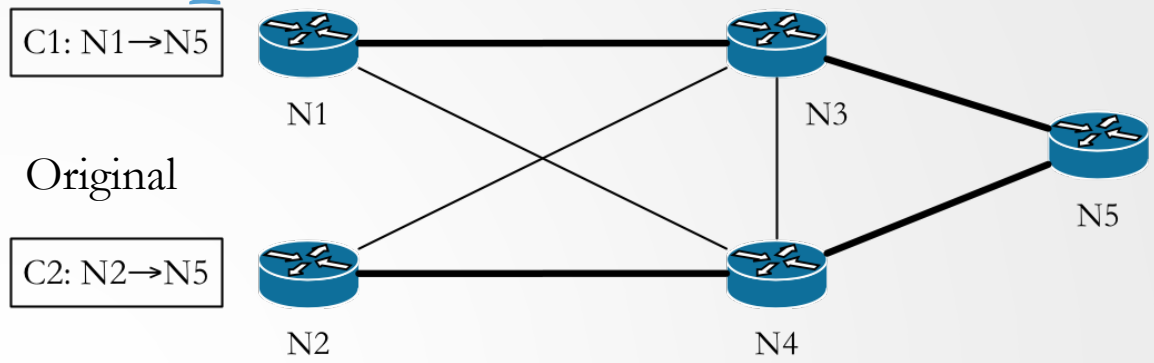
- Traffic engineering application
- Mininet + ONOS

0 → functioning network
in 15 seconds

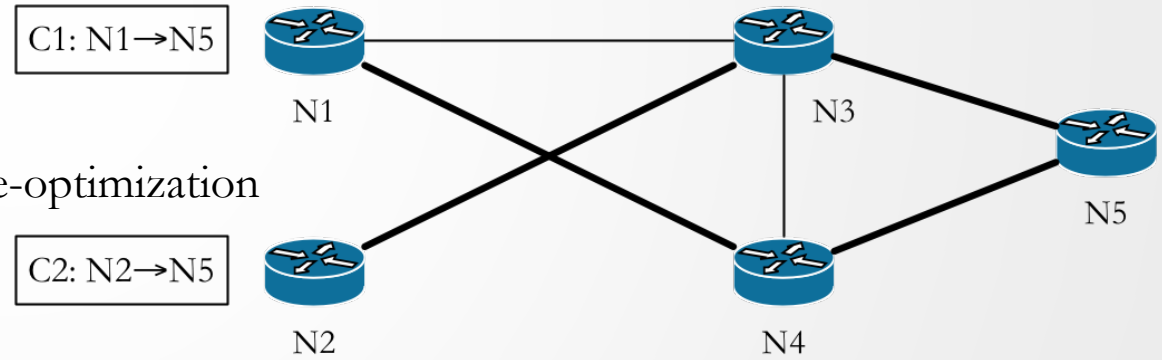


"Mindiff" Across Optimizations

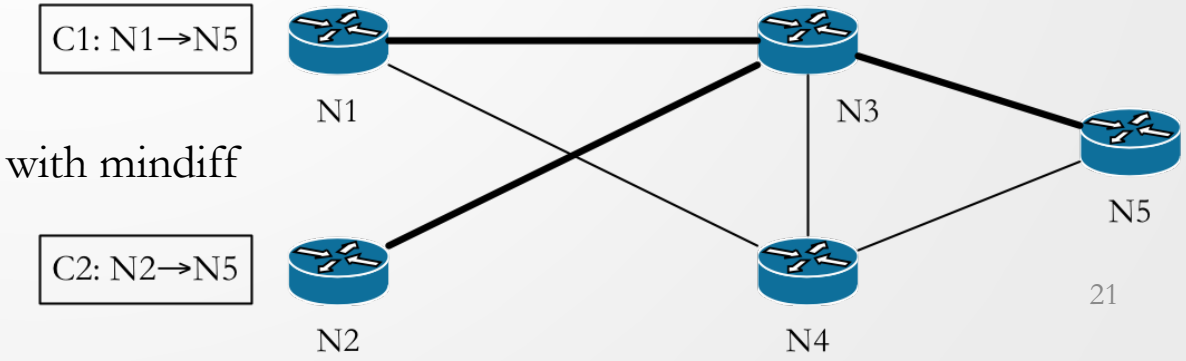
- Minimize network churn
- Minimize reconfiguration time
- Application agnostic



Original



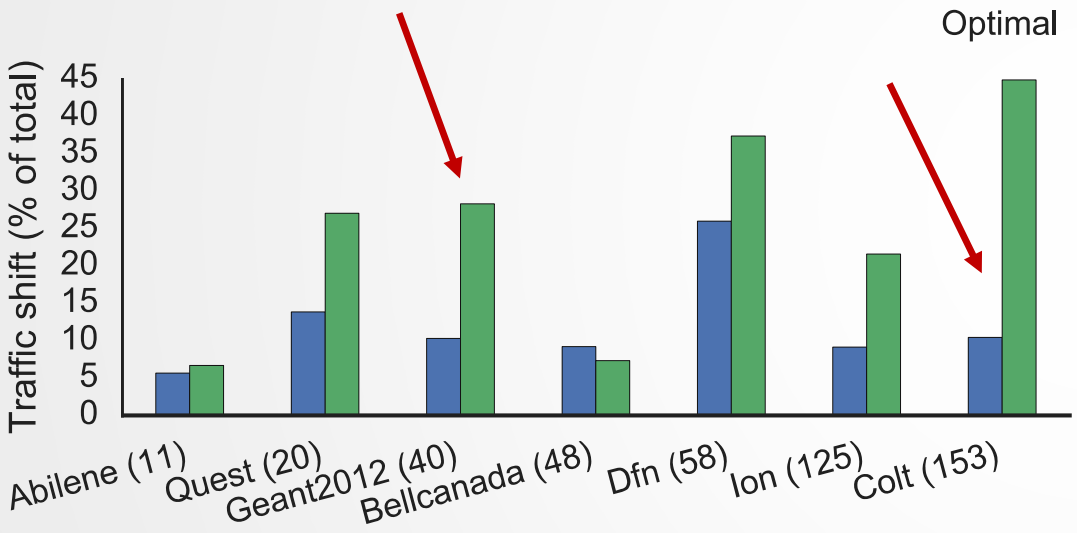
Re-optimization

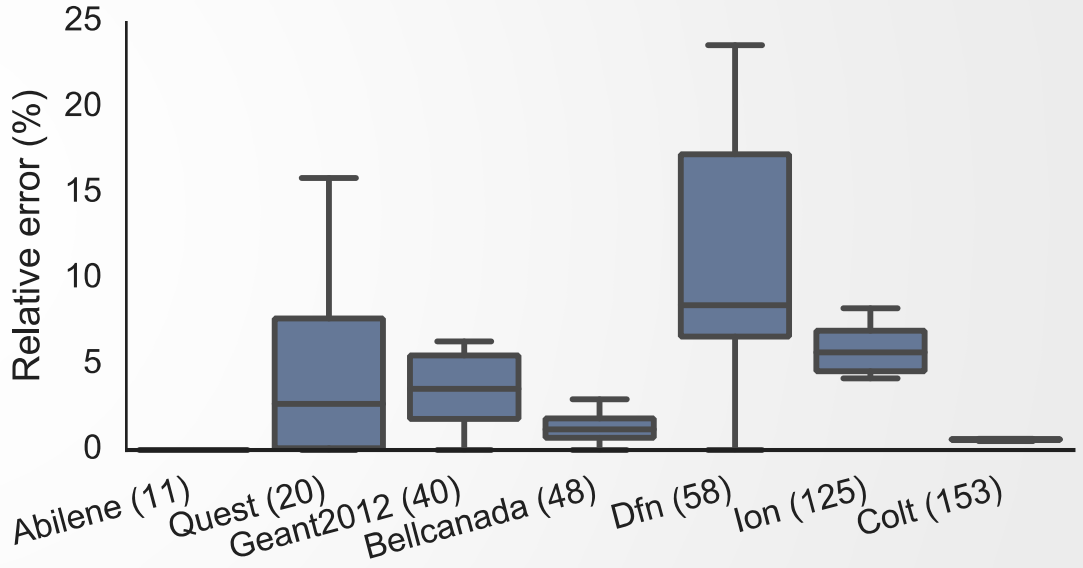


Re-optimization with mindiff

Results: Reconfiguration

Traffic engineering application; Change in traffic demands triggers re-computation





Lower is better

Summary

- Getting SDN benefits requires a lot of optimization knowledge
- SOL lowers barrier of entry for developers
- Leverages the path abstraction: generation + selection
- Efficient: deploy in seconds!

- Code available at https://github.com/progwriter/SOL

Thank you!

Questions?