Panopticon: Reaping the benefits of Incremental SDN Deployment in Enterprise Networks

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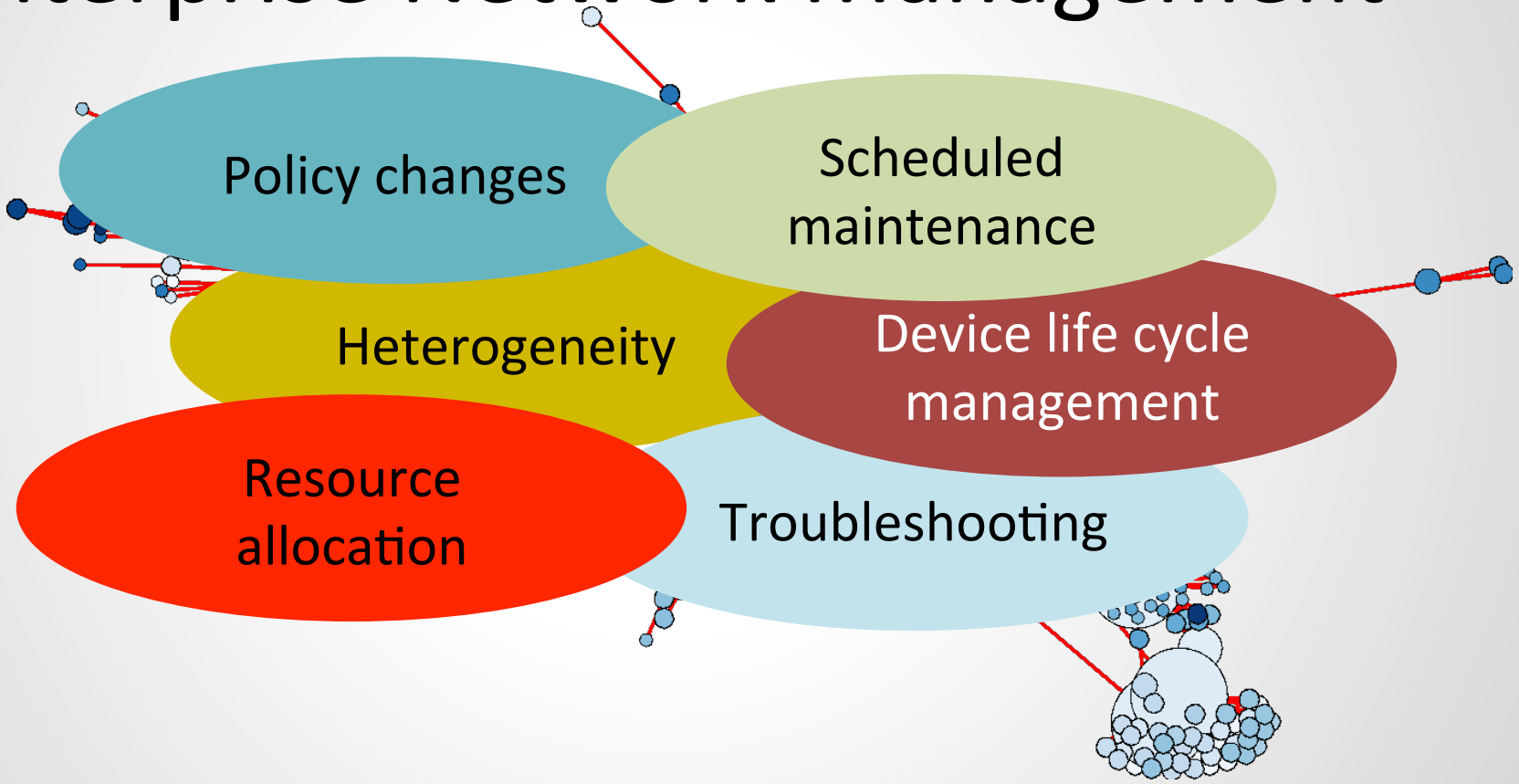
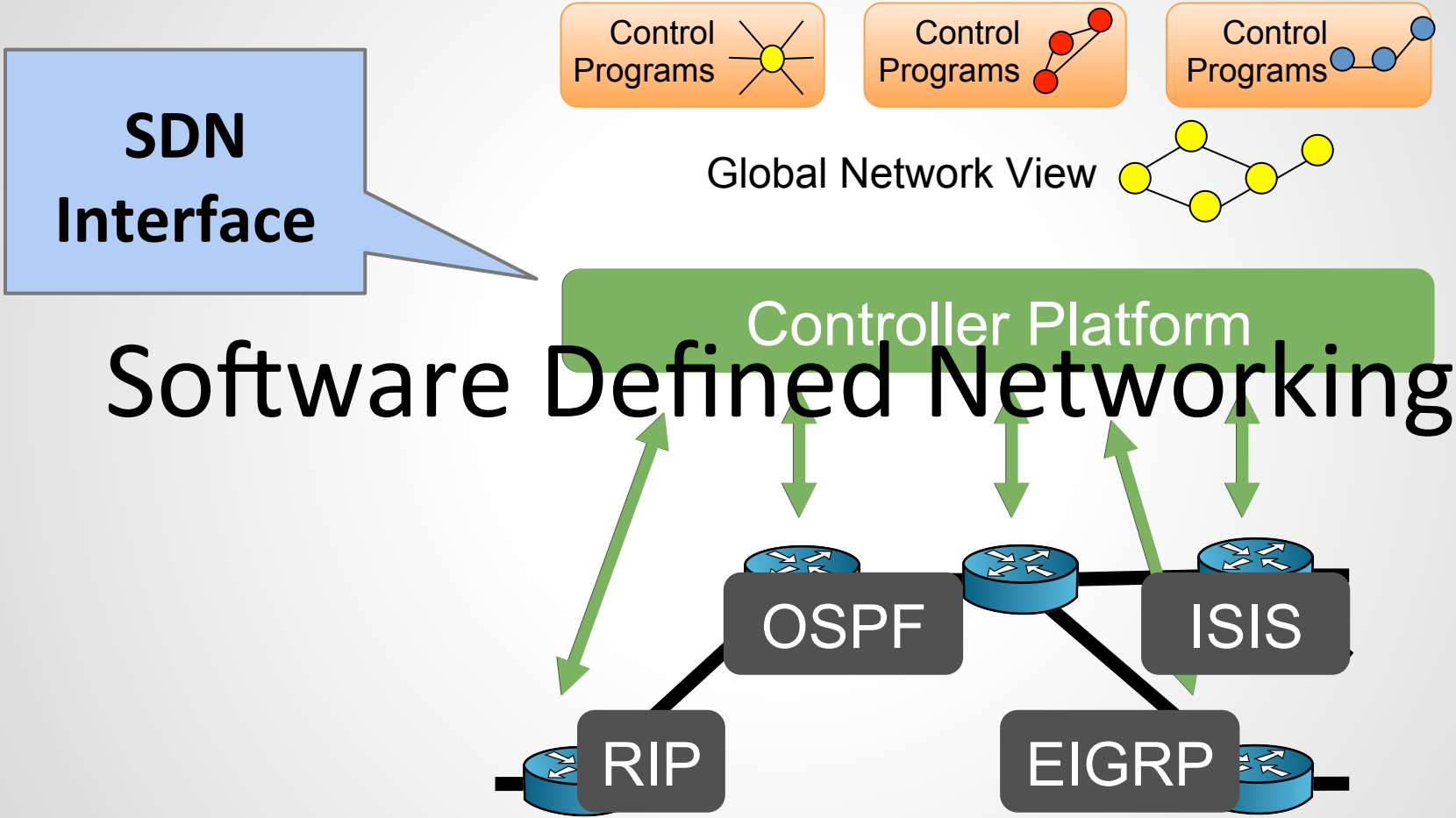
Enterprise Network Management



Software Defined Networking

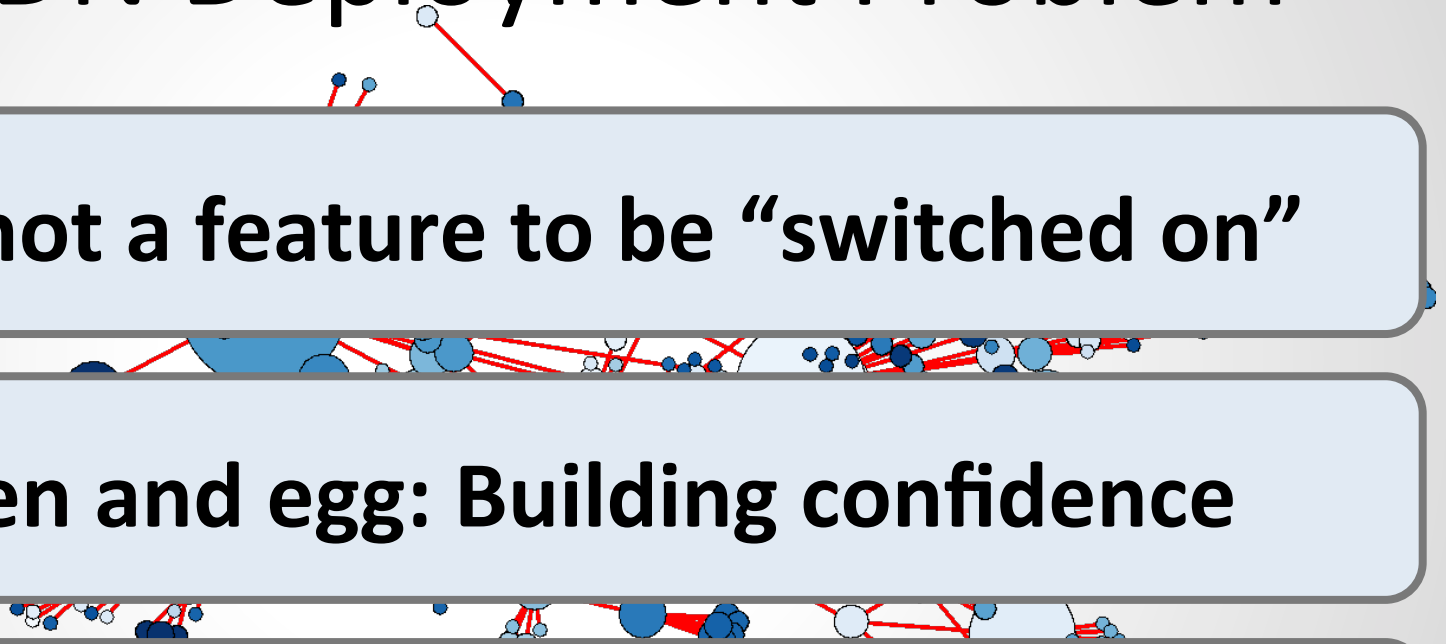


Principled Network Policy Orchestration

- Consistent Network Updates [Reitblatt'12]
- Modular Policy Composition [Monsanto'13]
- Network Invariants Static Checking [Kazemian'12]
- Automated Dataplane Troubleshooting [Zeng'12]
- And more…

All leverage an existing SDN deployment

The SDN Deployment Problem



SDN is not a feature to be “switched on”

Chicken and egg: Building confidence

Deployment must be Incremental

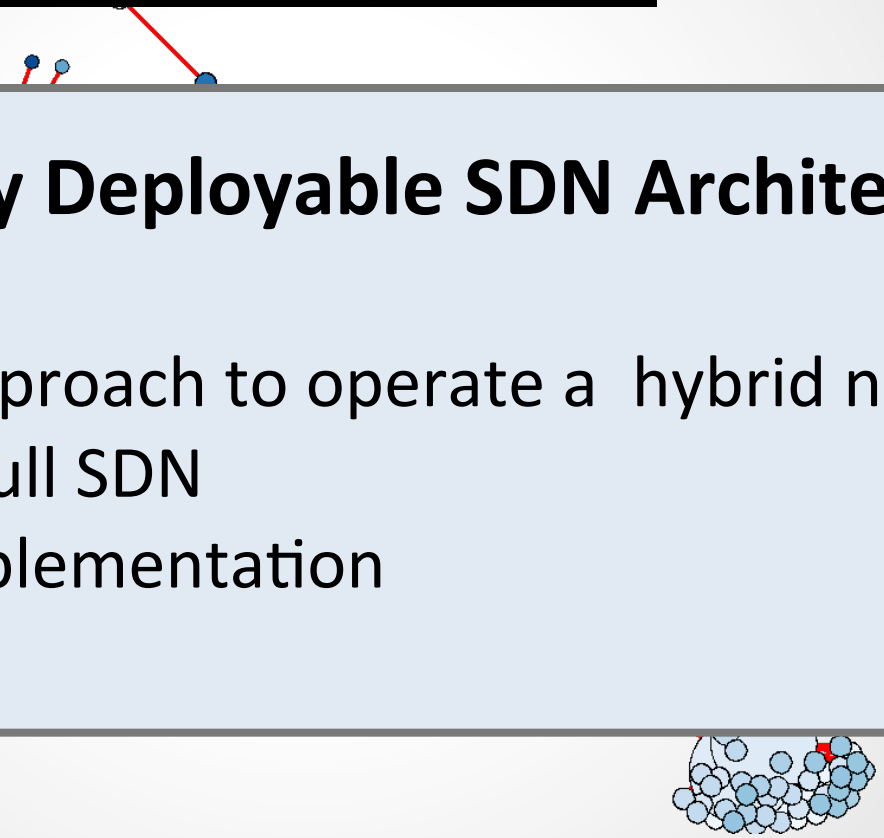
Key Questions

1. How can we **incrementally deploy the SDN interface** into enterprise networks?

2. What **benefits** can be realized from a **hybrid SDN** deployment?

3. What **limitations** or performance costs?

PANOPTICON



Incrementally Deployable SDN Architecture

- Systematic approach to operate a hybrid network as a (nearly) full SDN
- Prototype Implementation
- Planning tool

Key Questions

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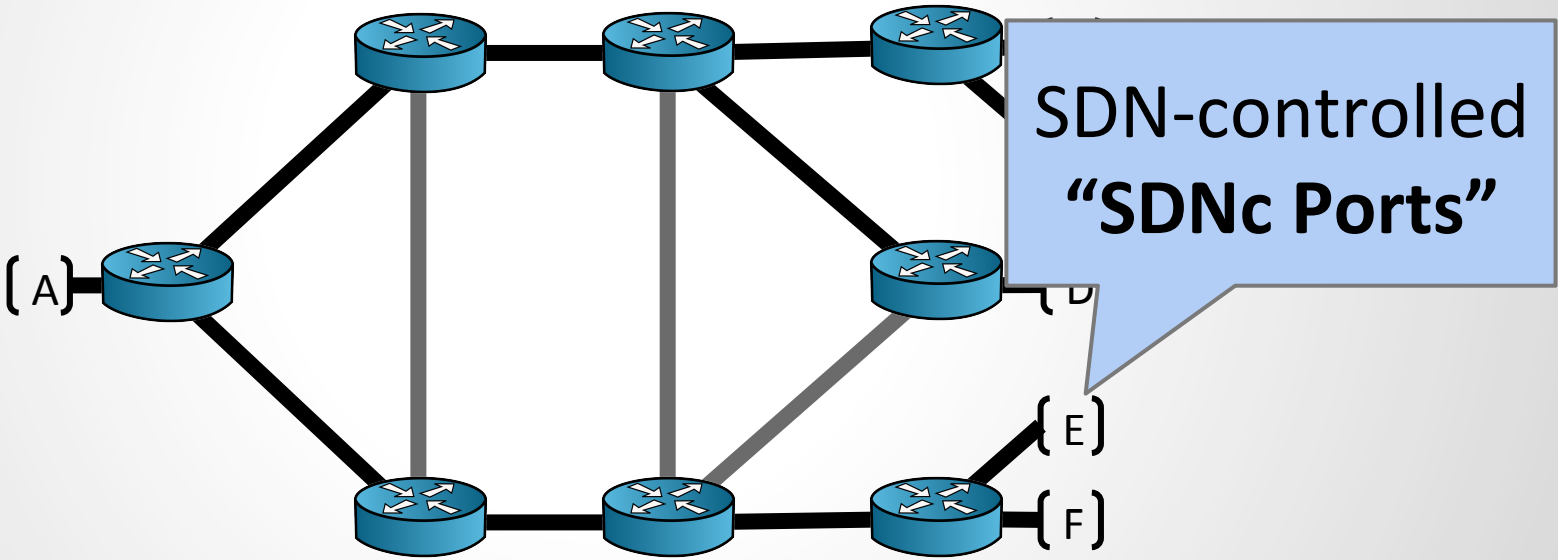
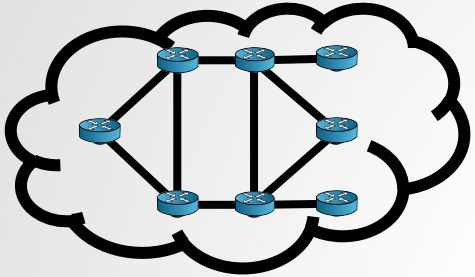
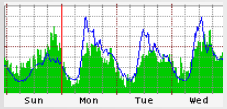
The Existing Network



Network Topology





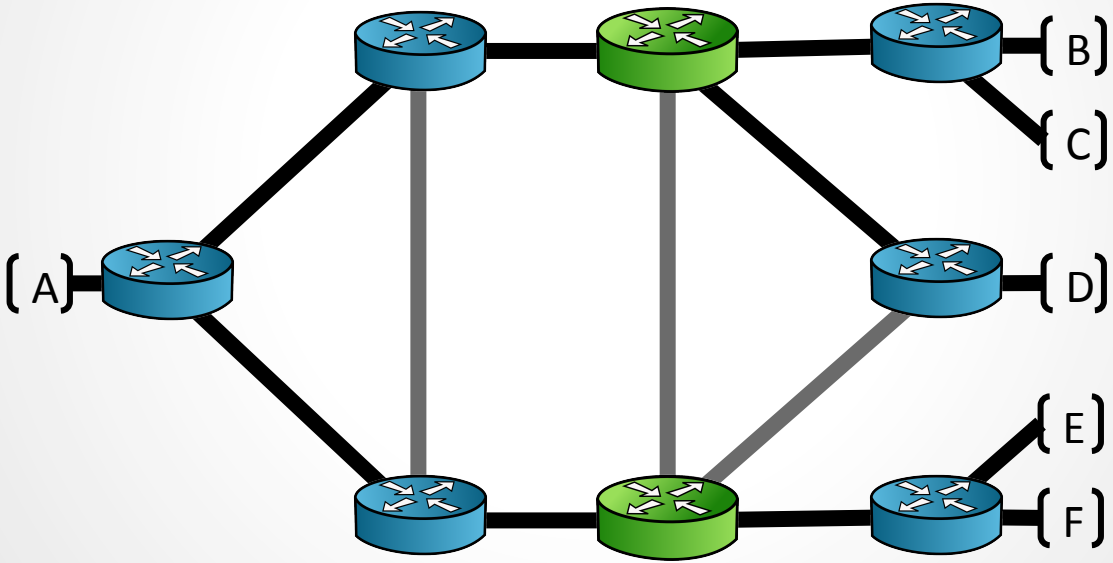
Traffic Estimates

Planning Strategy

Hybrid SDN Deployment

- Path Delay
- Link Utilizations
- Resource Constraints

The Hybrid SDN Deployment ()



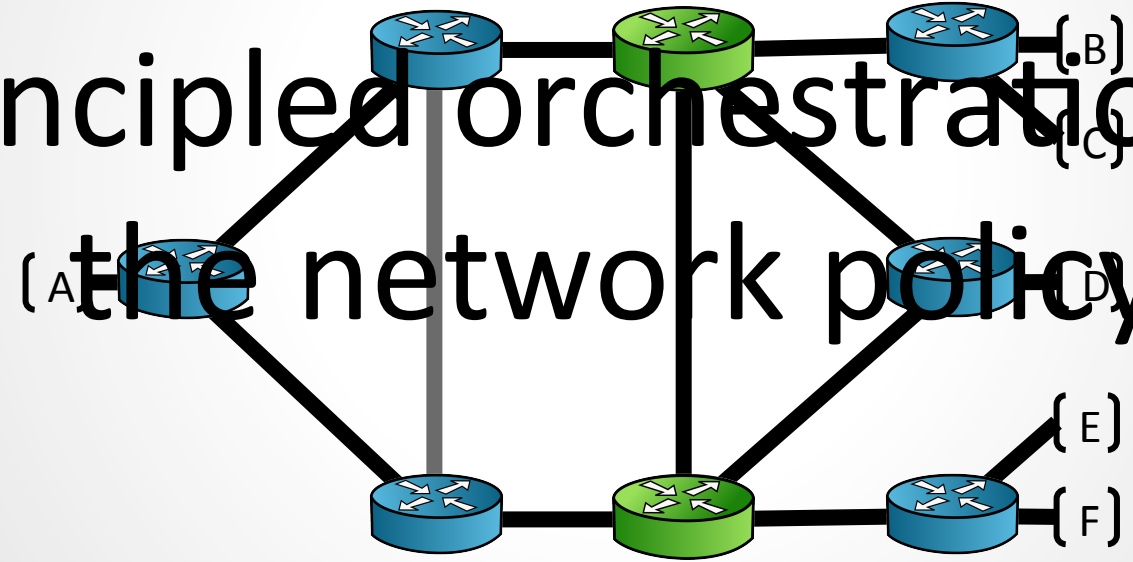
Key Questions

1. How can we **incrementally deploy the SDN interface** into enterprise networks?

2. What **benefits** can be realized from a **hybrid SDN** deployment?

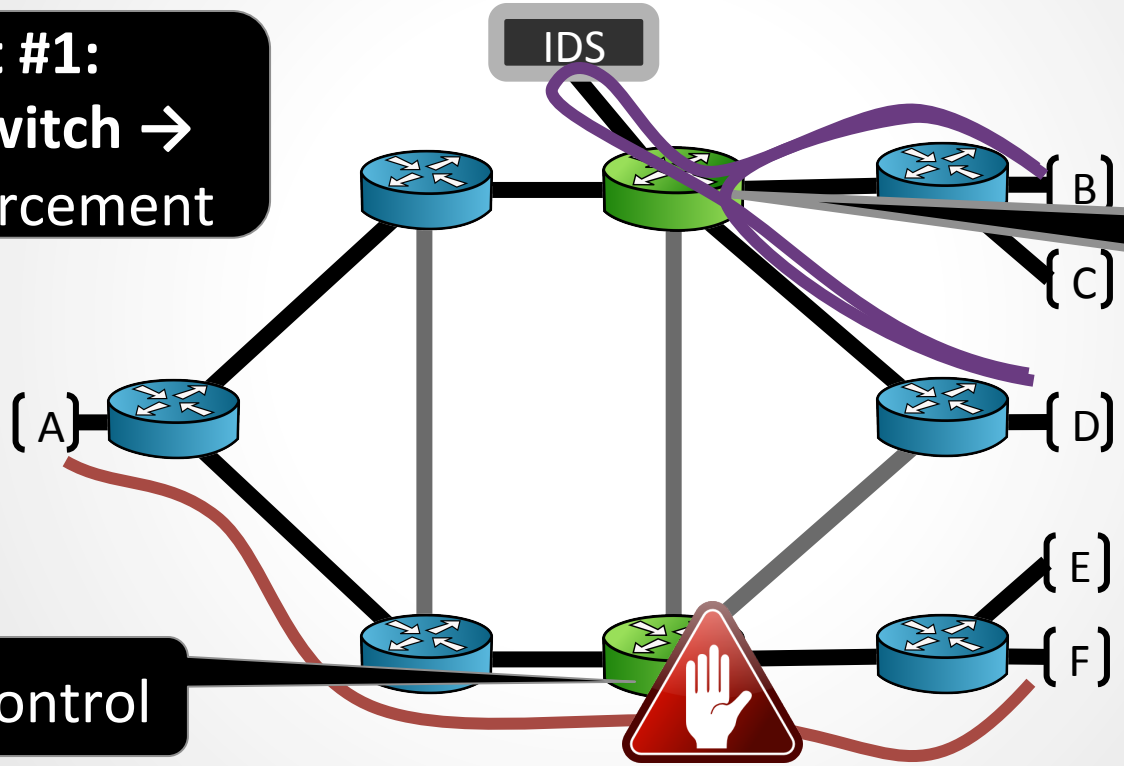
3. What limitations or performance costs?

Main benefits of **SDN**= Principled orchestration of the network policy



Realizing the Benefits of SDN

Insight #1:
≥ 1 SDN switch →
Policy enforcement

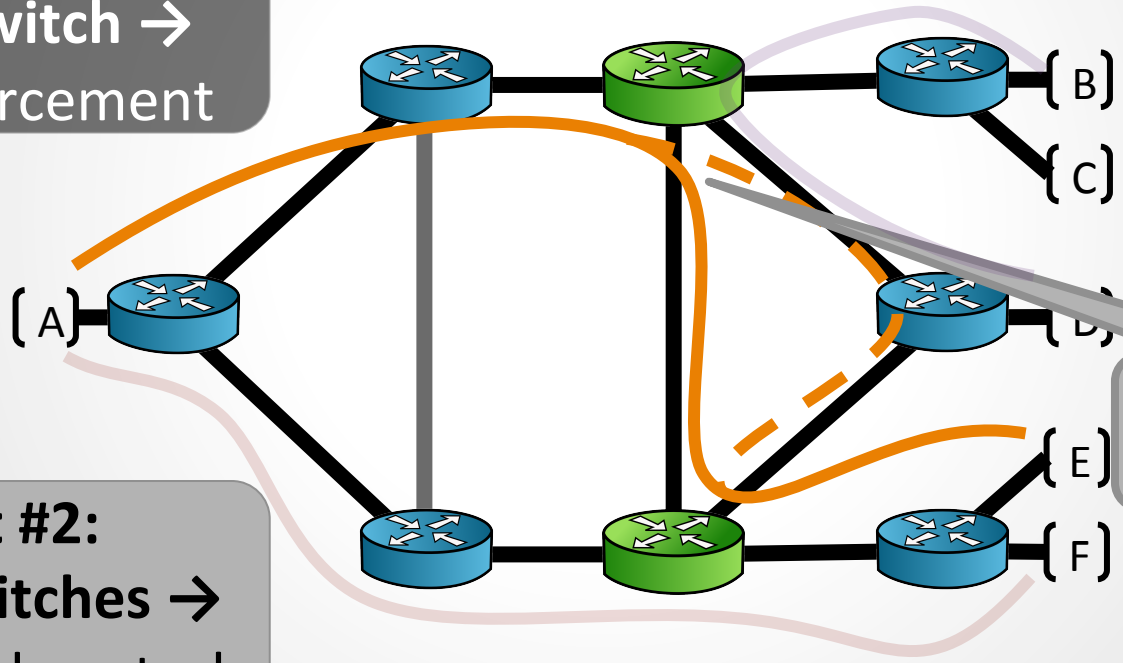


Middlebox traversal

Access control

2. Realizing the Benefits of SDN

Insight #1:
≥ 1 SDN switch →
Policy enforcement



Traffic load-balancing

Insight #2:
≥ 2 SDN switches →
Fine-grained control

Insight #1:
≥ 1 SDN switch →
Policy enforcement

Insight #2:
≥ 2 SDN switches →
Fine-grained control

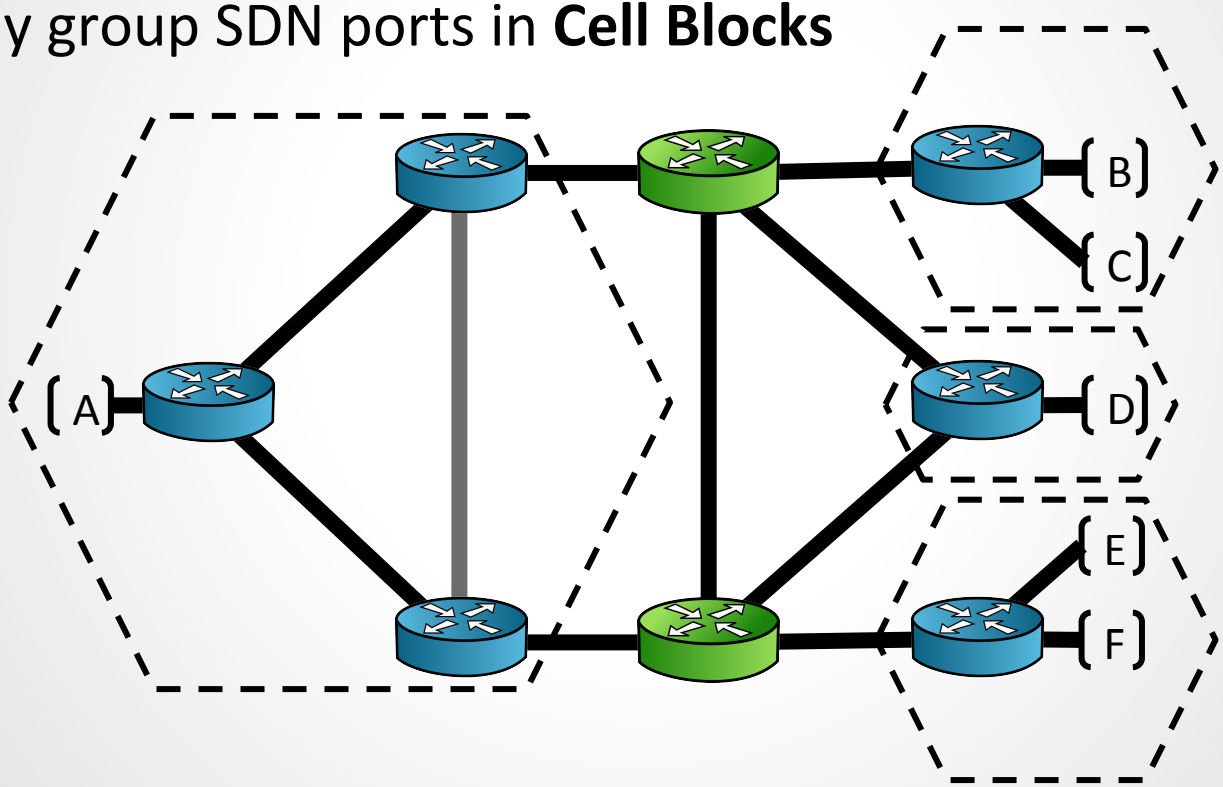
Ensure that all traffic to/from an SDN-controlled port always **traverses at least one SDN switch**

SDN Waypoint Enforcement

Legacy devices must direct traffic to SDN switches

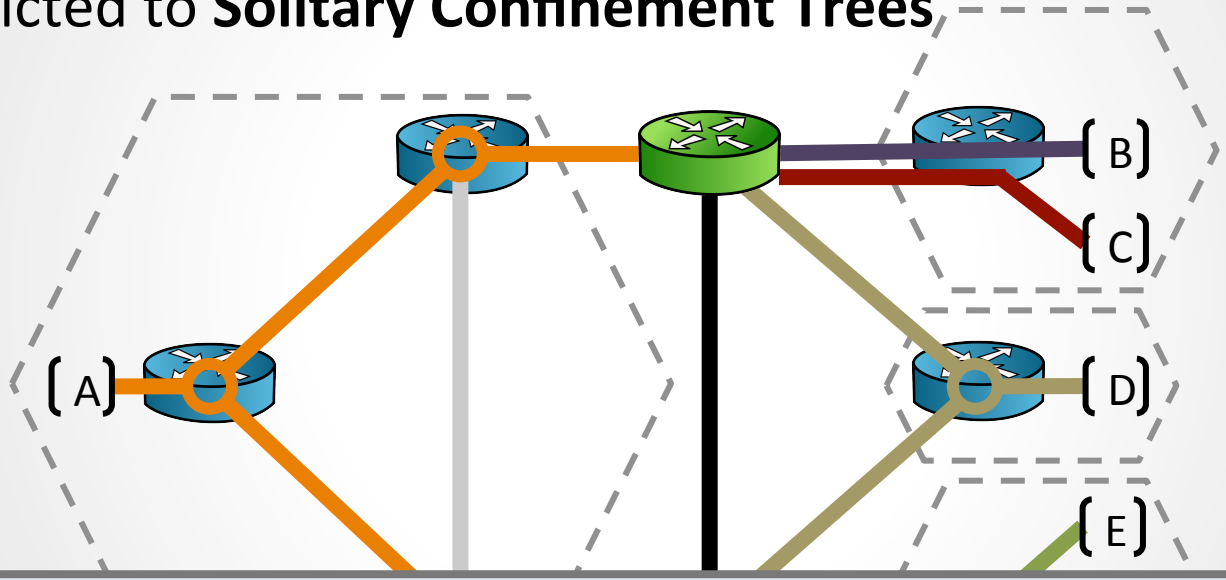
The **PANOPTICON** SDN Architecture

Conceptually group SDN ports in **Cell Blocks**



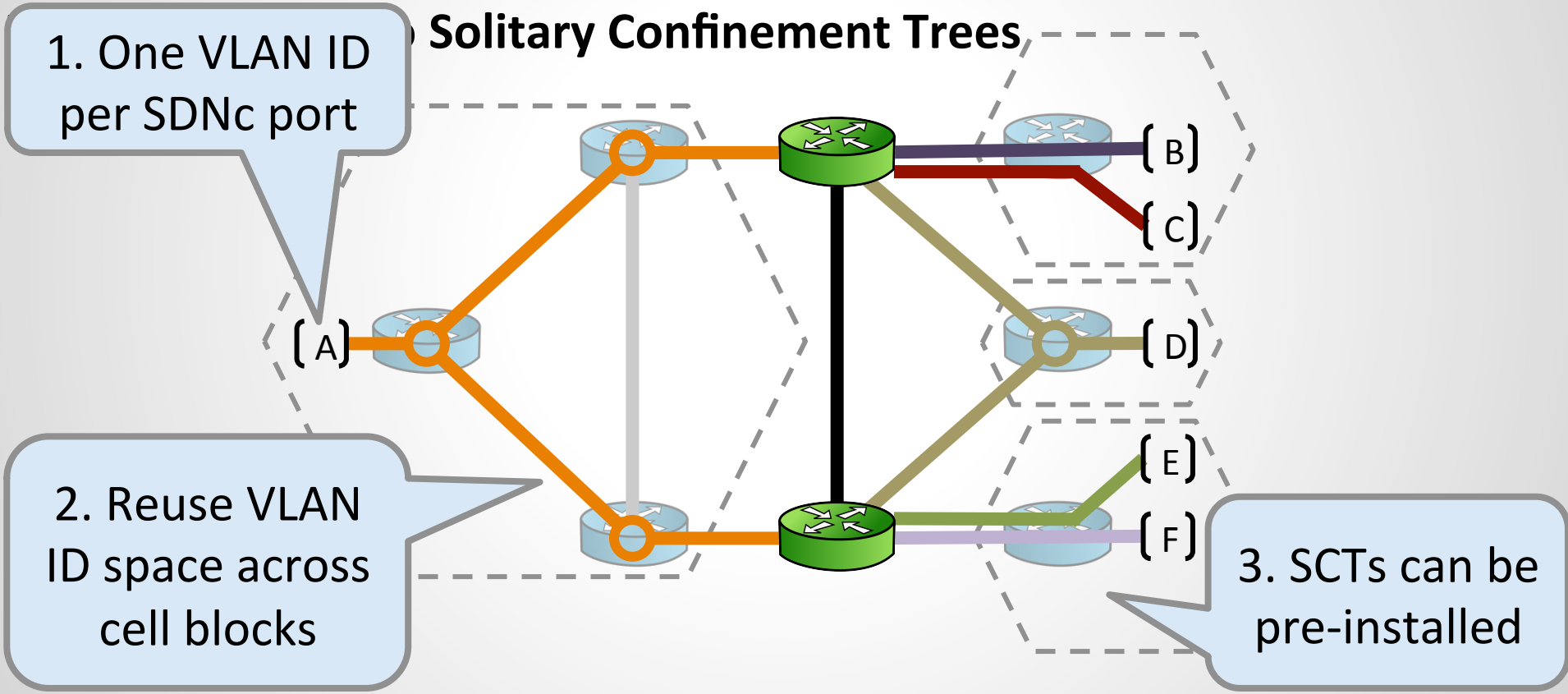
The **PANOPTICON** SDN Architecture

Traffic restricted to **Solitary Confinement Trees**



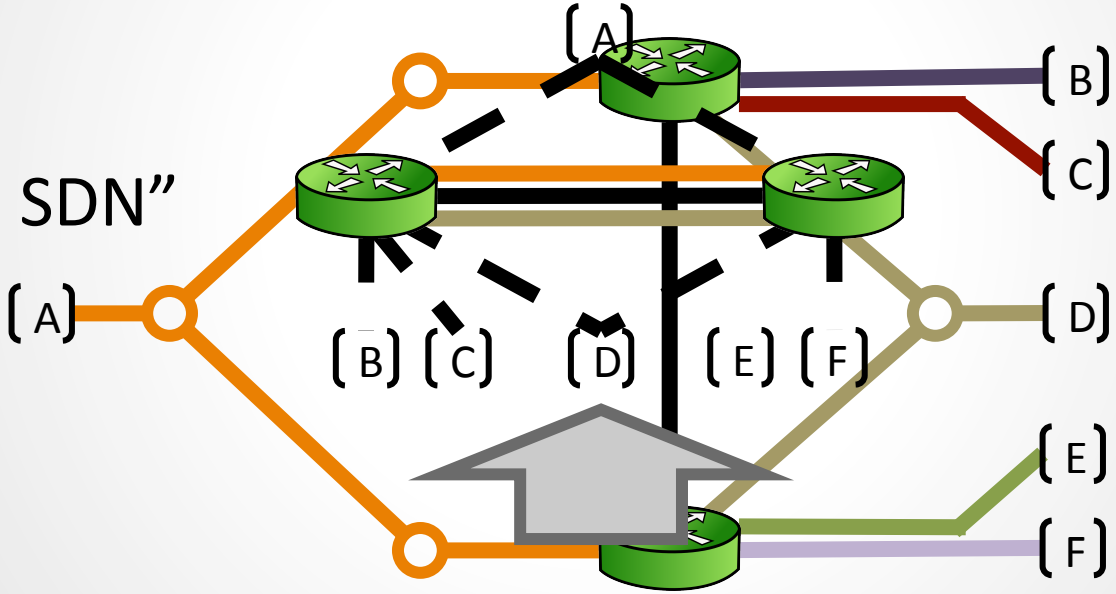
Per-port spanning trees that ensure waypoint enforcement

The PANOPTICON SDN Architecture



PANOPTICON

“Logical SDN”



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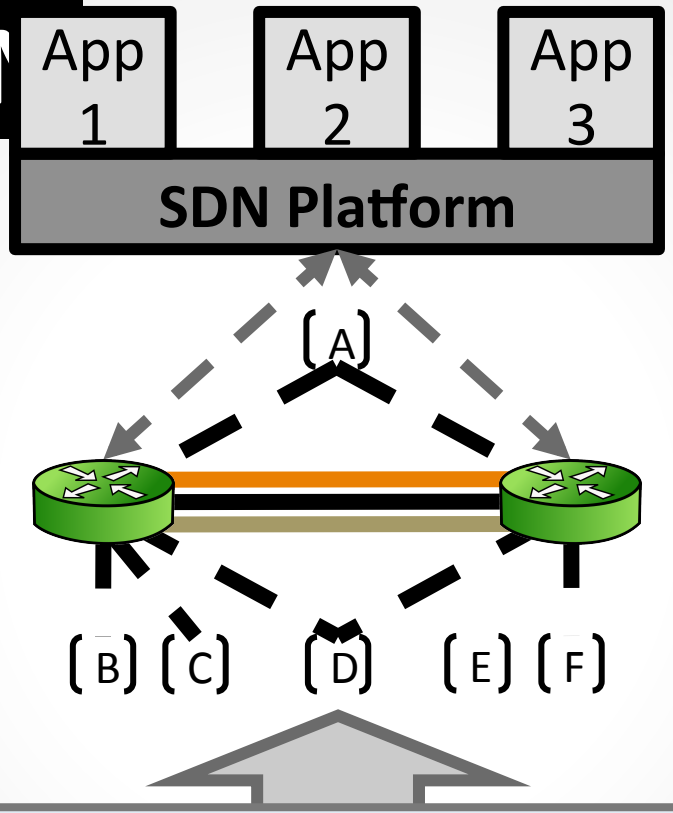


"Logical SDN"

PANOPTICON provides the abstraction of a (nearly) fully-deployed SDN in a partially upgraded network

Evaluation

Simulation	Emulation	Testbed

How many SDNc ports do I get as the deployment grows?

How will Panopticon Affect Network Traffic?

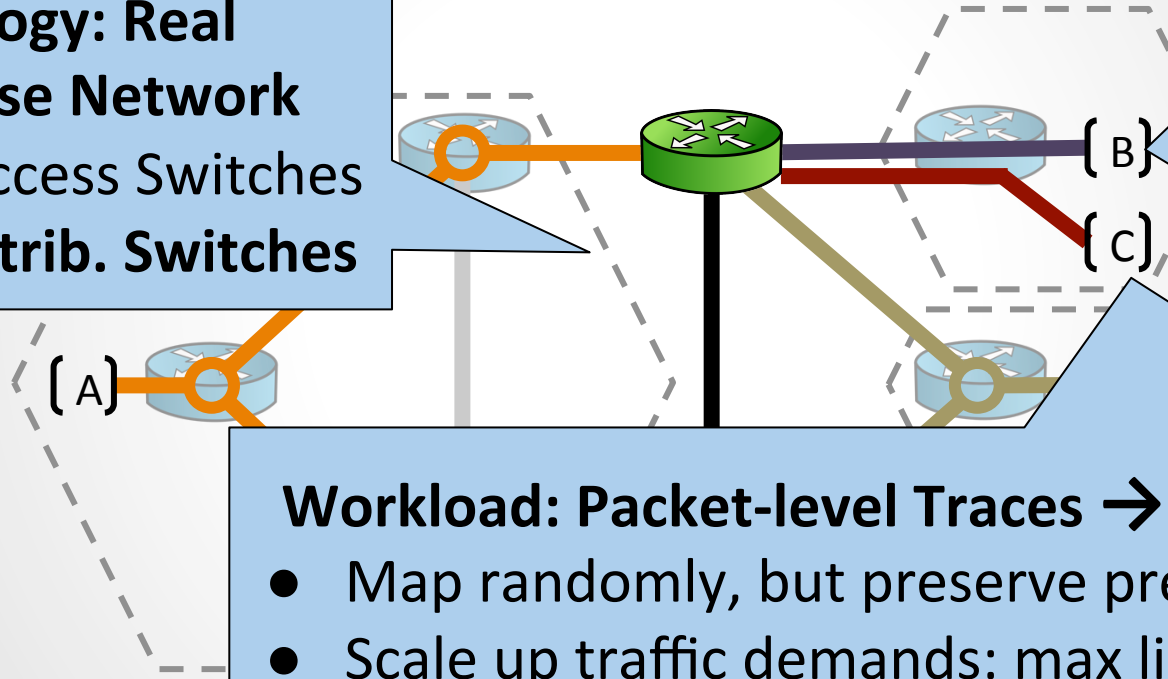
Prototype Implementation

Fault Tolerance

Simulation Methodology

Topology: Real Enterprise Network

- 1296 Access Switches
- **412 Distrib. Switches**

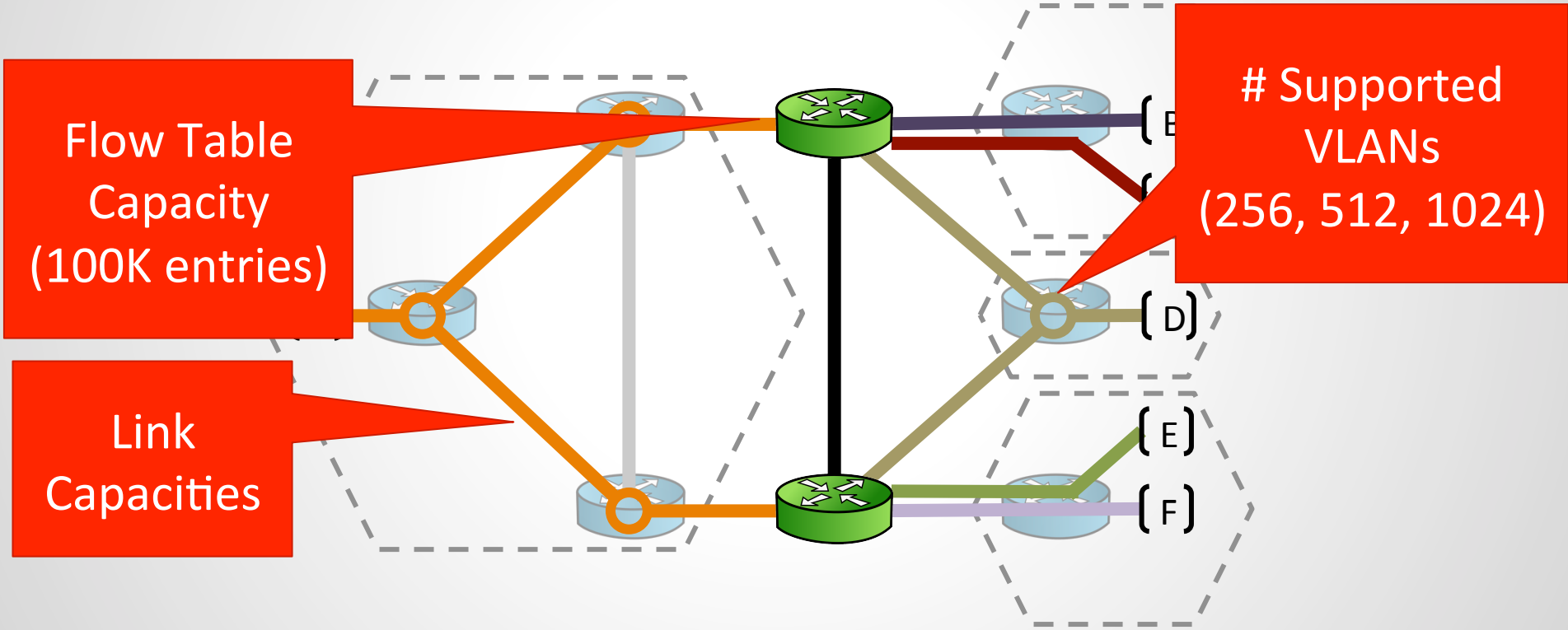


1296 SDNc Port Candidates

Workload: Packet-level Traces → Traffic Matrix

- Map randomly, but preserve prefix locality
- Scale up traffic demands: max link util at 50%
- Each src-dst pair consumes avg. 10 fwd rules

Resource Constraints

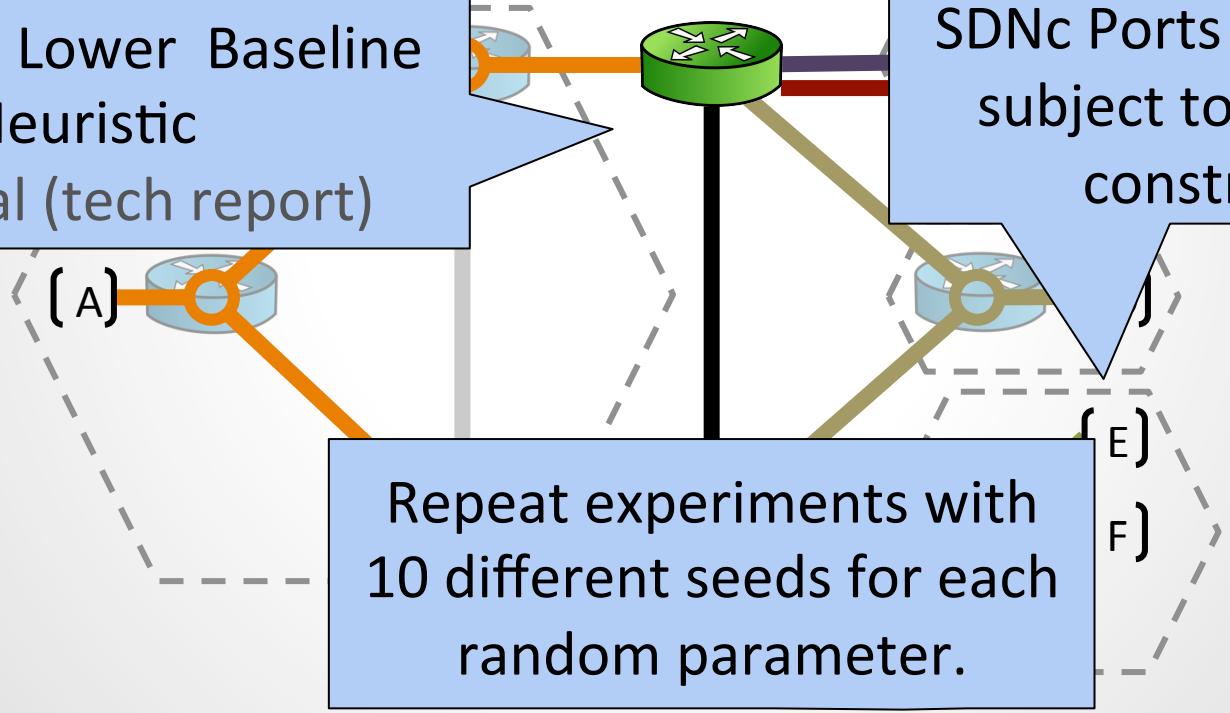


How many SDNc ports do I get?

Switch Placement Heuristic

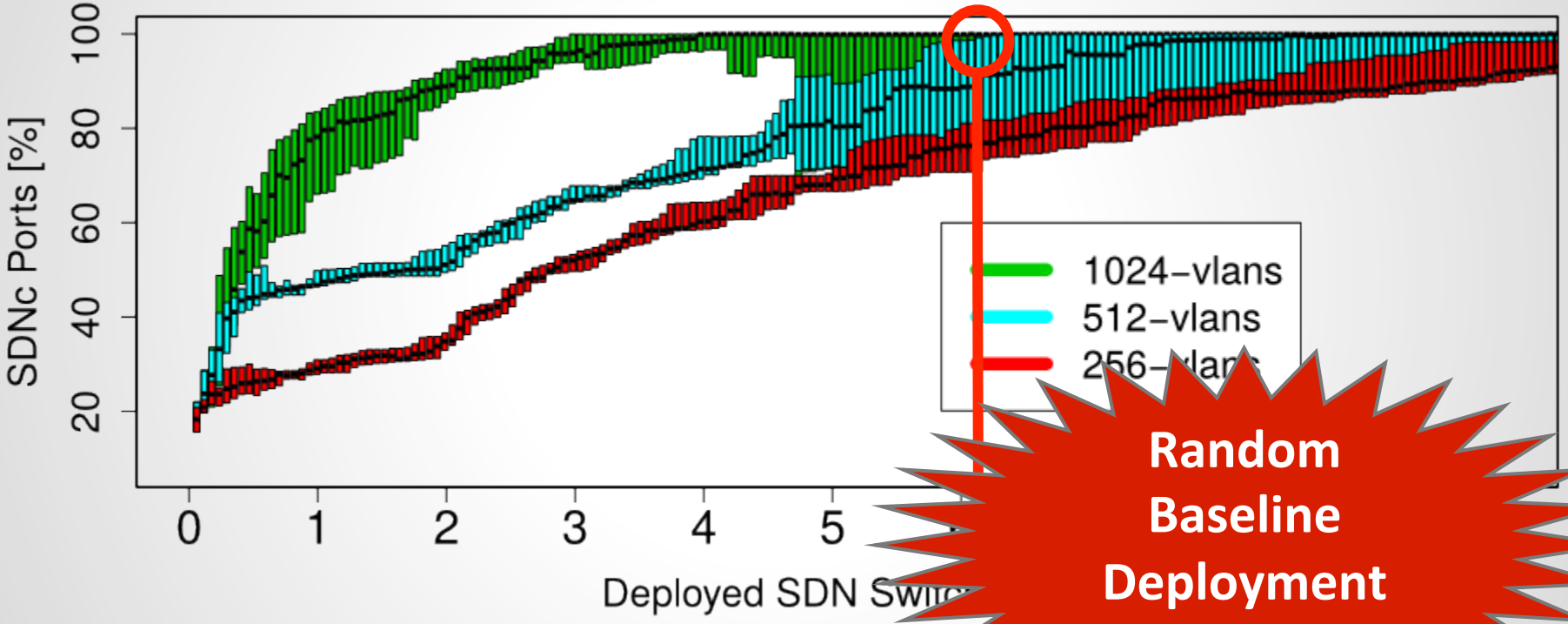
1. **RAND** - Lower Baseline
2. **VOL** - Heuristic
3. Optimal (tech report)

Accomodate as many SDNc Ports as possible subject to resource constraints

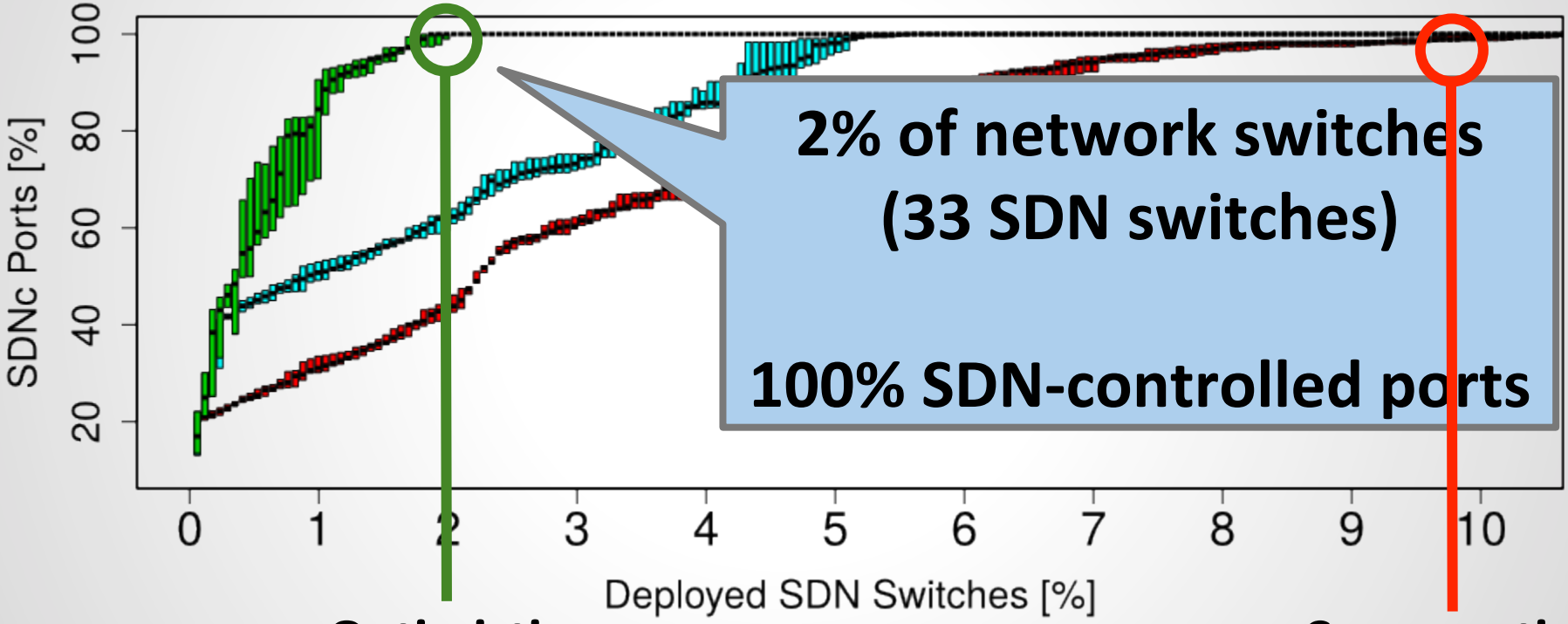


Repeat experiments with 10 different seeds for each random parameter.

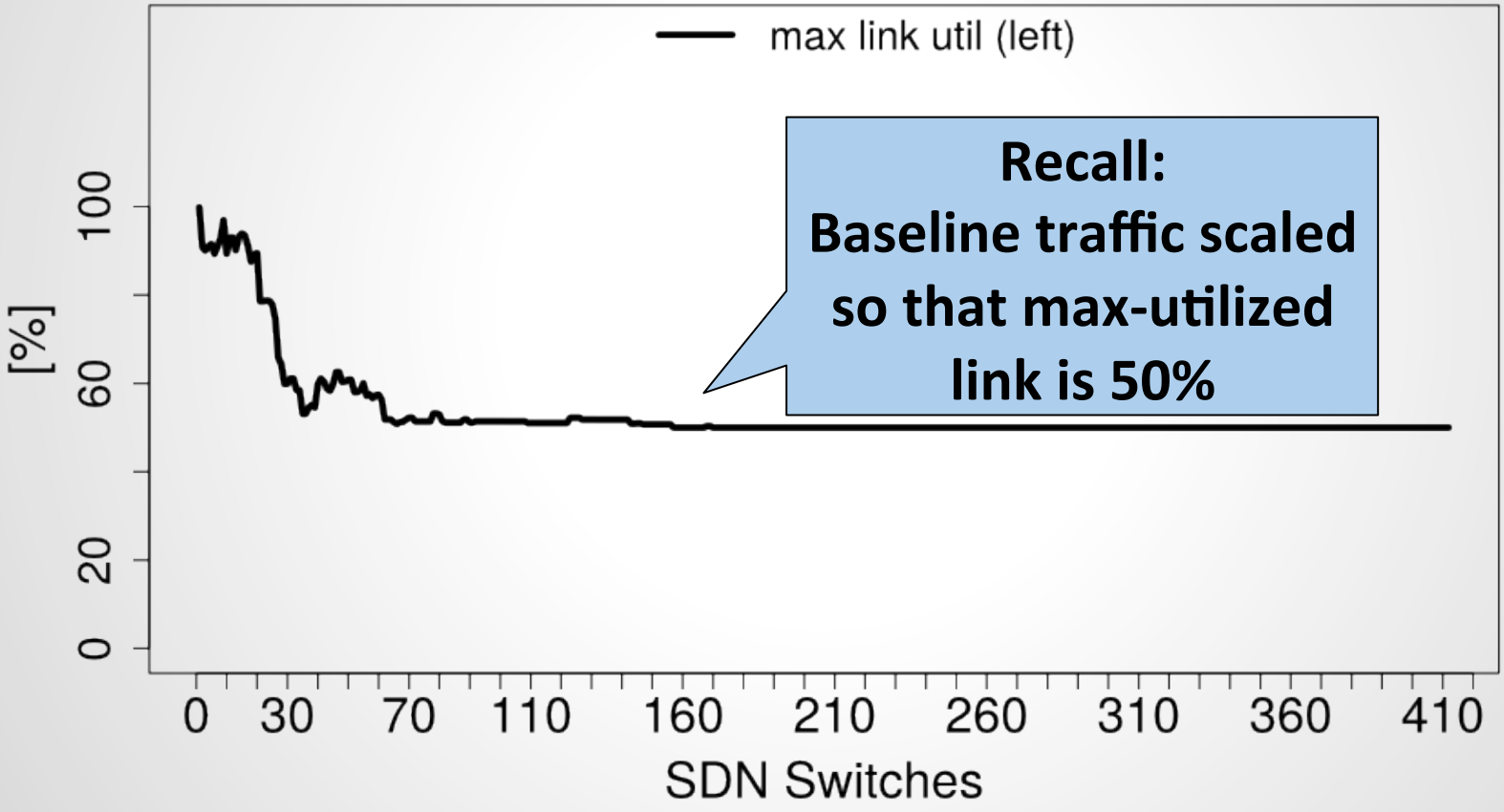
How many SDNc ports do I get?



Feasibility with **VOL** heuristic



How will Panopticon affect my traffic?



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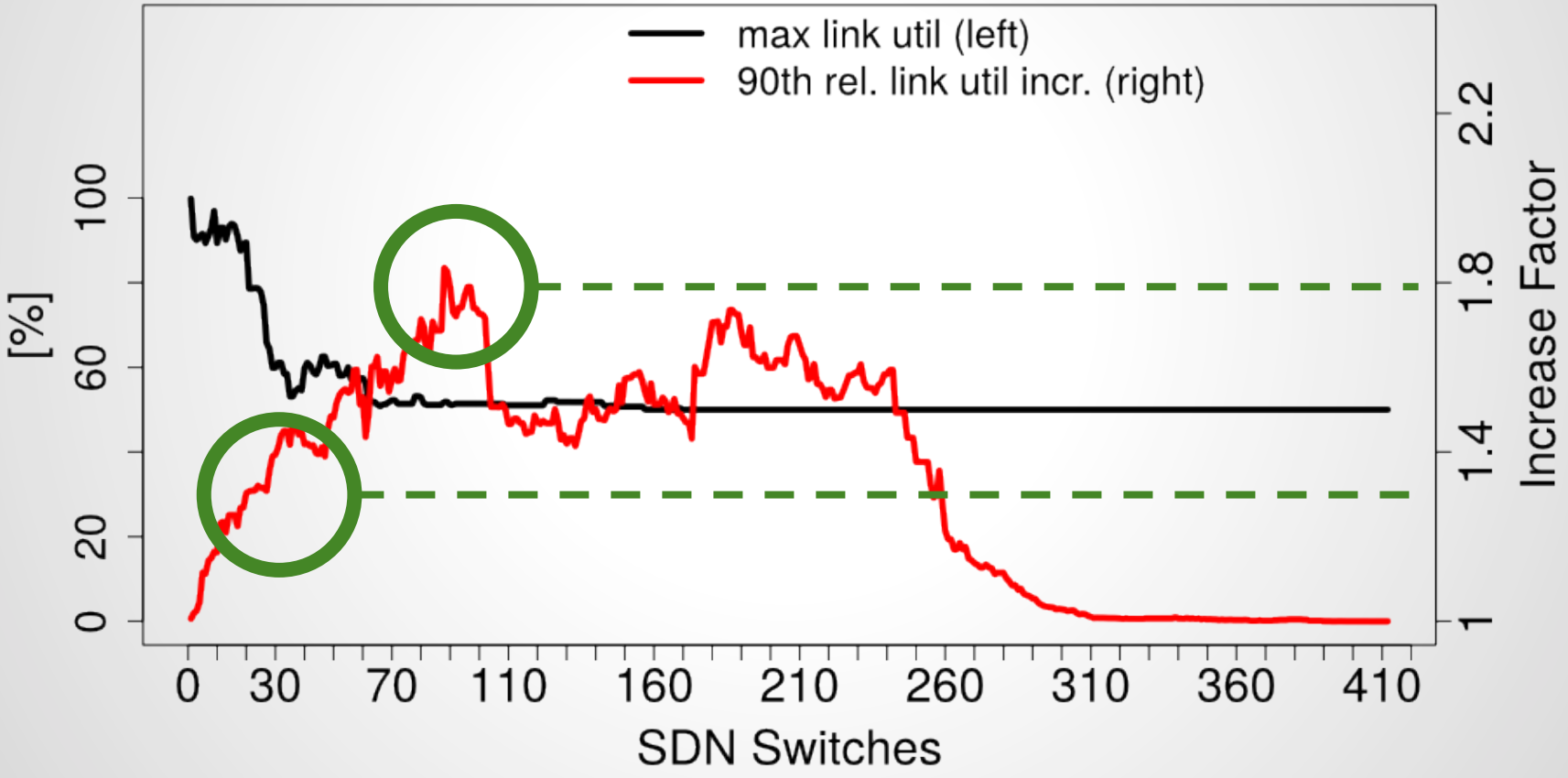

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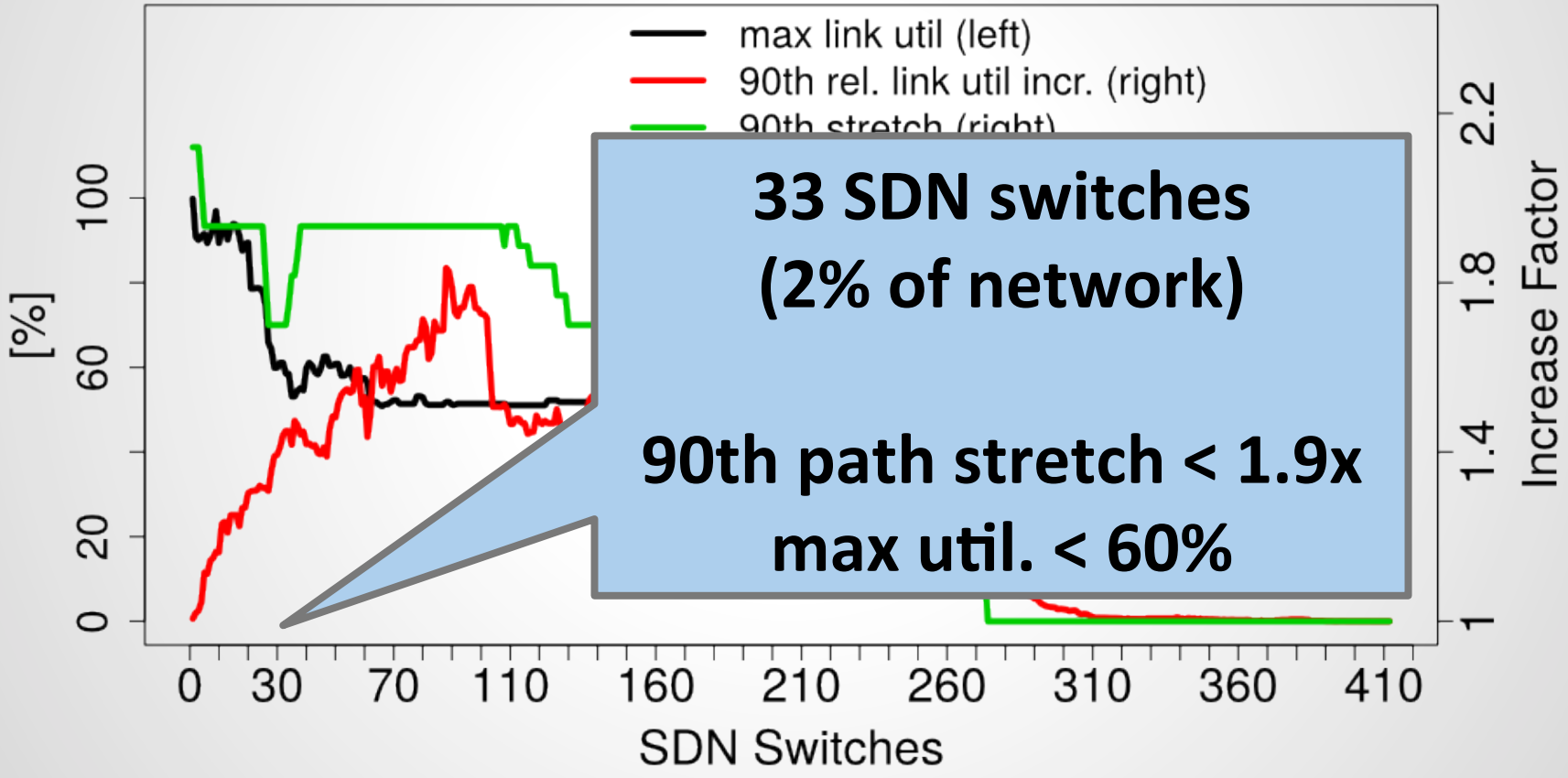


Key Evaluation Results

Optimistically at 2% deployed SDN switches	**Conservatively at 10%** deployed SDN switches

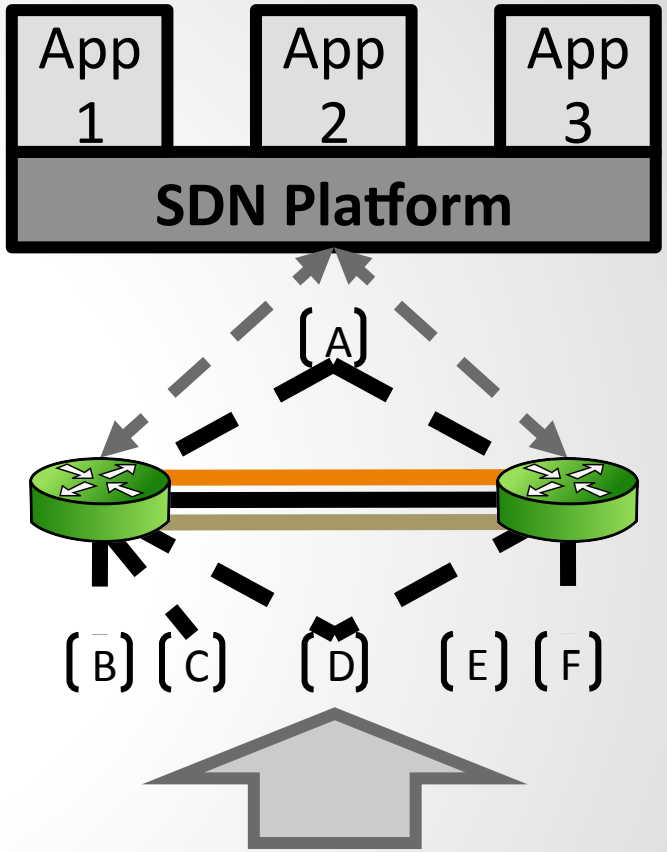
- Every access port controlled via SDN
- Moderate Path Stretch
- Moderate increase in link utilization

- Traffic Emulation: results support simulations
- Testbed: validate system and fault-tolerance

Summary

SDN ARCHITECTURE Operate the network as a (nearly) full SDN

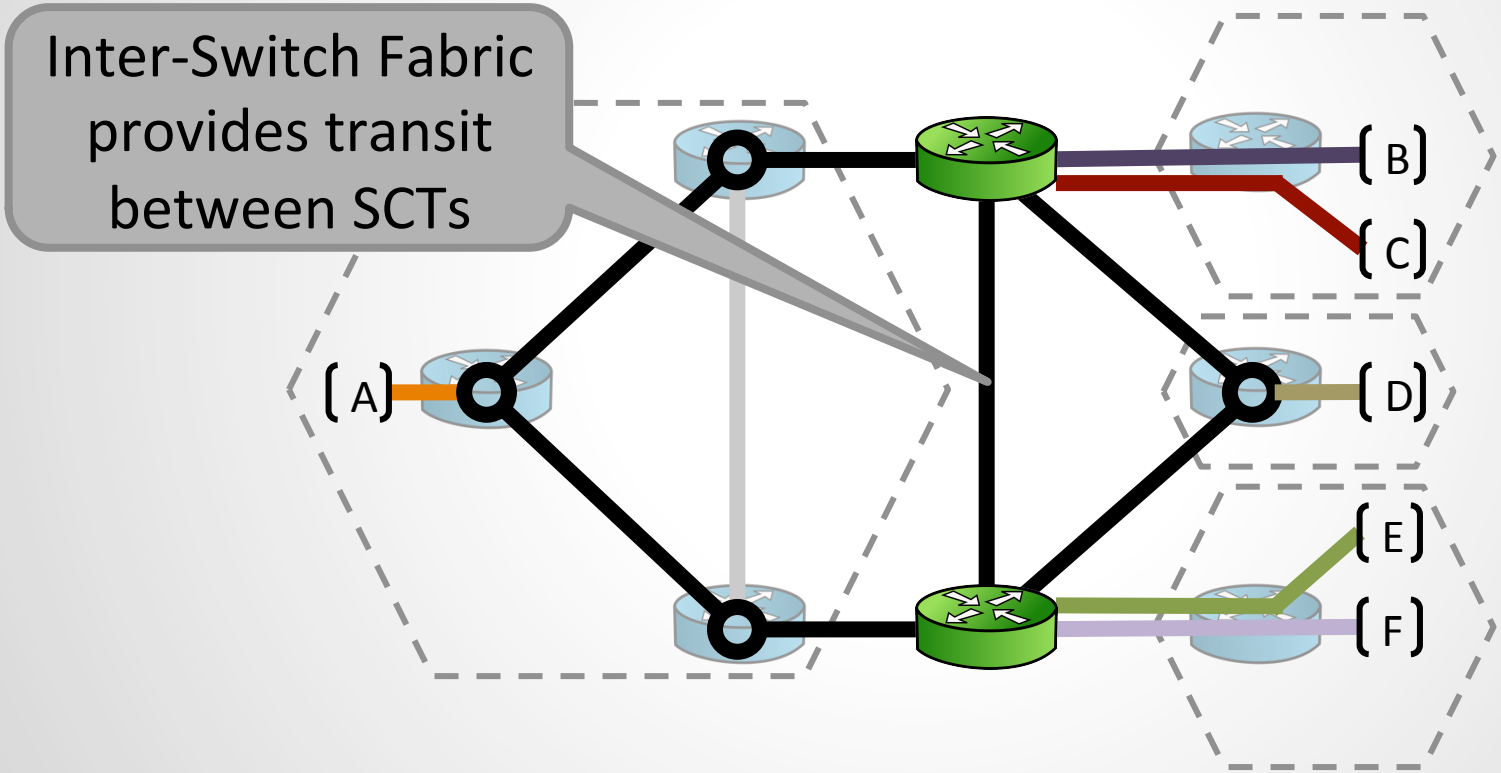
Planning TOOL Determine the partial SDN deployment



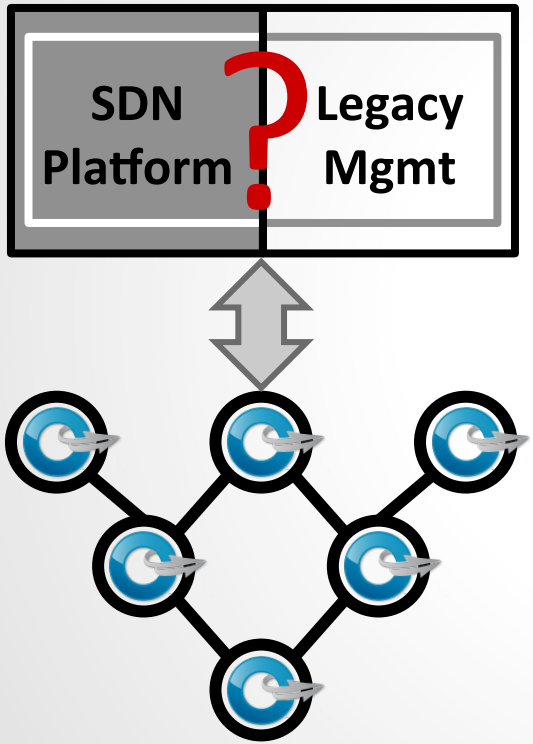
https://panoptisim.badpacket.in

PANOPTICON

Packet Forwarding

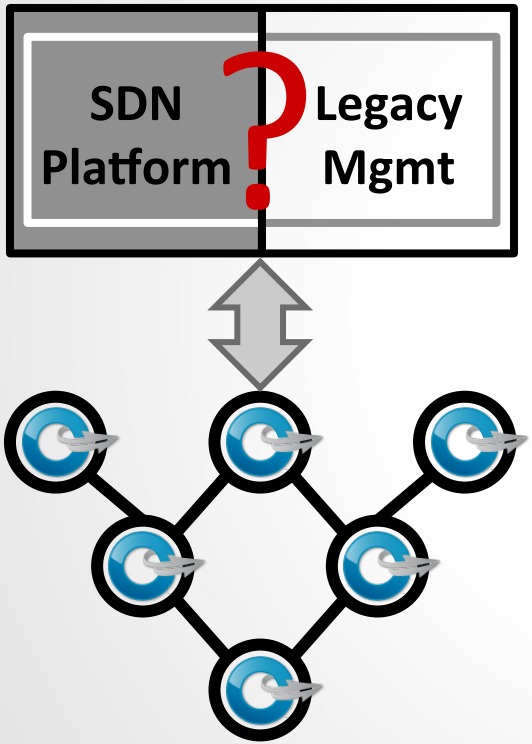


Current Hybrid Networks



Dual-stack approach

Current Hybrid Networks



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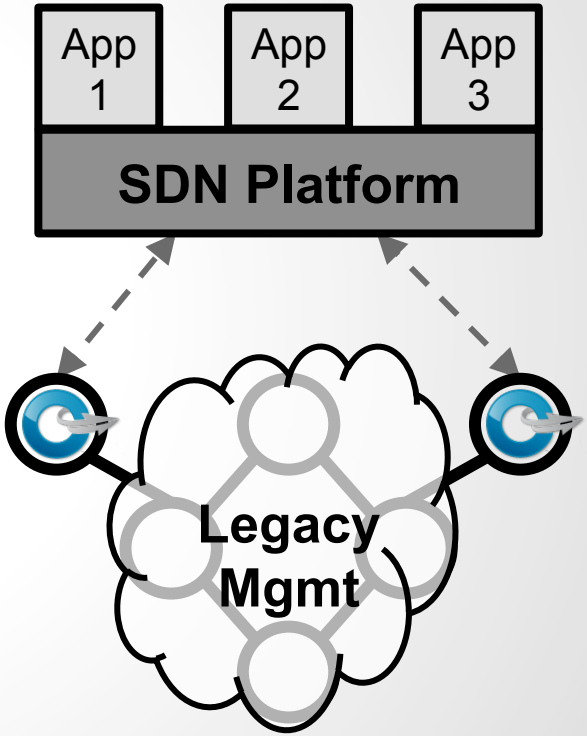
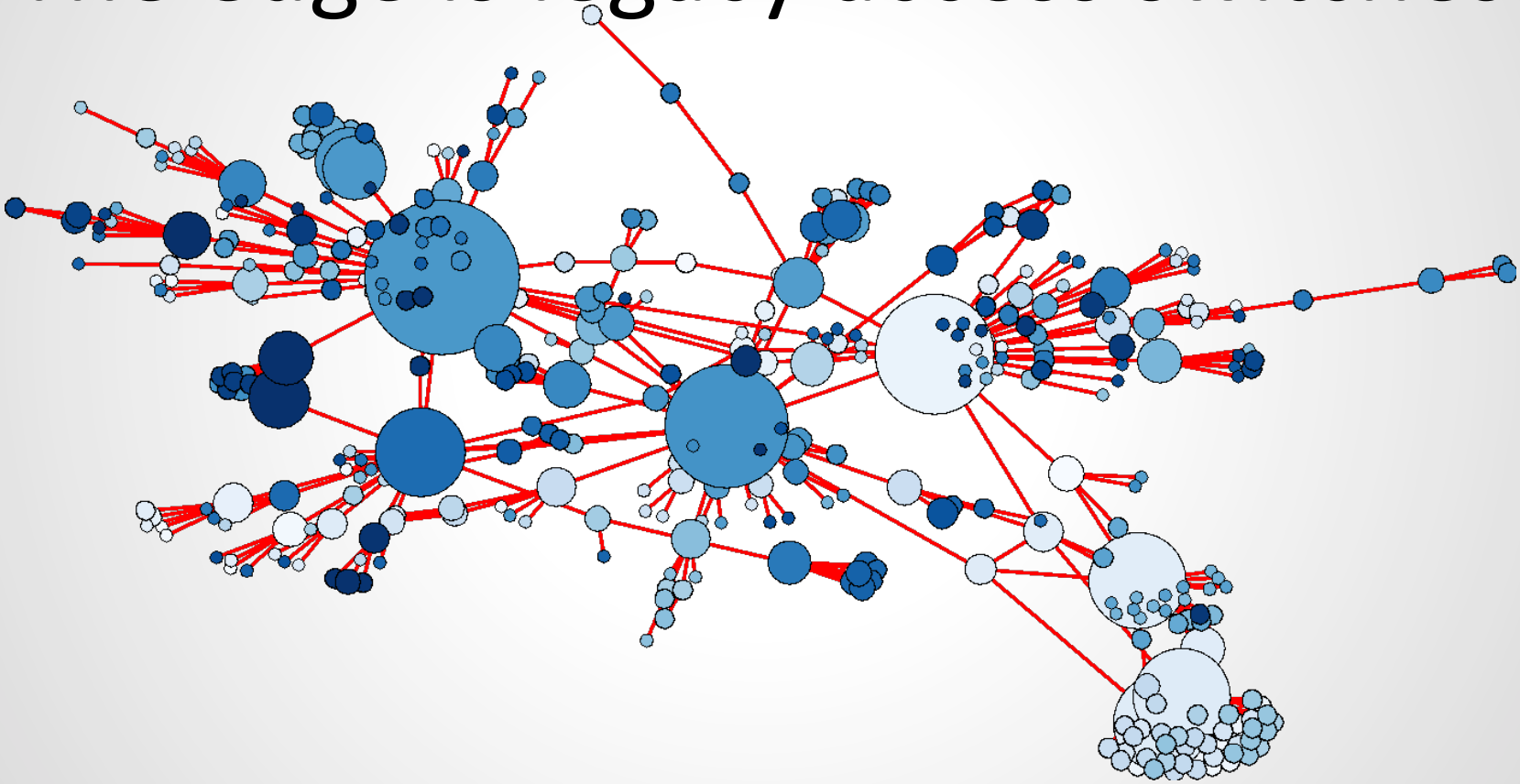


Edge-only approach

The edge is legacy access switches



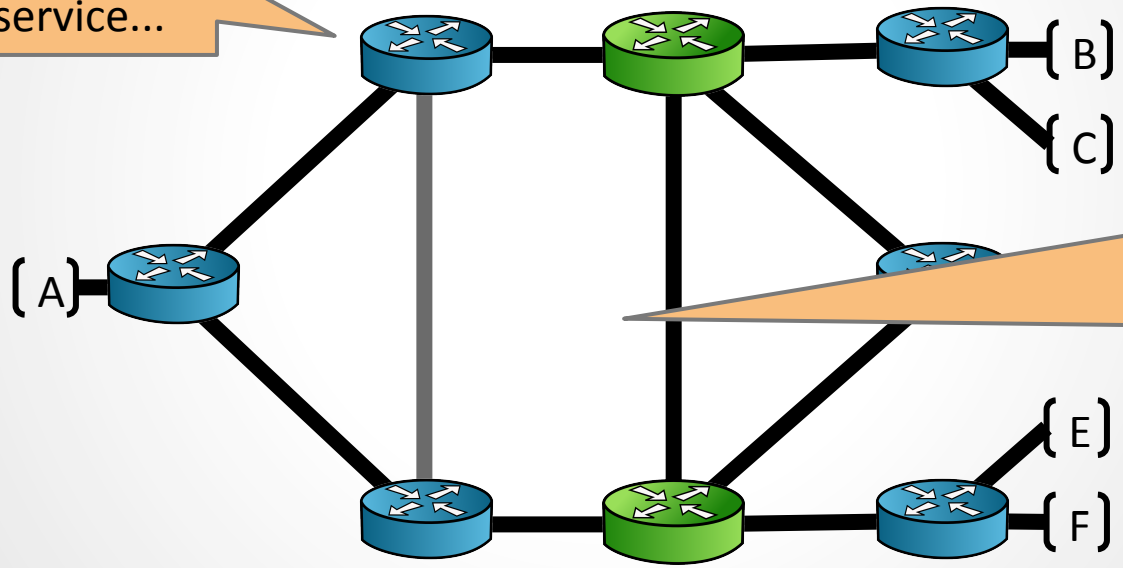
Hybrid SDN Use Cases

- **Automated Planned Maintenance Tool**

- Lightweight IP Subnet Mobility
- ACL refactorization
- Middle-box Traversal

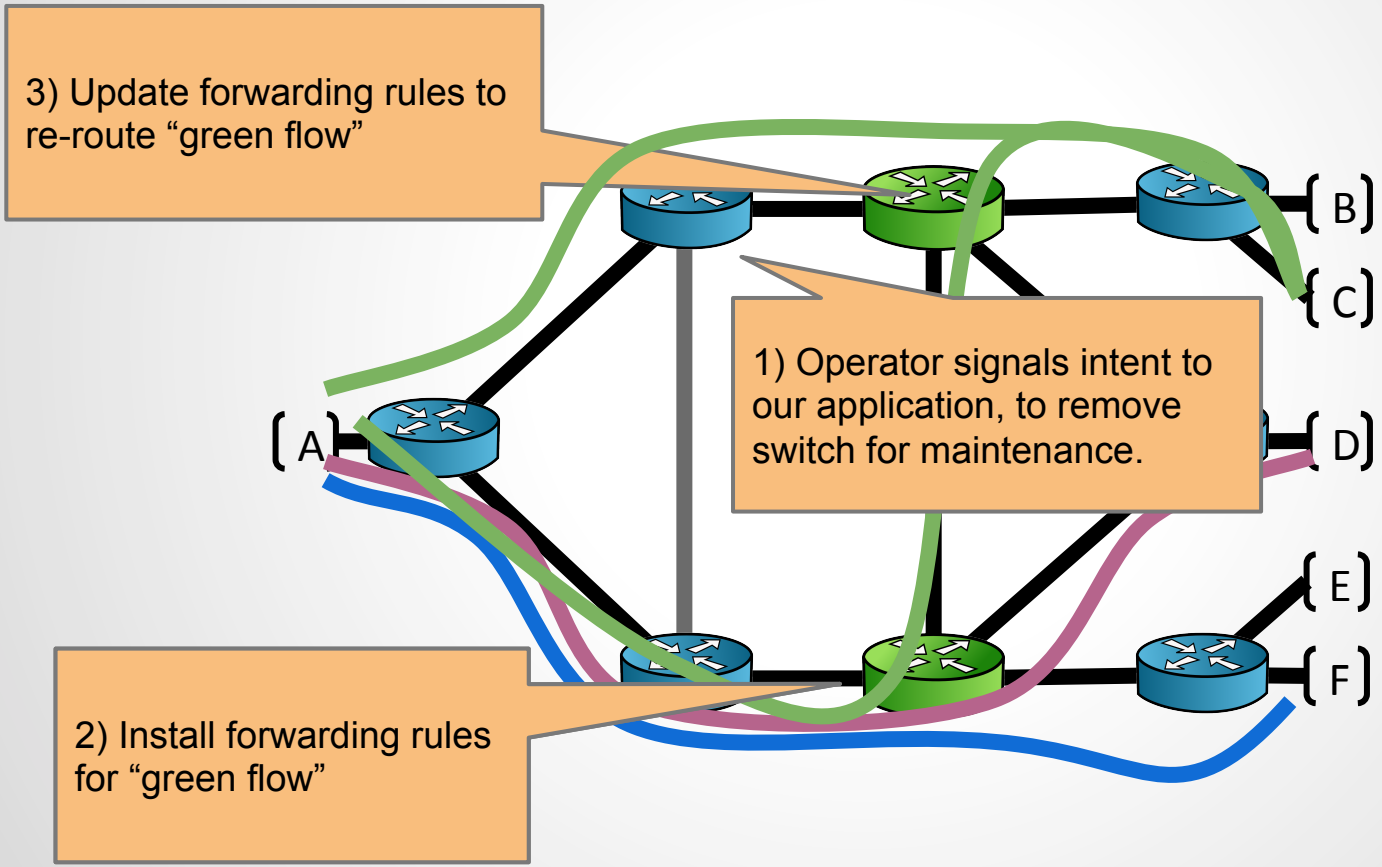
Use Case: Planned Maintenance

Operator says:
"You're Going down for service...



...and, could the rest of you switches cooperate to minimize the disruption?

Use Case: Planned Maintenance



Use Case Testbed Evaluation

2x NEC IP8800 (OF 1.0)

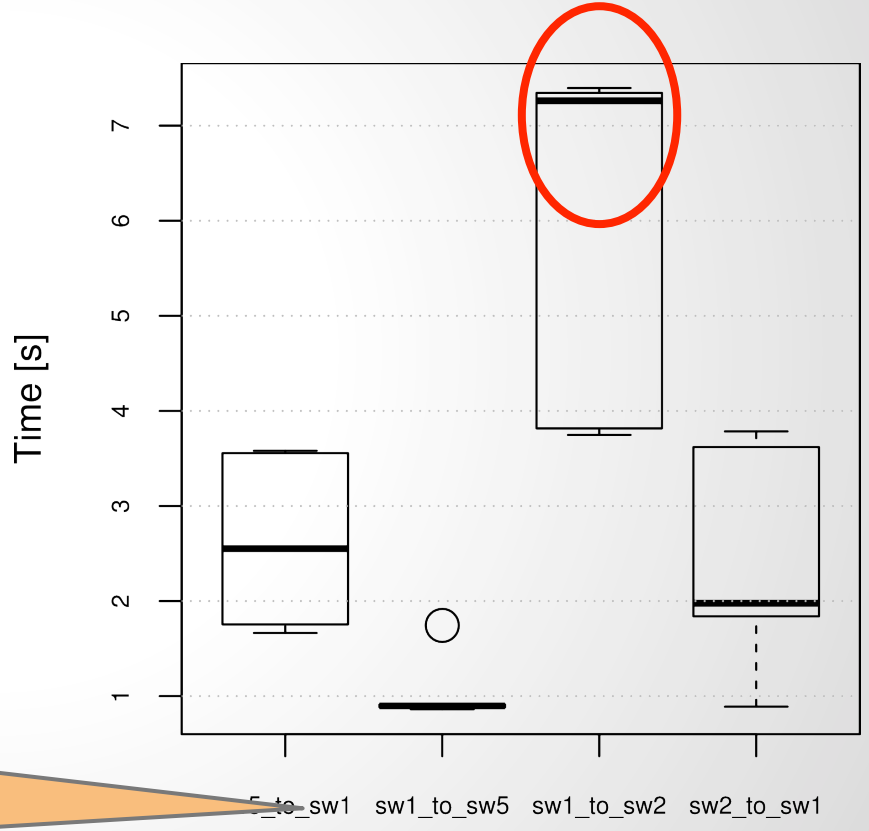
1x Cisco C3550XL

3x Cisco

2x HP 54

1x Pica8

TCP Connection Recovery Time

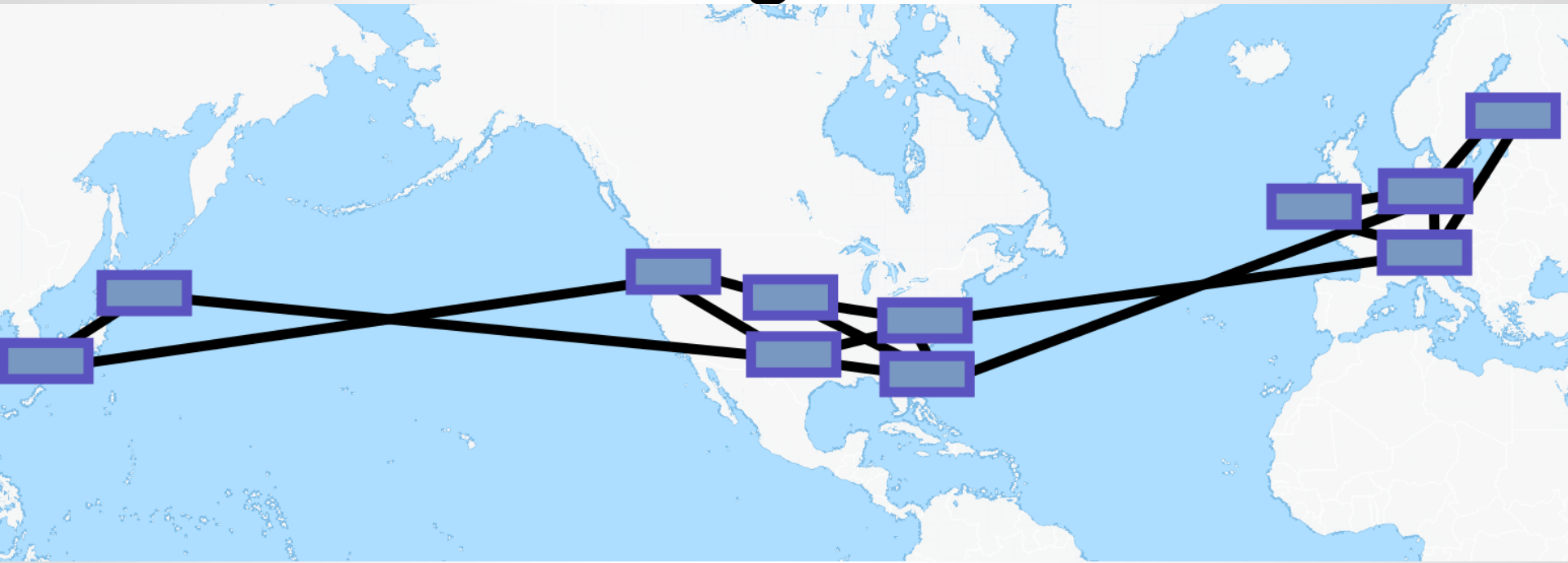


Locations of “port-down” events along one path traversing SDN switch.

Use Case Testbed Evaluation

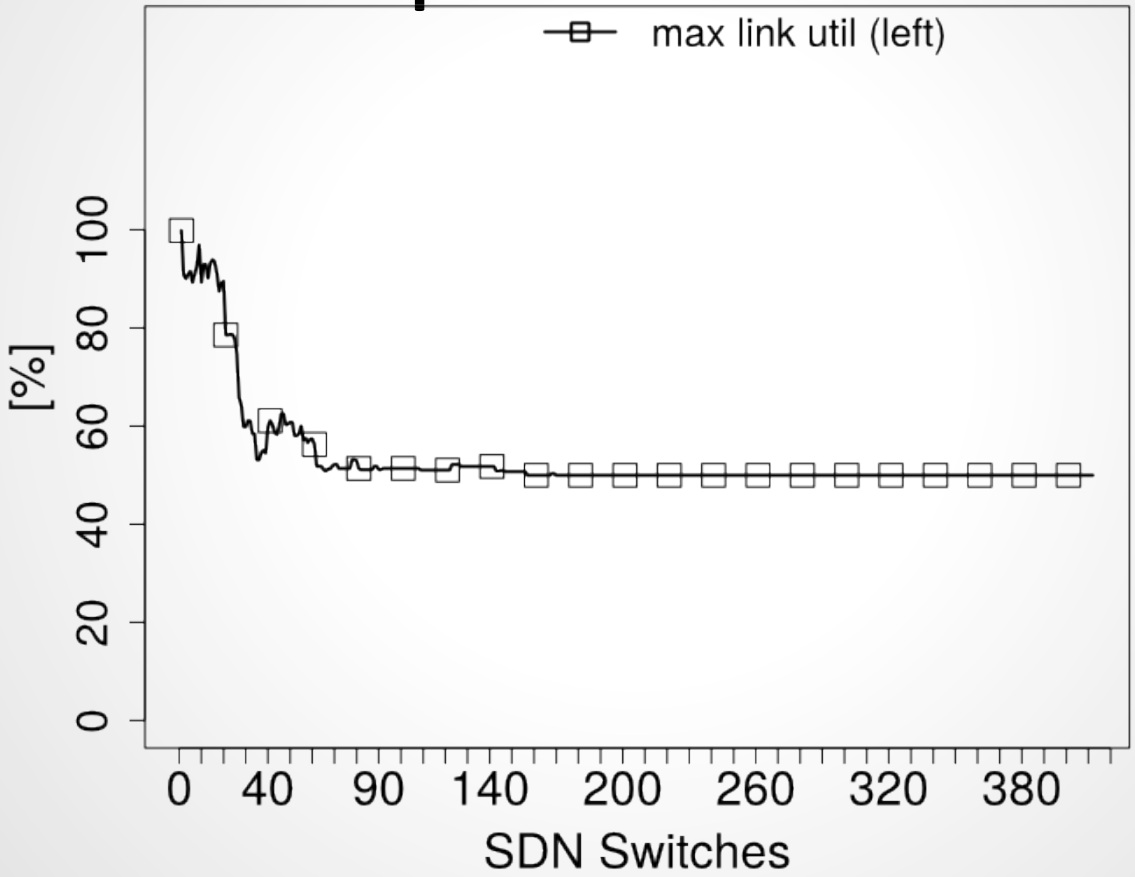
2x NEC IP8800 (OF 1.0)
1x Cisco C3550XL
3x Cisco C2960G
2x HP 5406zl
1x Pica8 3290

Google B4



Functionally Equivalent Deployment

How will Panopticon affect my traffic?



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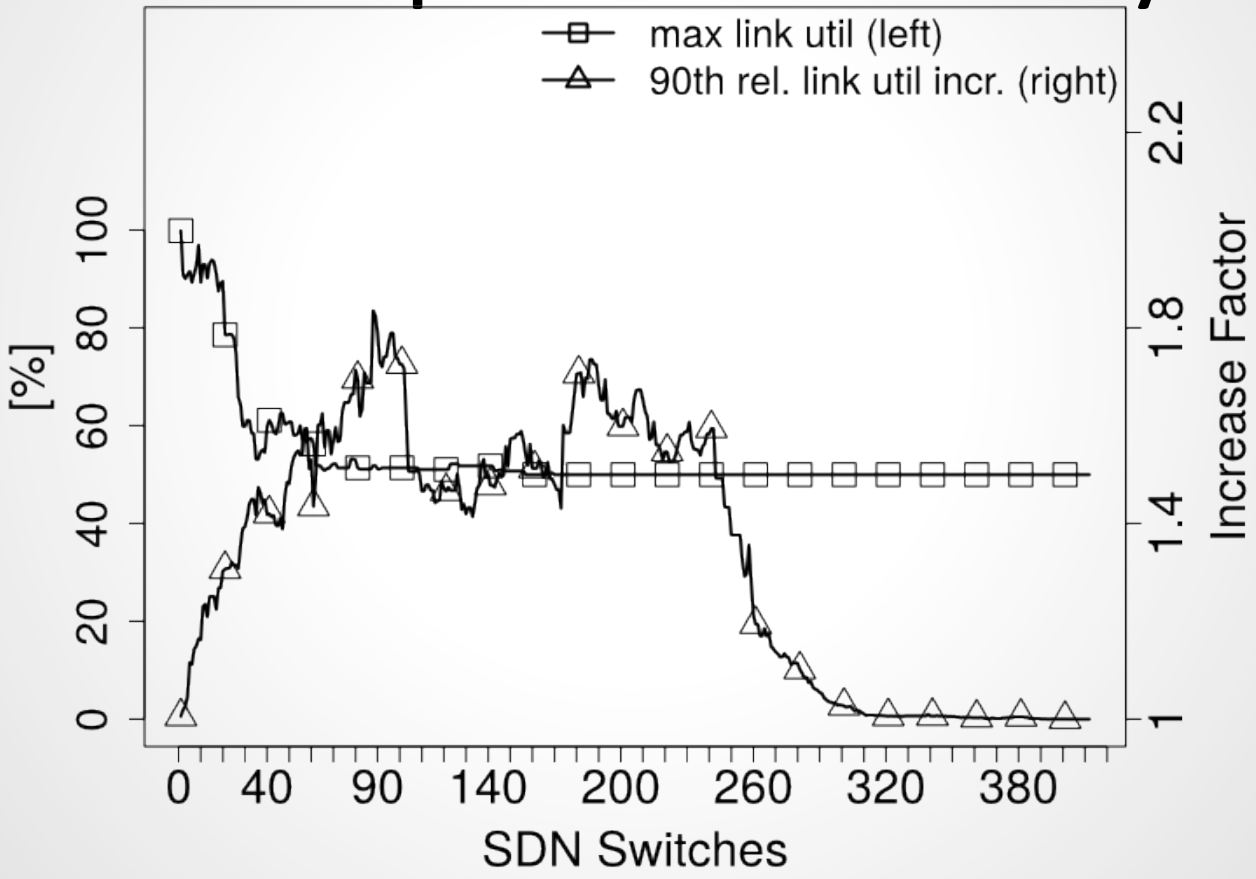

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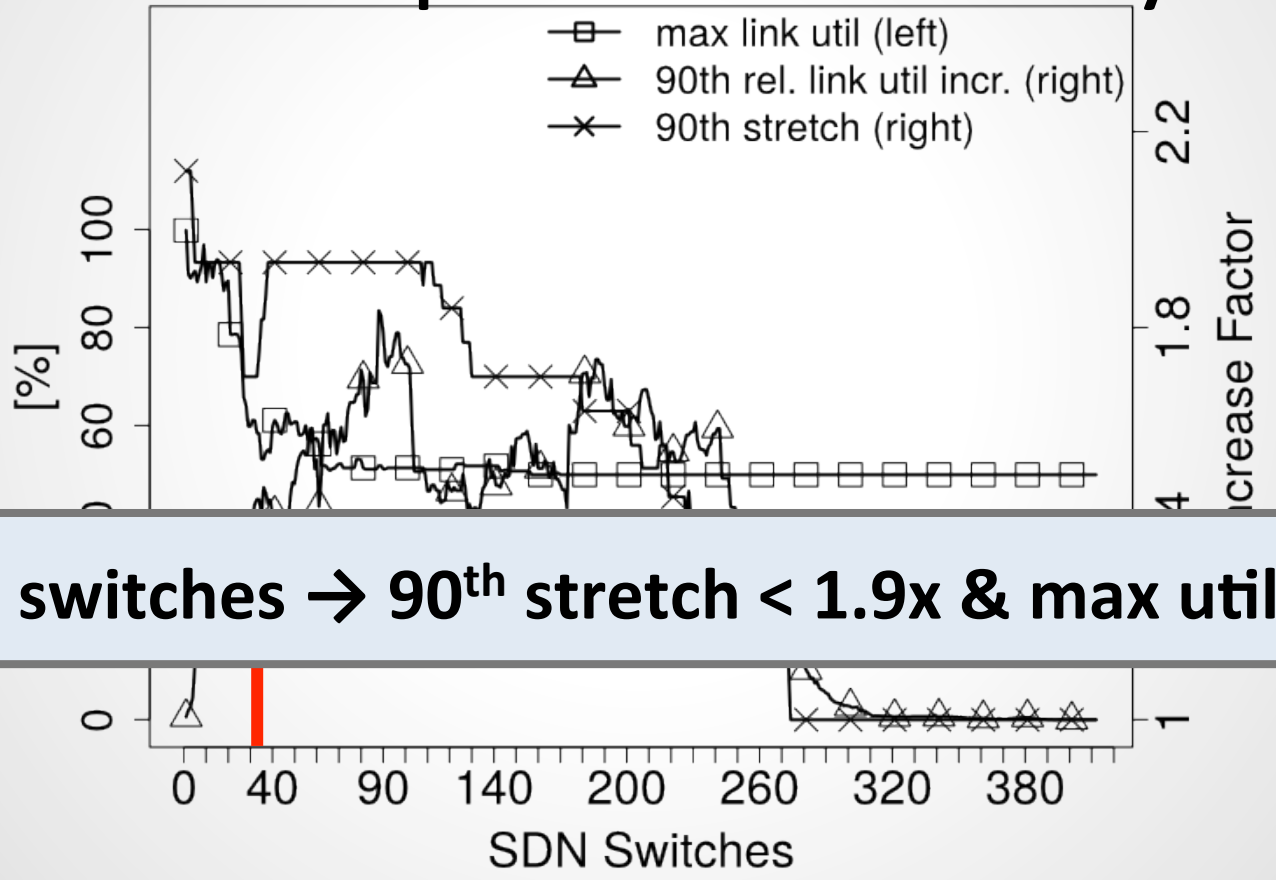
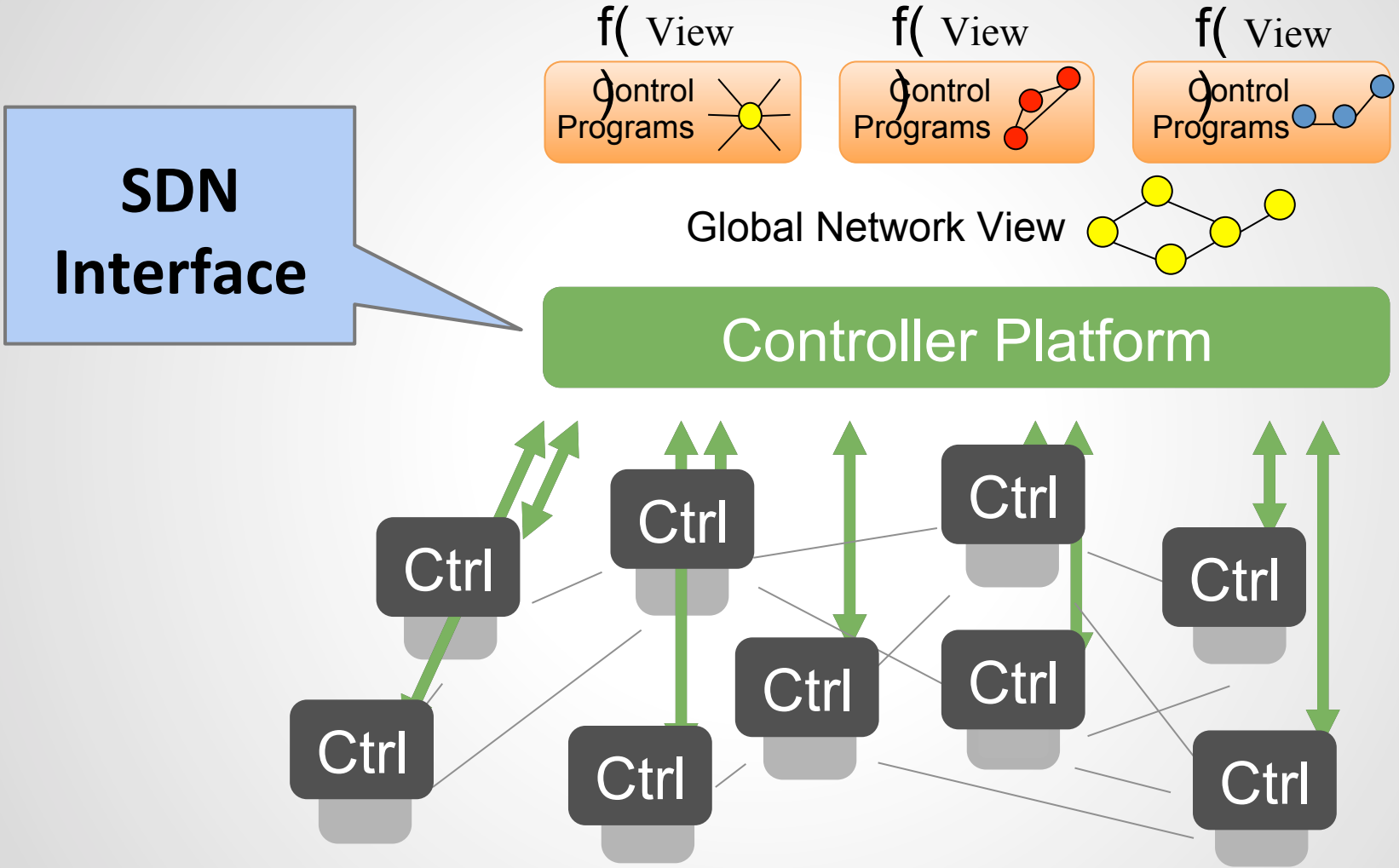


33 SDN switches → 90th stretch < 1.9x & max util. < 60%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Control Programs
f(View)
Control Programs
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Control Programs
Global Network View
SDN Interface
Controller Platform
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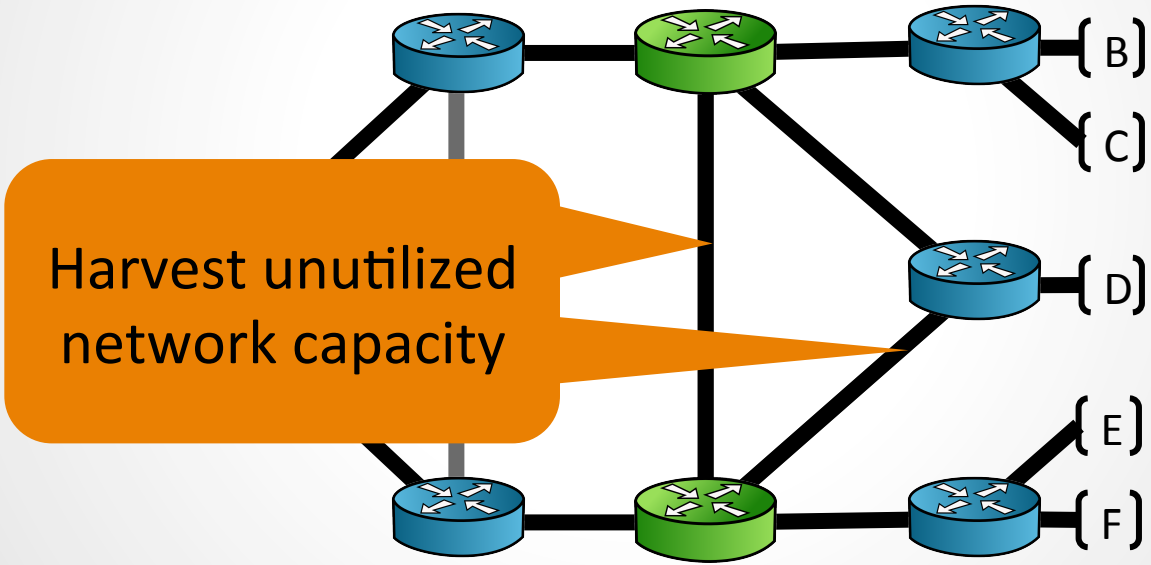
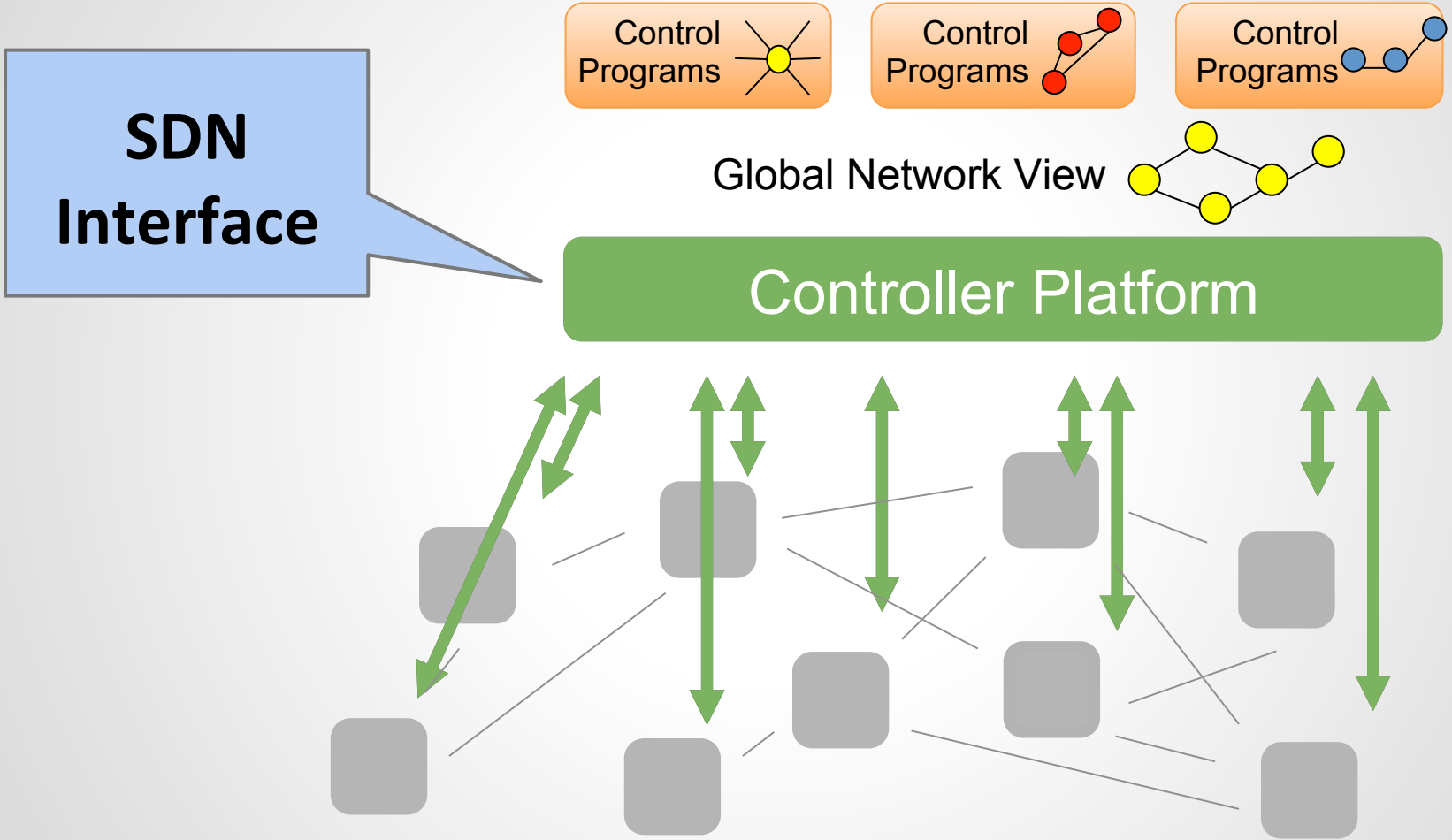
Simulation Methodology

- Real network topology
  - 1296 Access / **412 Distribution** / 3 Core
- Traffic estimates from LBNL packet traces
  - Map randomly while preserving prefix locality
  - Scale traffic projection so that the most utilized link is 50%
- SDN deployment strategies: **RANDOM** vs. **VOL**
  - **VOL**: iteratively upgrade switch that forwards most traffic

Benefits of Hybrid Deployment?




SDN Interface
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