

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

Dan Levin

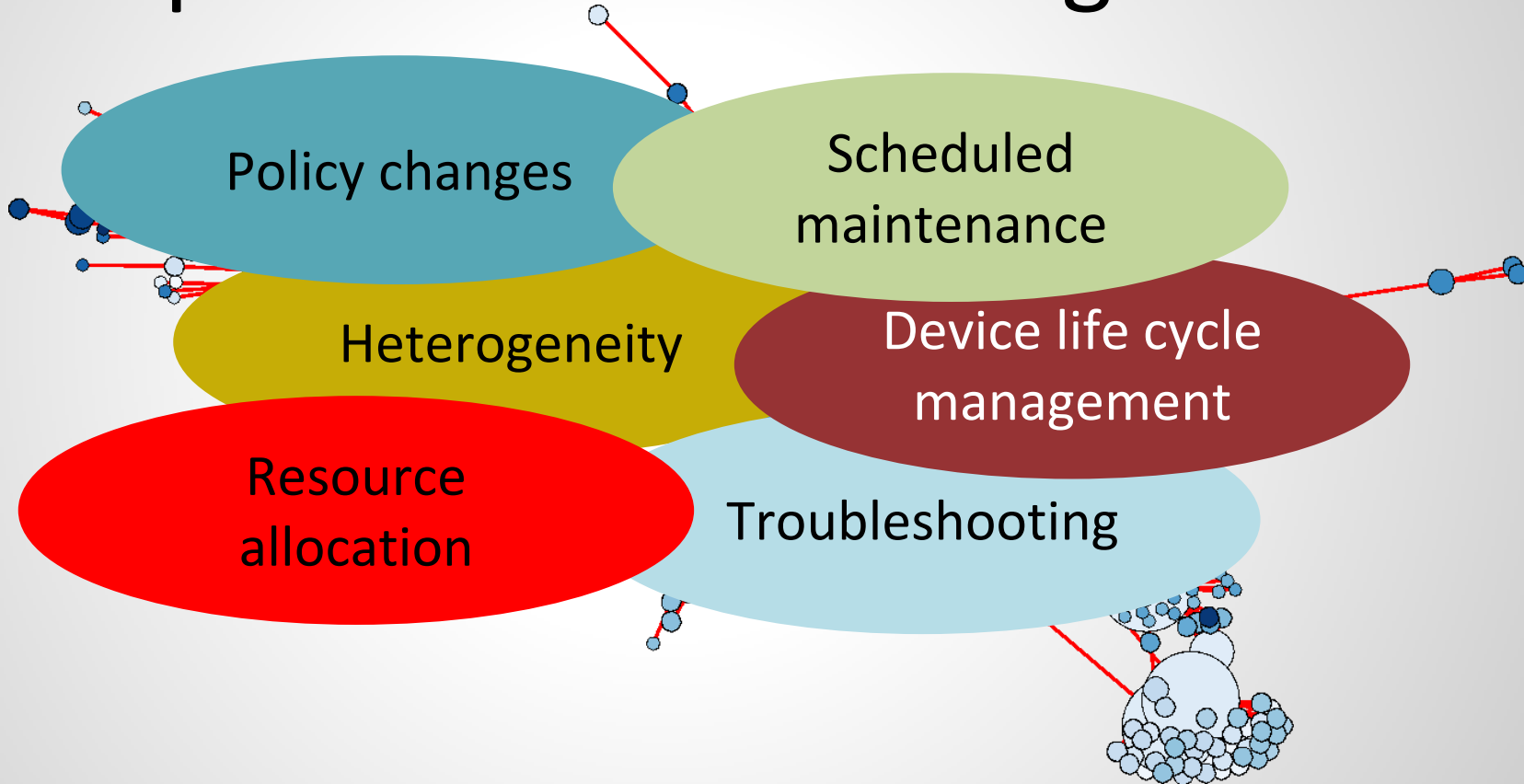
with Marco Canini, Stefan Schmid, Fabian Schaffert, Anja Feldmann



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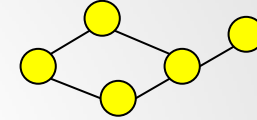
Enterprise Network Management



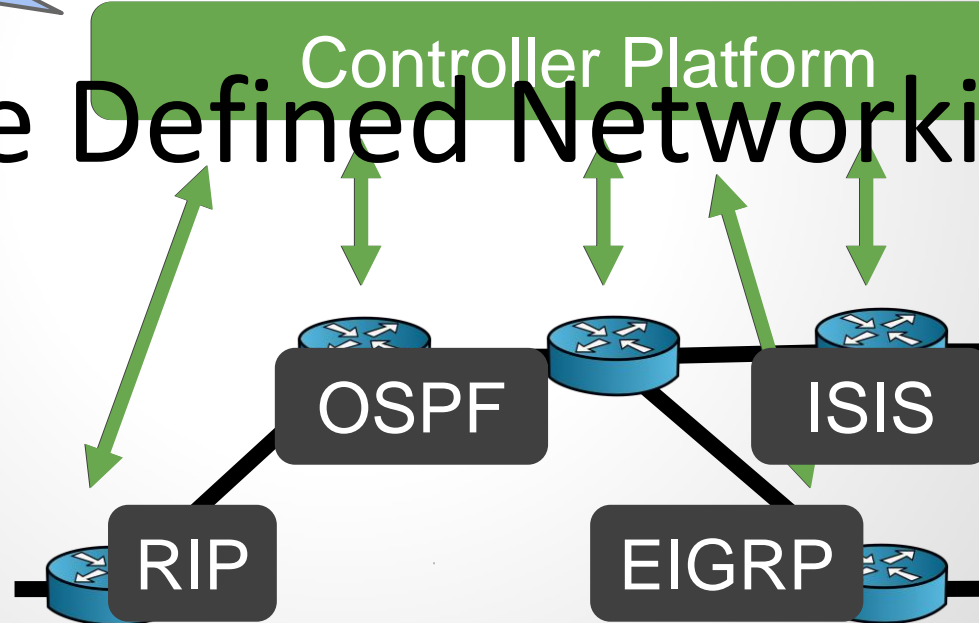
**SDN
Interface**



Global Network View



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

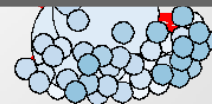
1. How can we **incrementally deploy the SDN interface** into enterprise networks?
2. What **benefits** can be realized from a **hybrid SDN** deployment?
3. What **limitations** or performance costs?

PANOPTICON



Incrementally Deployable SDN Architecture

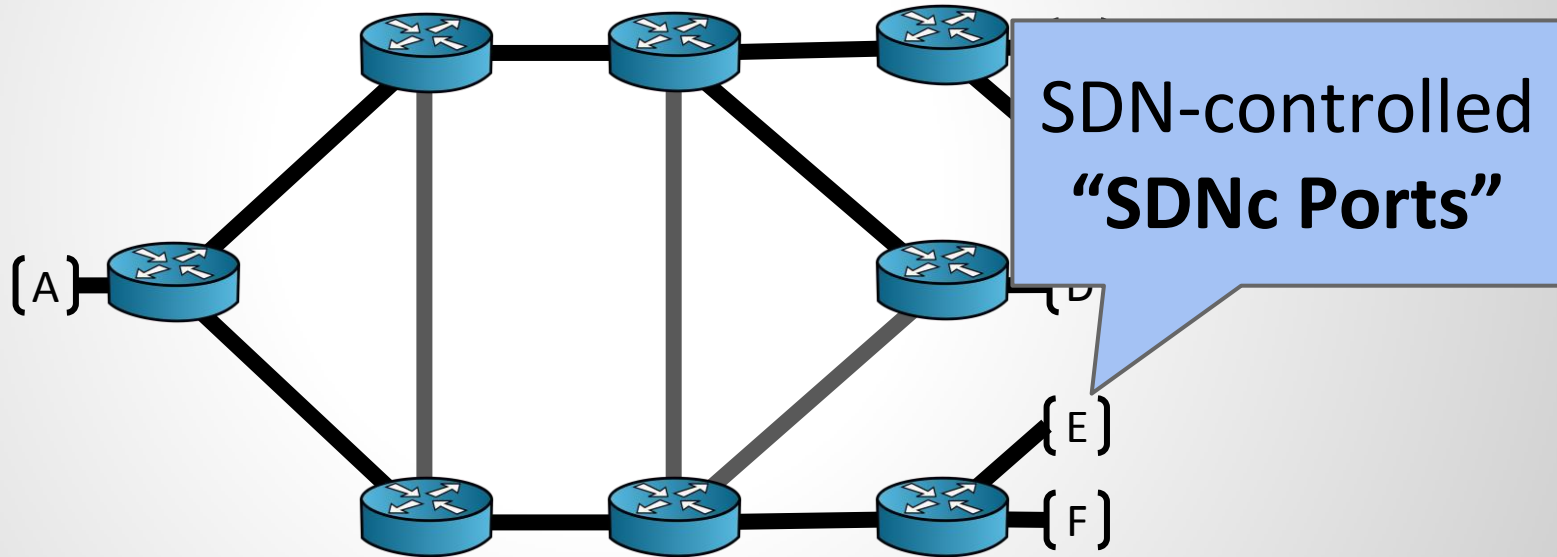
- Systematic approach to operate a hybrid network as a (nearly) full SDN
- Prototype Implementation
- Planning tool



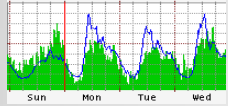
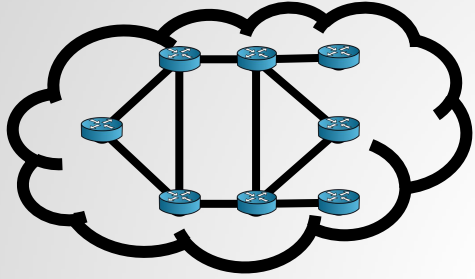
Key Questions

1. How can we **incrementally deploy the SDN interface** into enterprise networks?
2. What **benefits** can be realized from a **hybrid SDN** deployment?
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The Existing Network



Network Topology



Traffic
Estimates

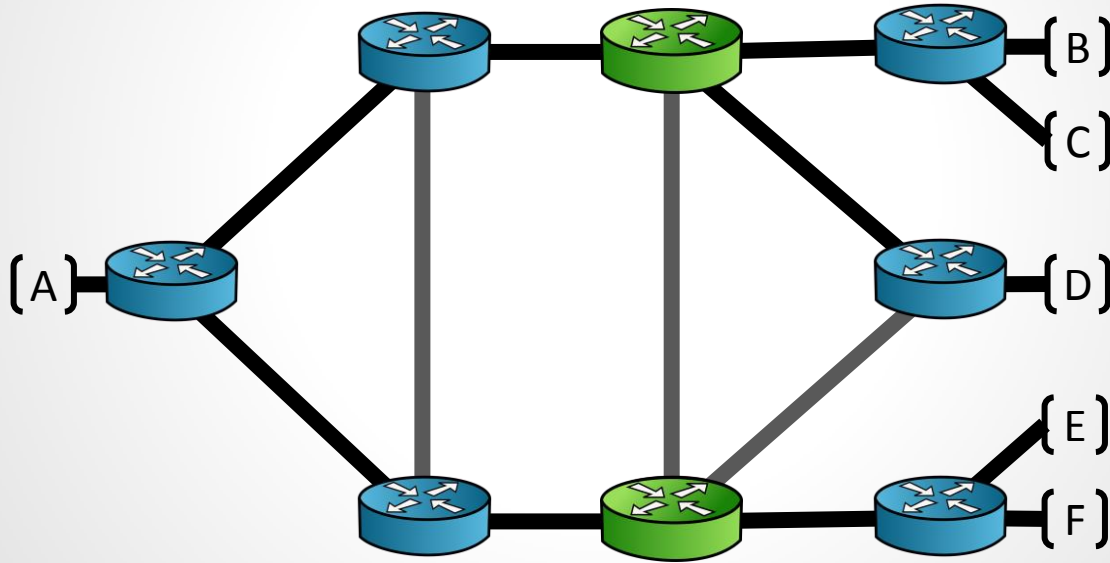


- Path Delay
- Link Utilizations
- Resource Constraints

**Planning
Strategy**

Hybrid SDN
Deployment

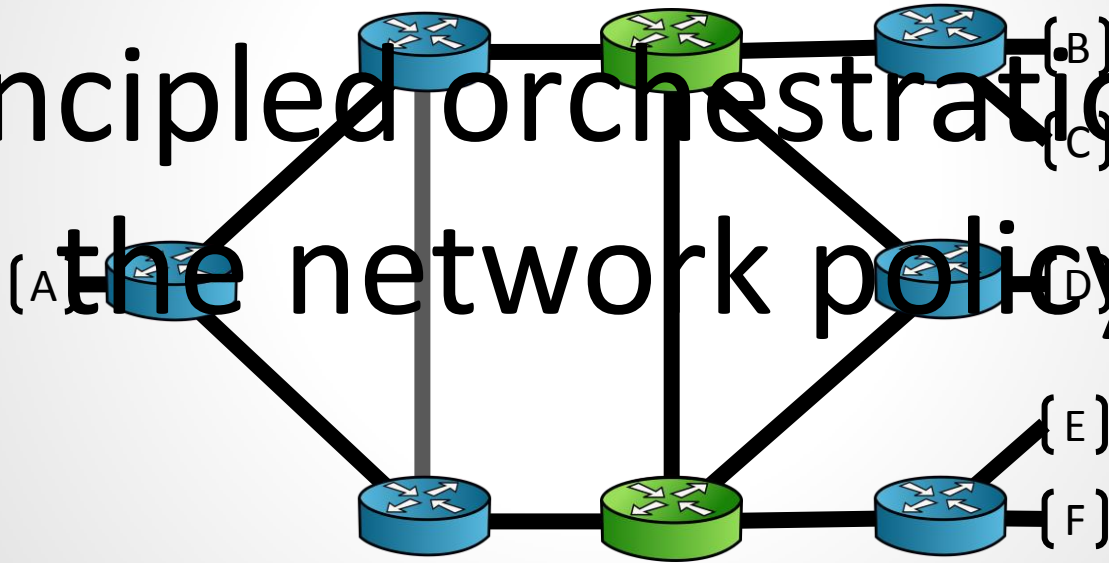
The Hybrid SDN Deployment ()



Key Questions

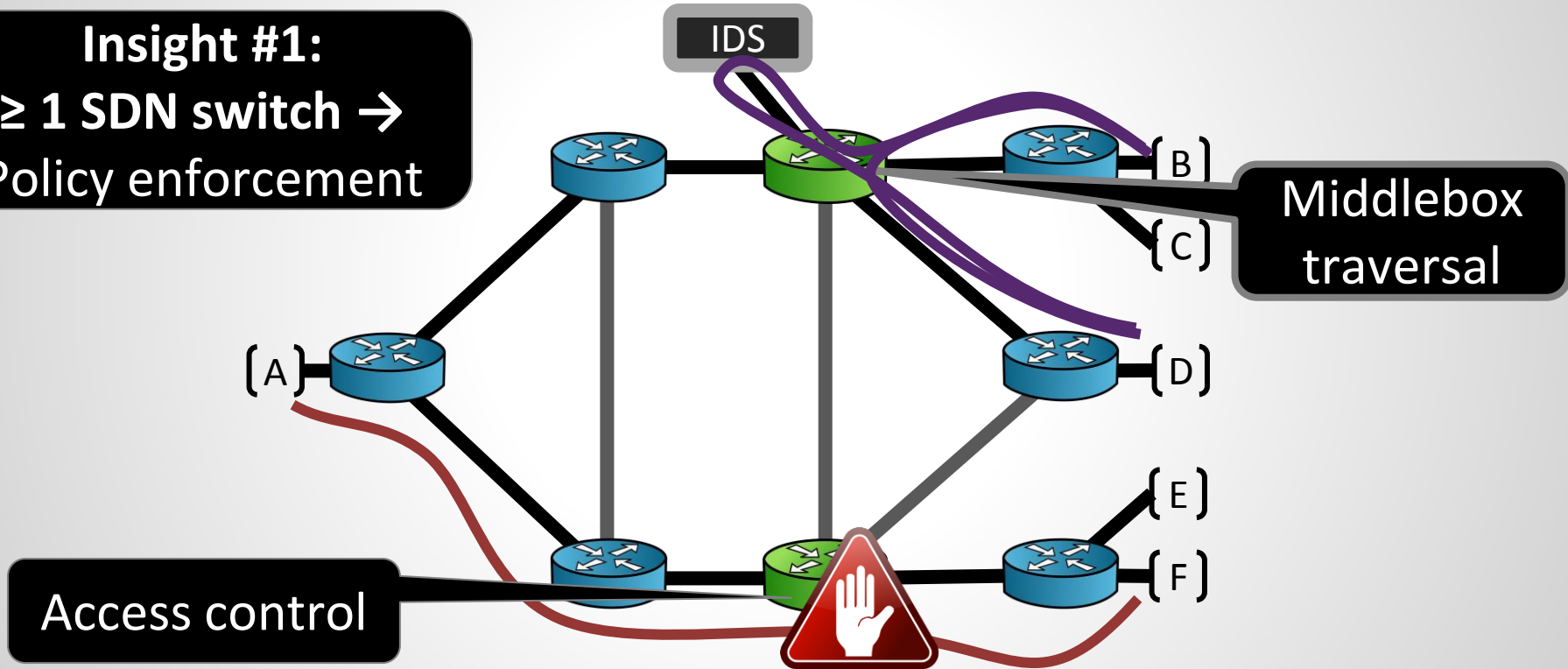
1. How can we **incrementally deploy the SDN interface** into enterprise networks?
2. What **benefits** can be realized from a **hybrid SDN** deployment?
3. What limitations or performance costs?

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



Realizing the Benefits of SDN

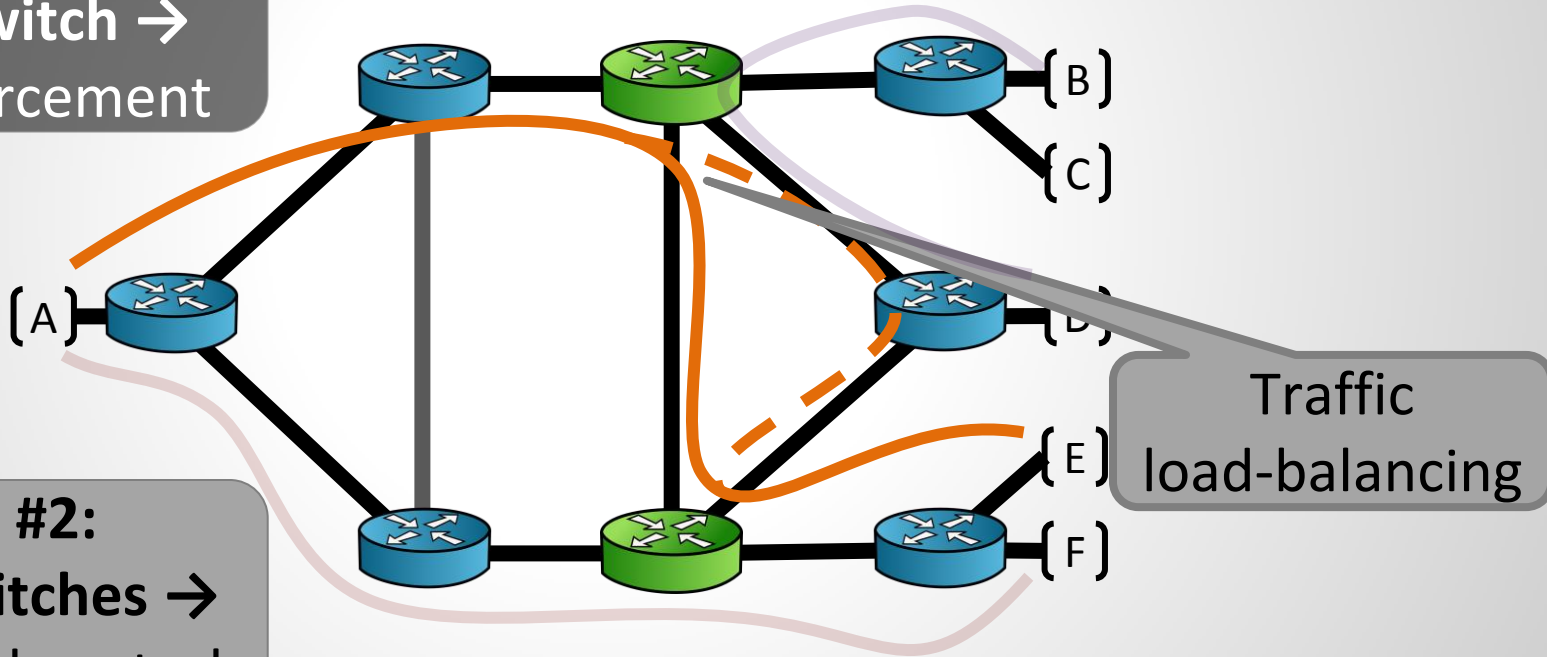
Insight #1:
 ≥ 1 SDN switch \rightarrow
Policy enforcement



2. Realizing the Benefits of SDN

Insight #1:
 ≥ 1 SDN switch \rightarrow
Policy enforcement

Insight #2:
 ≥ 2 SDN switches \rightarrow
 Fine-grained control



Insight #1:
 ≥ 1 SDN switch \rightarrow
Policy enforcement

Insight #2:
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Fine-grained control

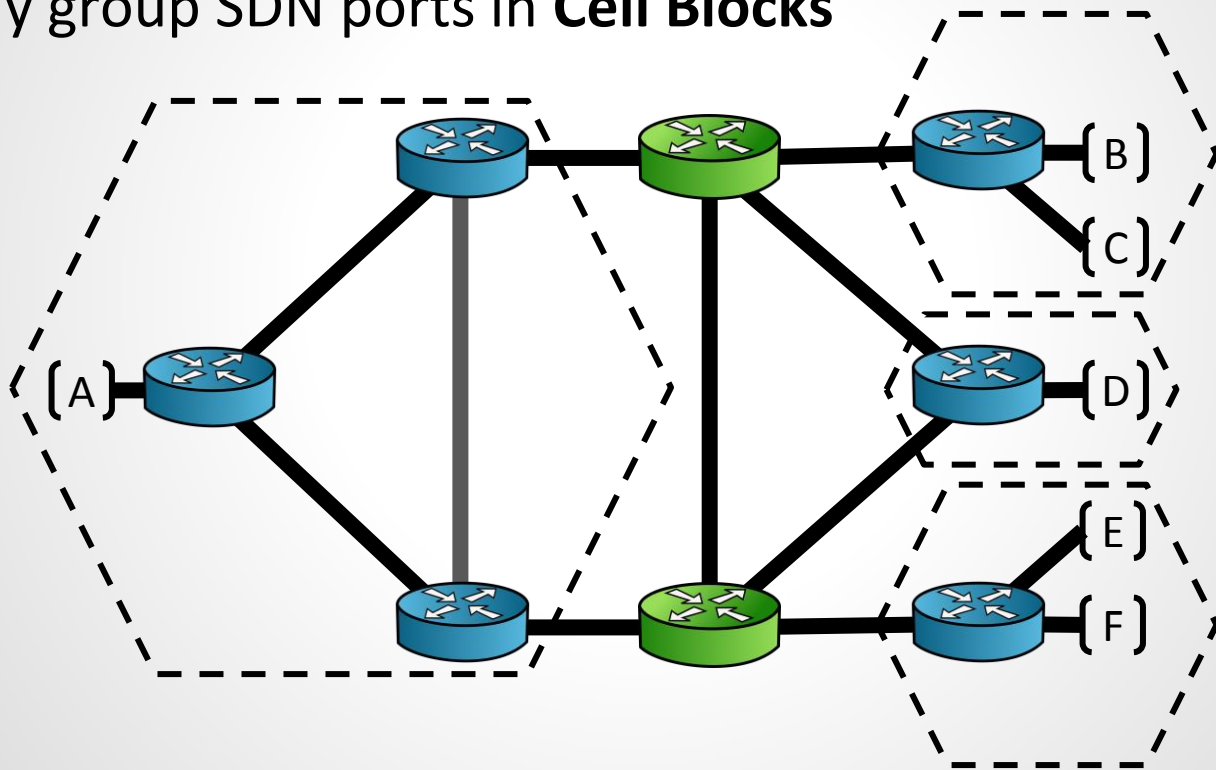
Ensure that all traffic to/from
an SDN-controlled port always
traverses at least one SDN switch

SDN Waypoint Enforcement

Legacy devices must direct traffic to SDN switches

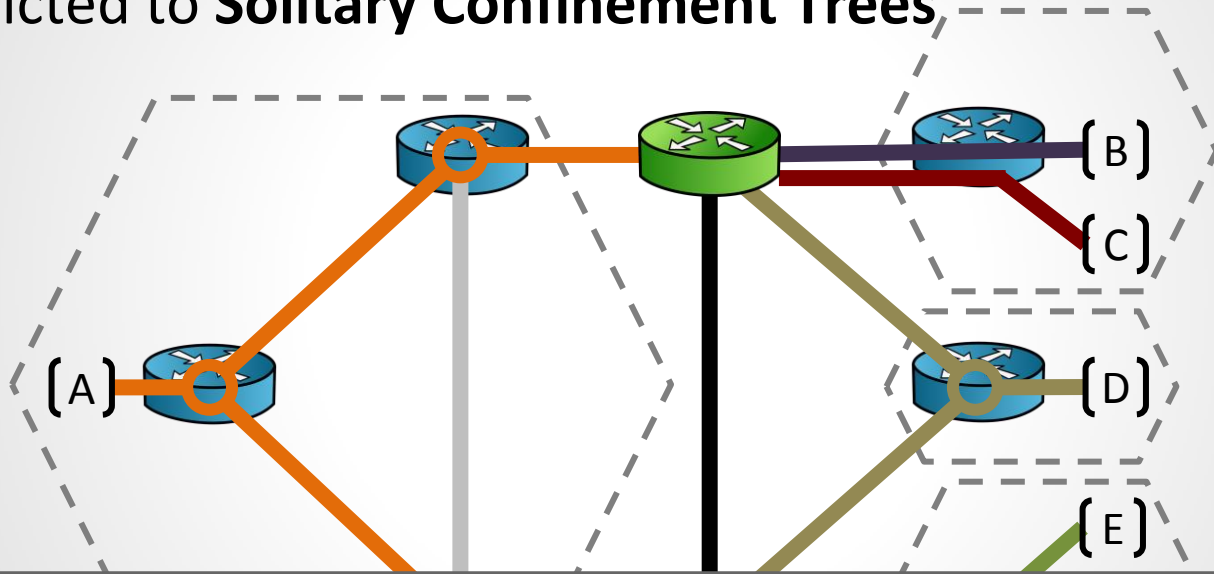
The **PANOPTICON** SDN Architecture

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**

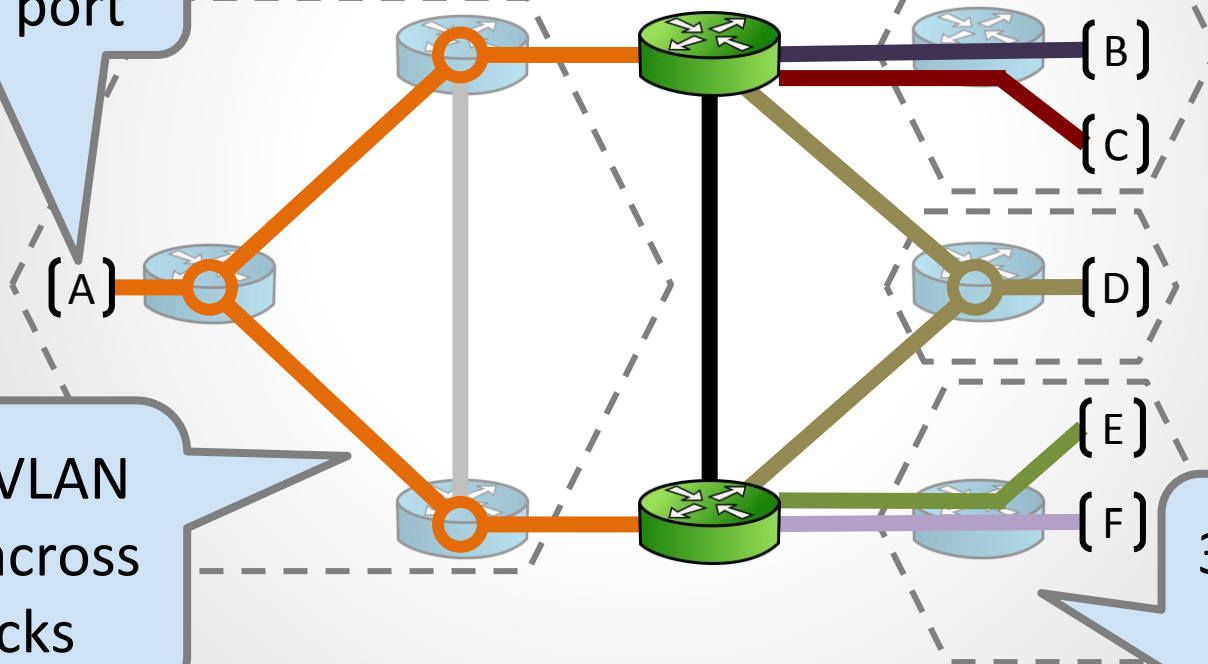
The **PANOPTICON** SDN Architecture

Solitary Confinement Trees

1. One VLAN ID per SDNc port

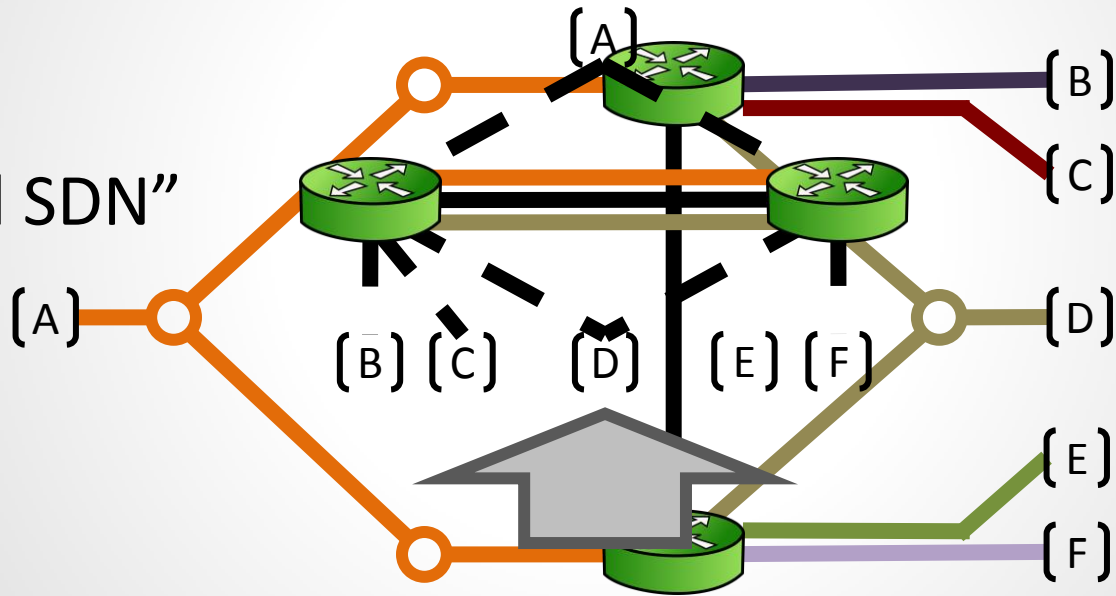
2. Reuse VLAN ID space across cell blocks

3. SCTs can be pre-installed

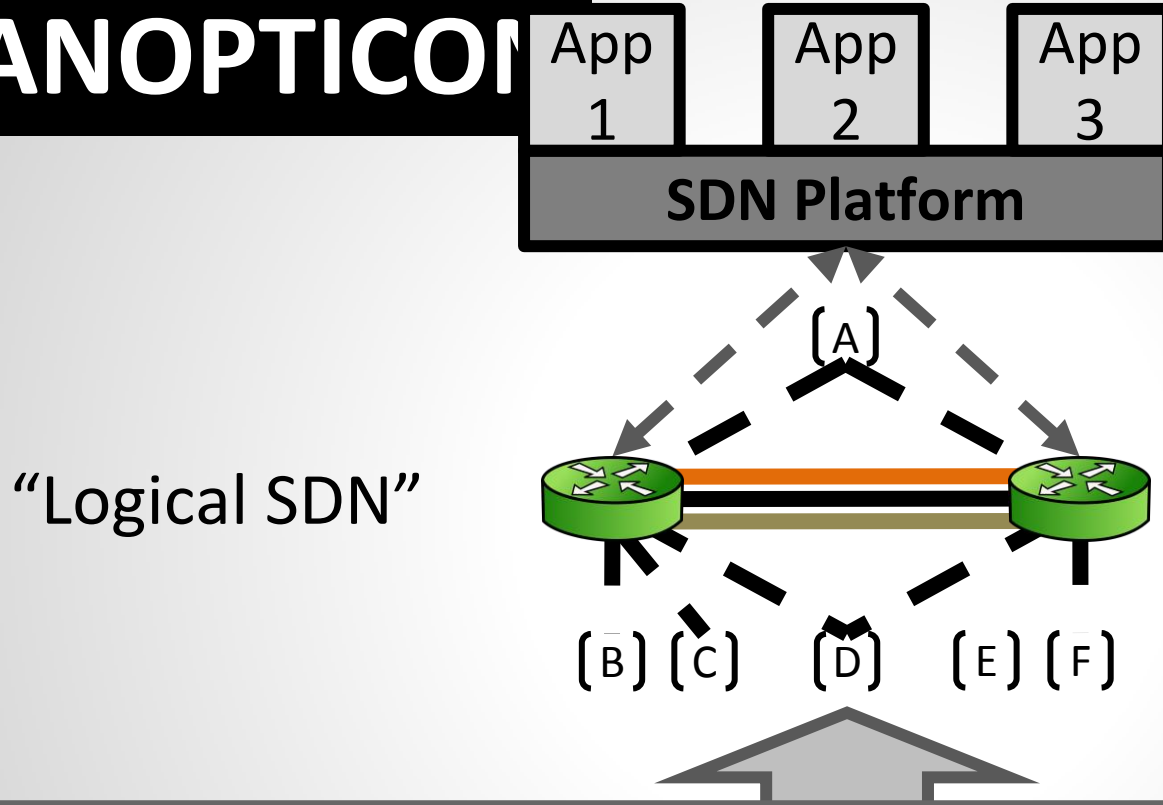


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“Logical SDN”




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

Evaluation

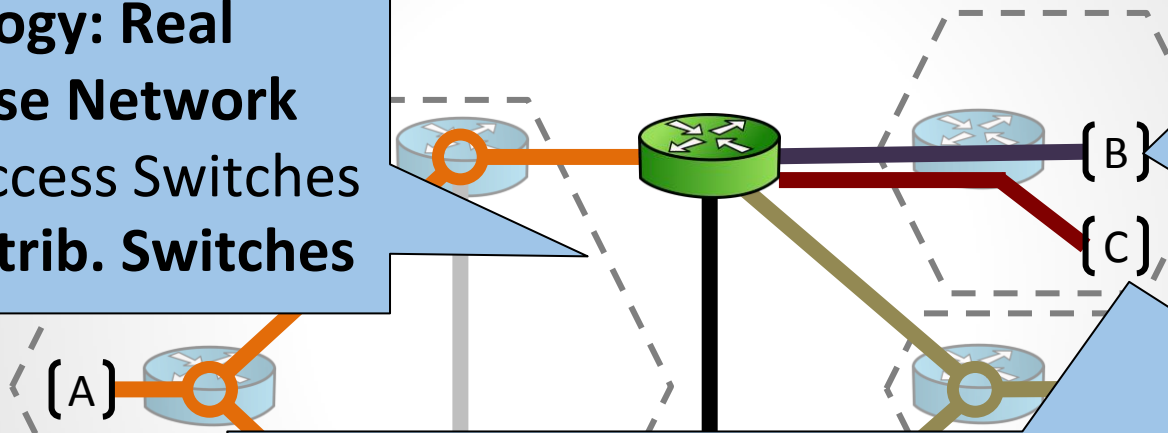
Simulation	Emulation	Testbed
How many SDNc ports do I get as the deployment grows?	<p>Prototype Implementation</p>  <p>TC W der ent</p> <p>Fault Tolerance</p>	
How will Panopticon Affect Network Traffic?		

Simulation Methodology

Topology: Real Enterprise Network

- 1296 Access Switches
- 412 Distrib. Switches

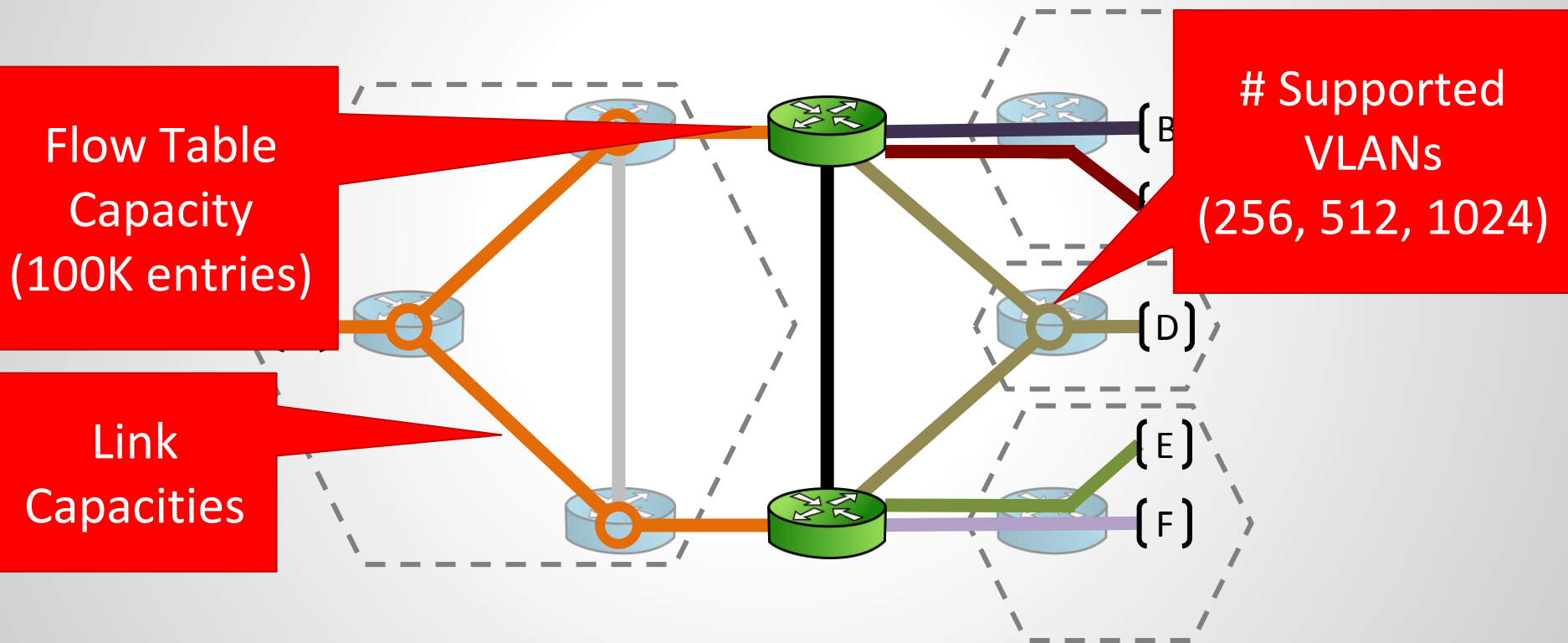
1296 SDNc Port Candidates



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)

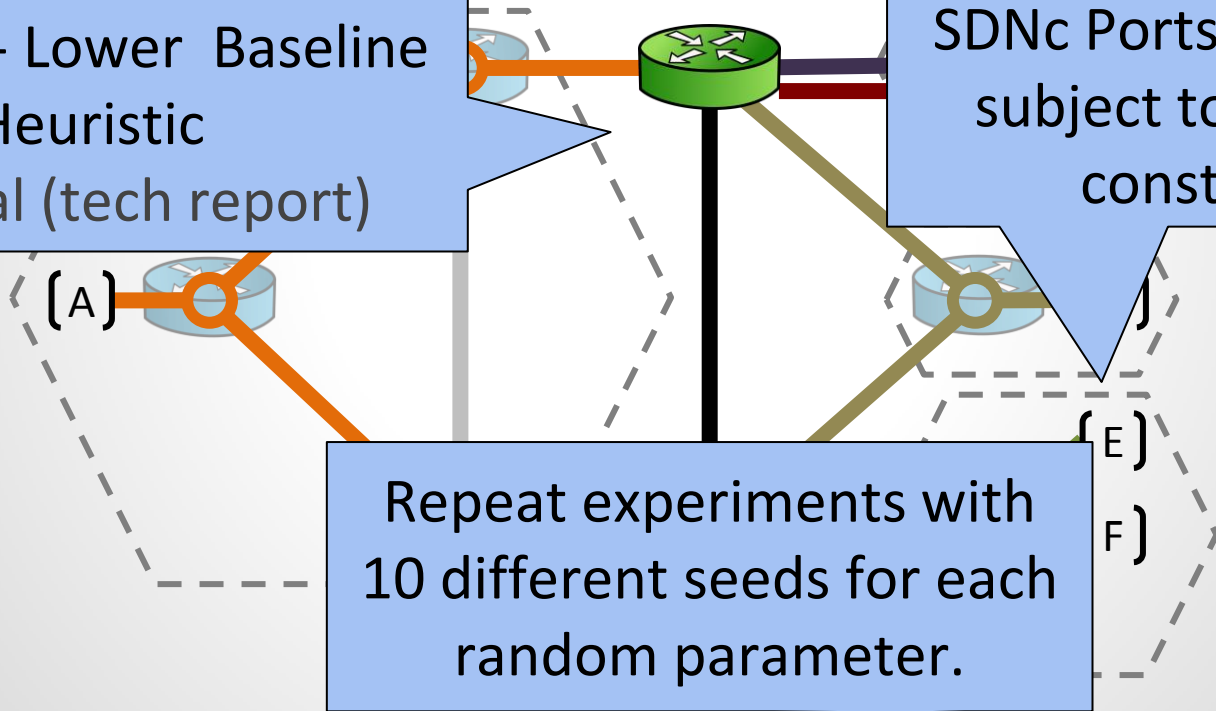
Accomodate as many SDNc Ports as possible subject to resource constraints

(A)

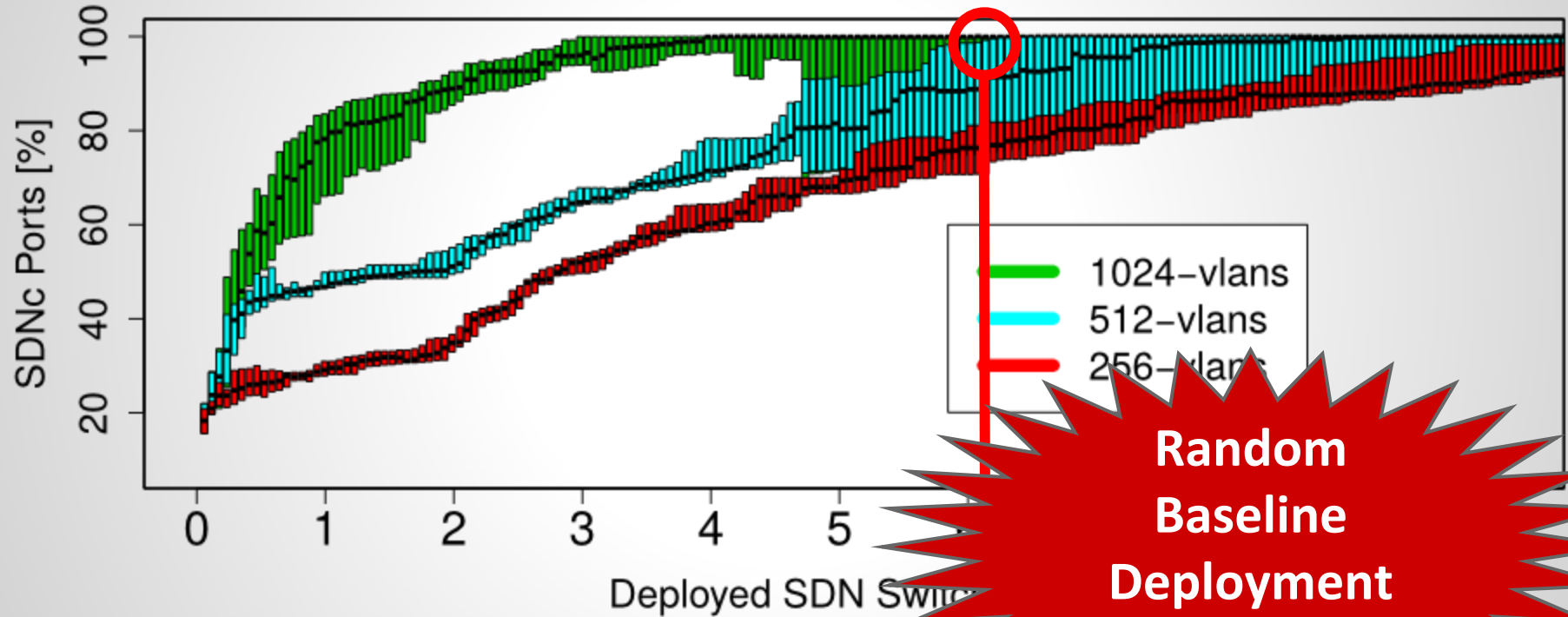
Repeat experiments with 10 different seeds for each random parameter.

(E)

(F)

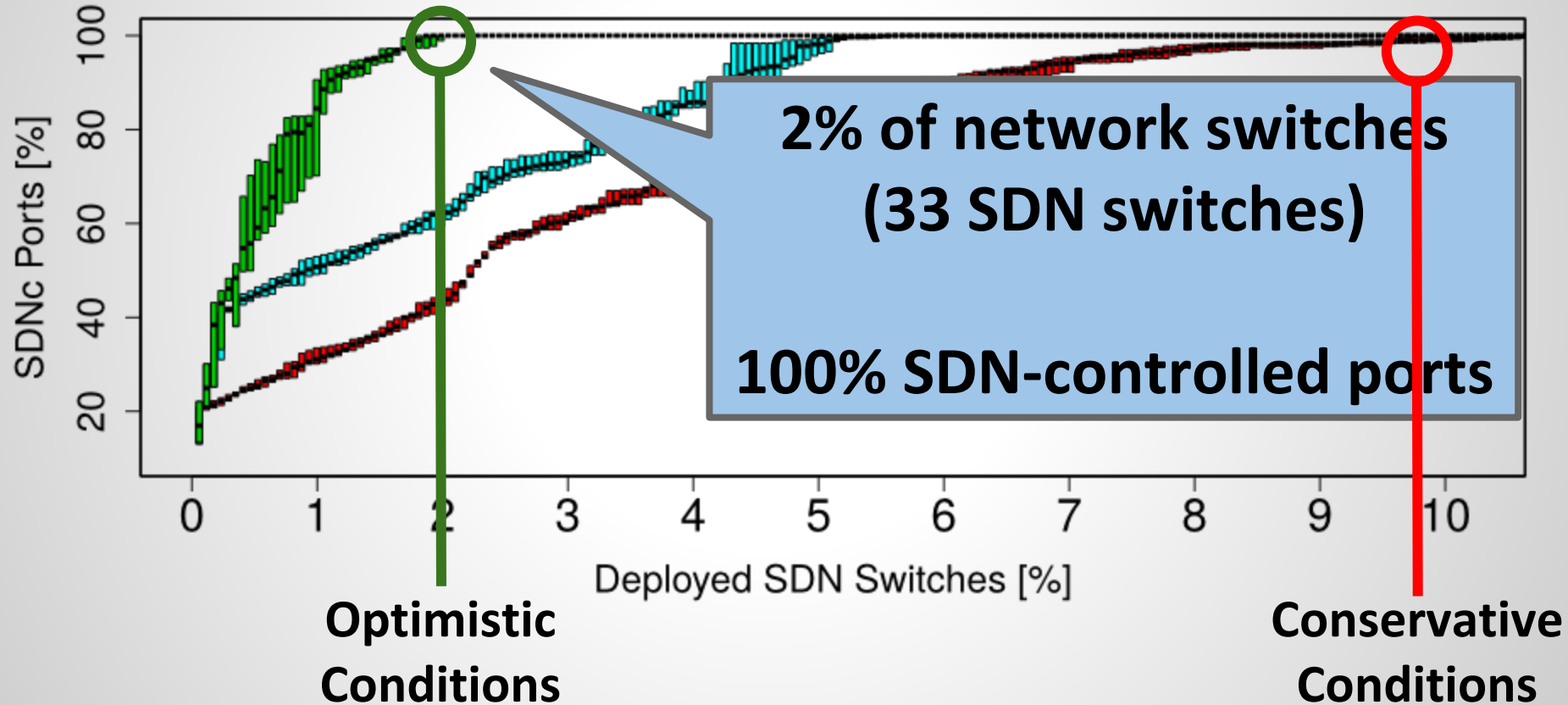


How many SDNc ports do I get?

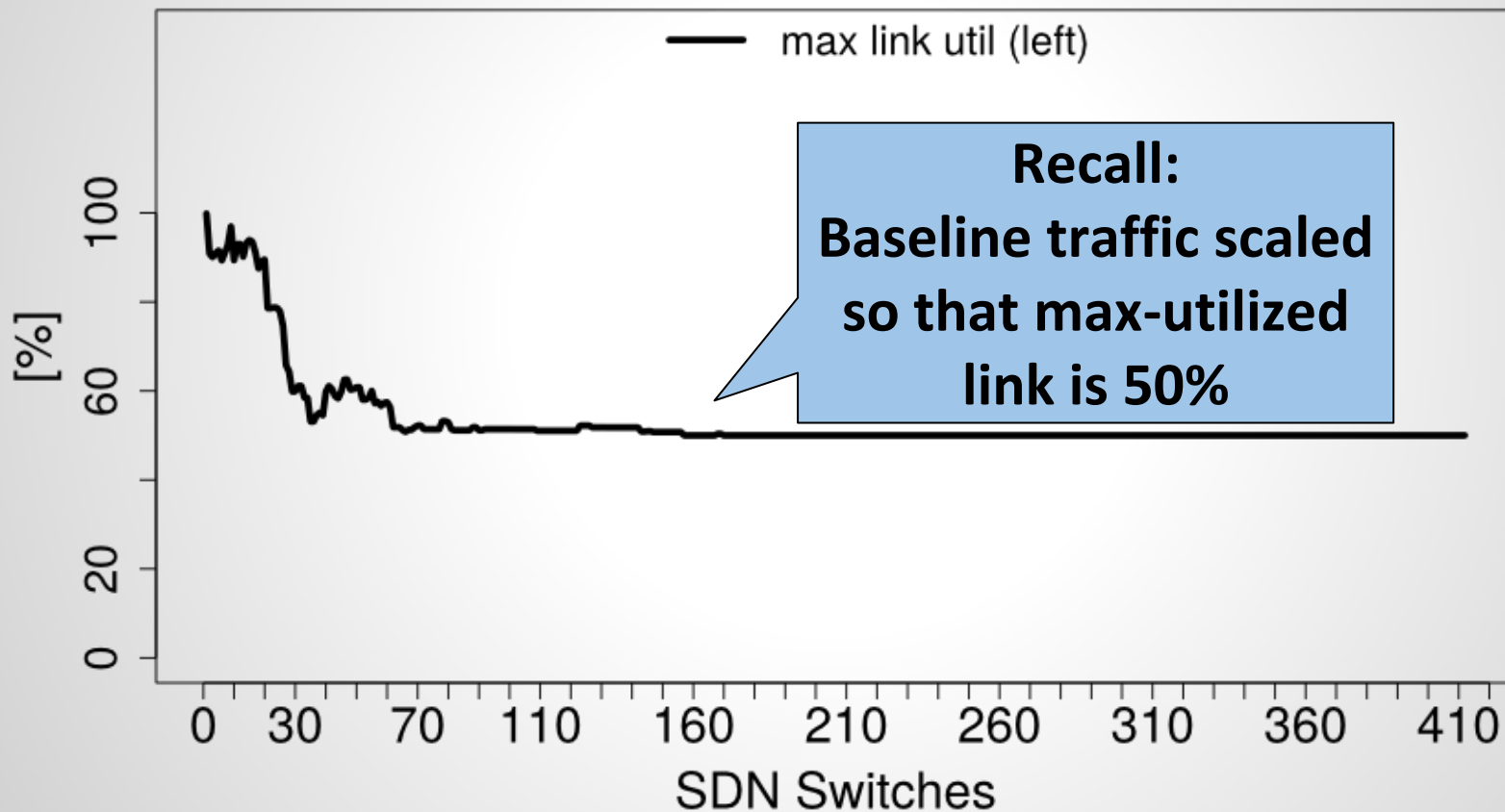


**Random
Baseline
Deployment
Strategy**

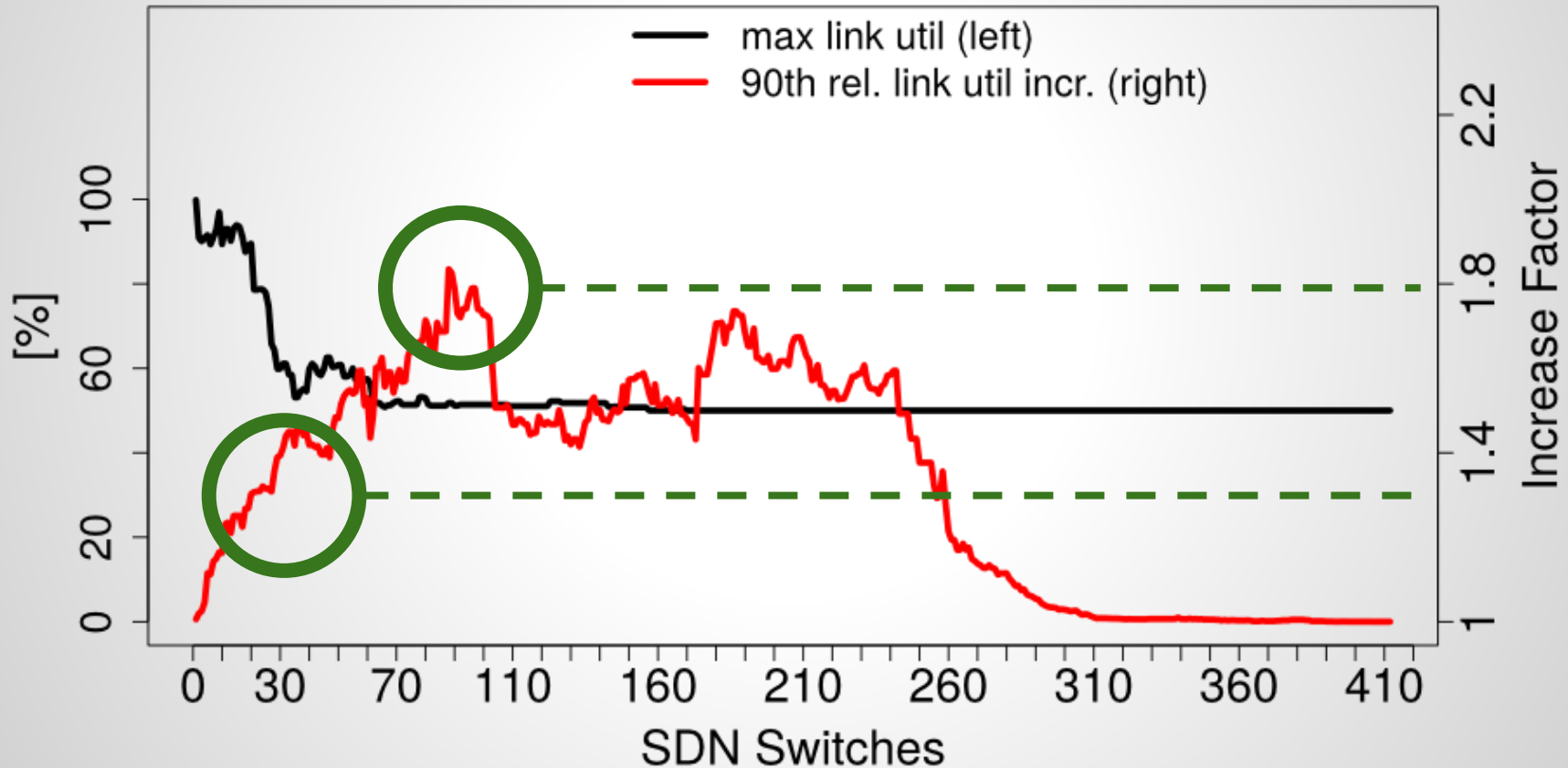
Feasibility with VOL heuristic



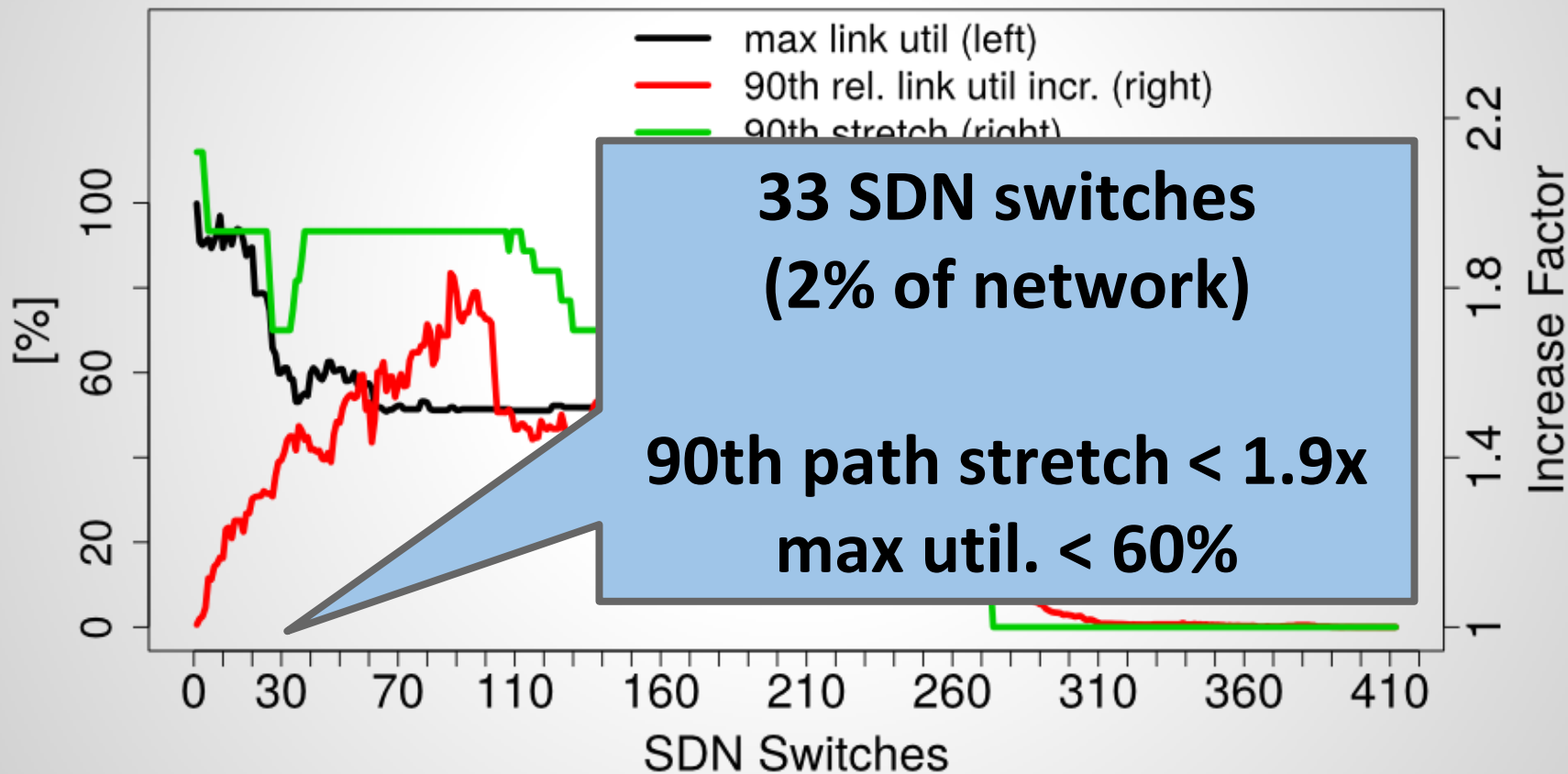
How will Panopticon affect my traffic?



How will Panopticon affect my traffic?



How will Panopticon affect my traffic?



Key Evaluation Results

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

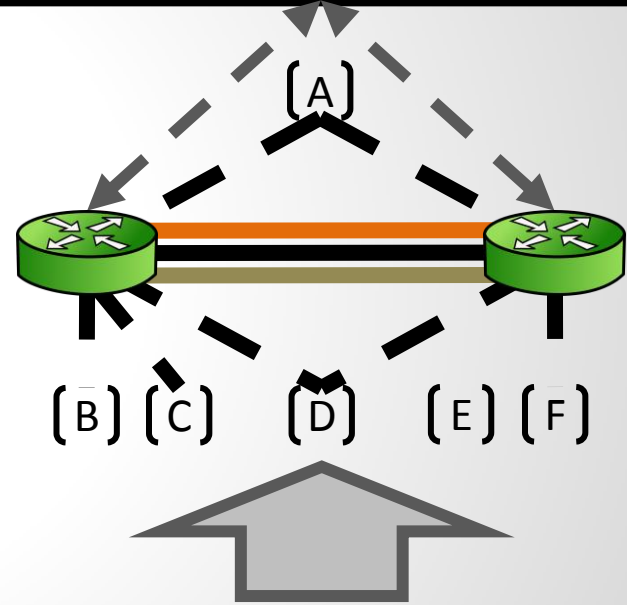
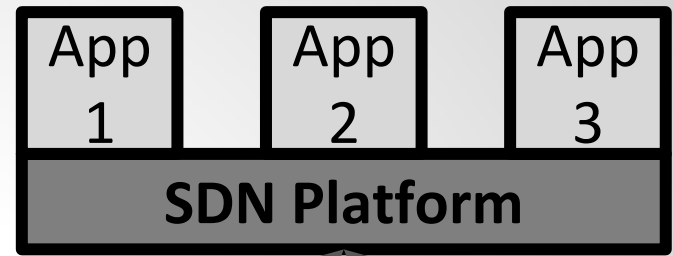
Summary

SDN

ARCHITECTURE Operate
the network as
a (nearly) full SDN

Planning

TOOL Determine the
partial
SDN deployment

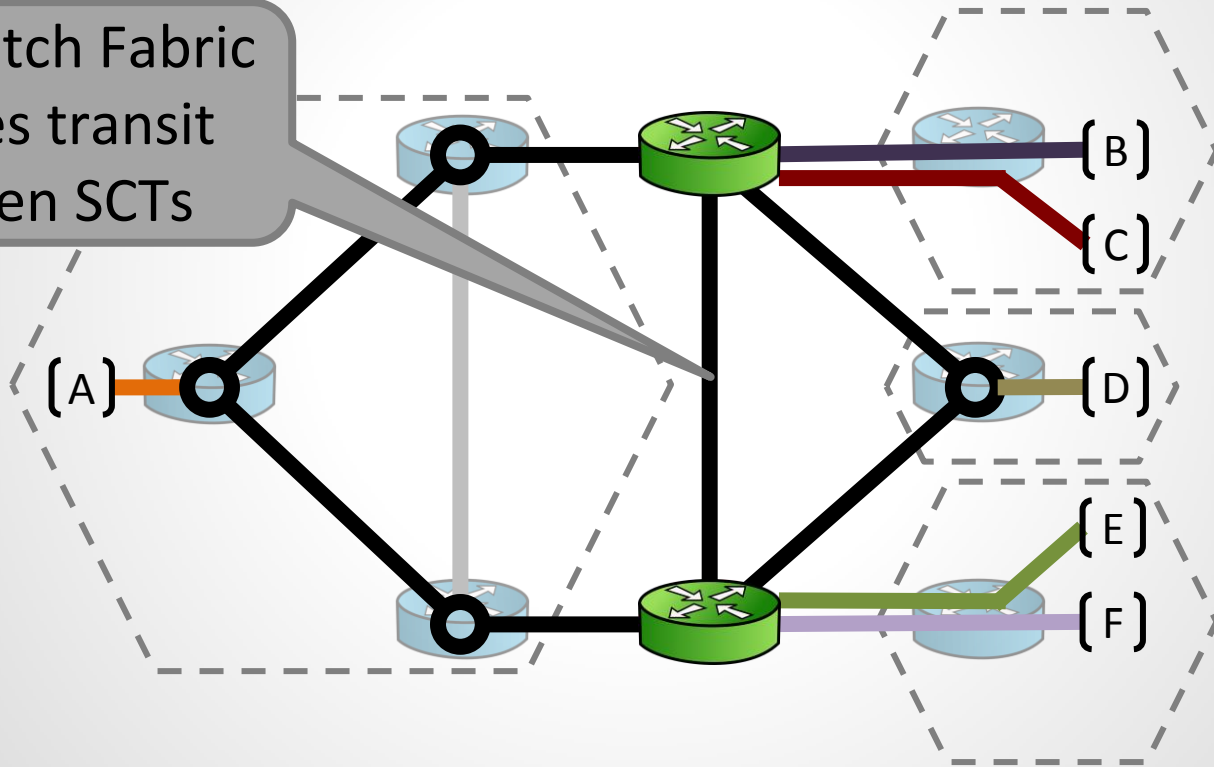


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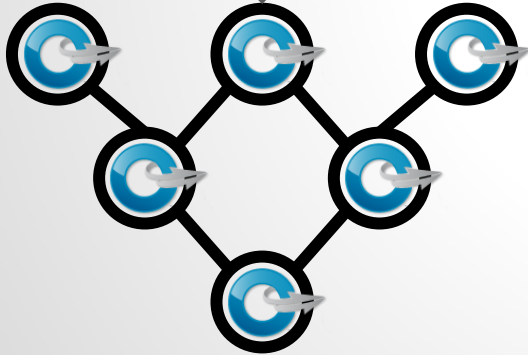
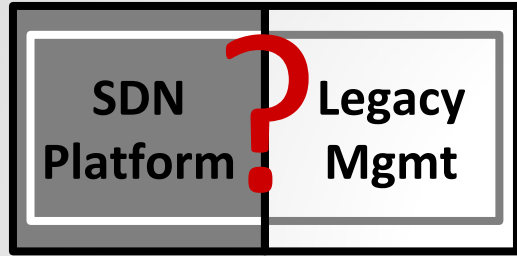
<https://panoptisim.badpacket.in>

Packet Forwarding

Inter-Switch Fabric
provides transit
between SCTs

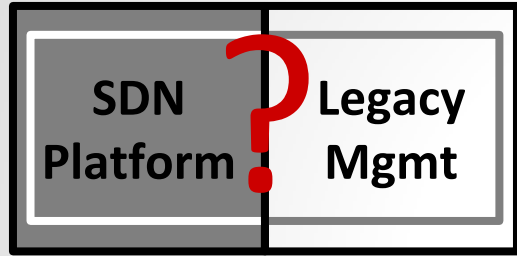


Current Hybrid Networks

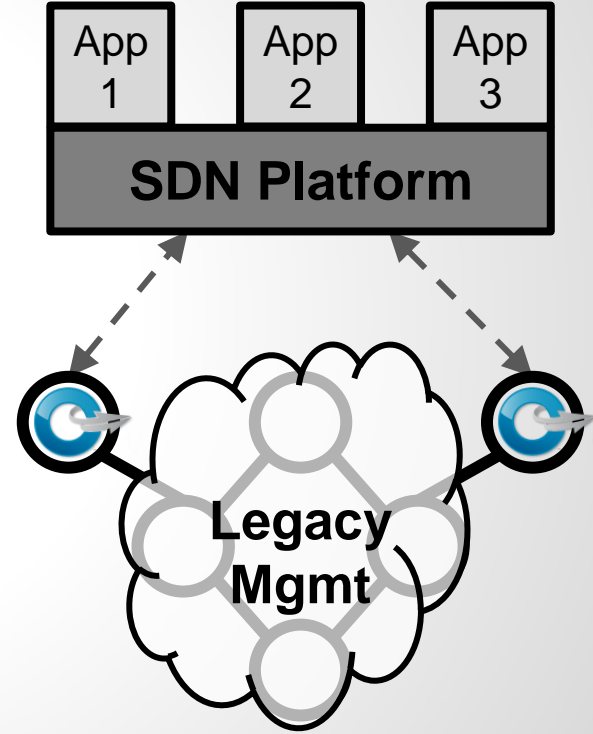


Dual-stack approach

Current Hybrid Networks

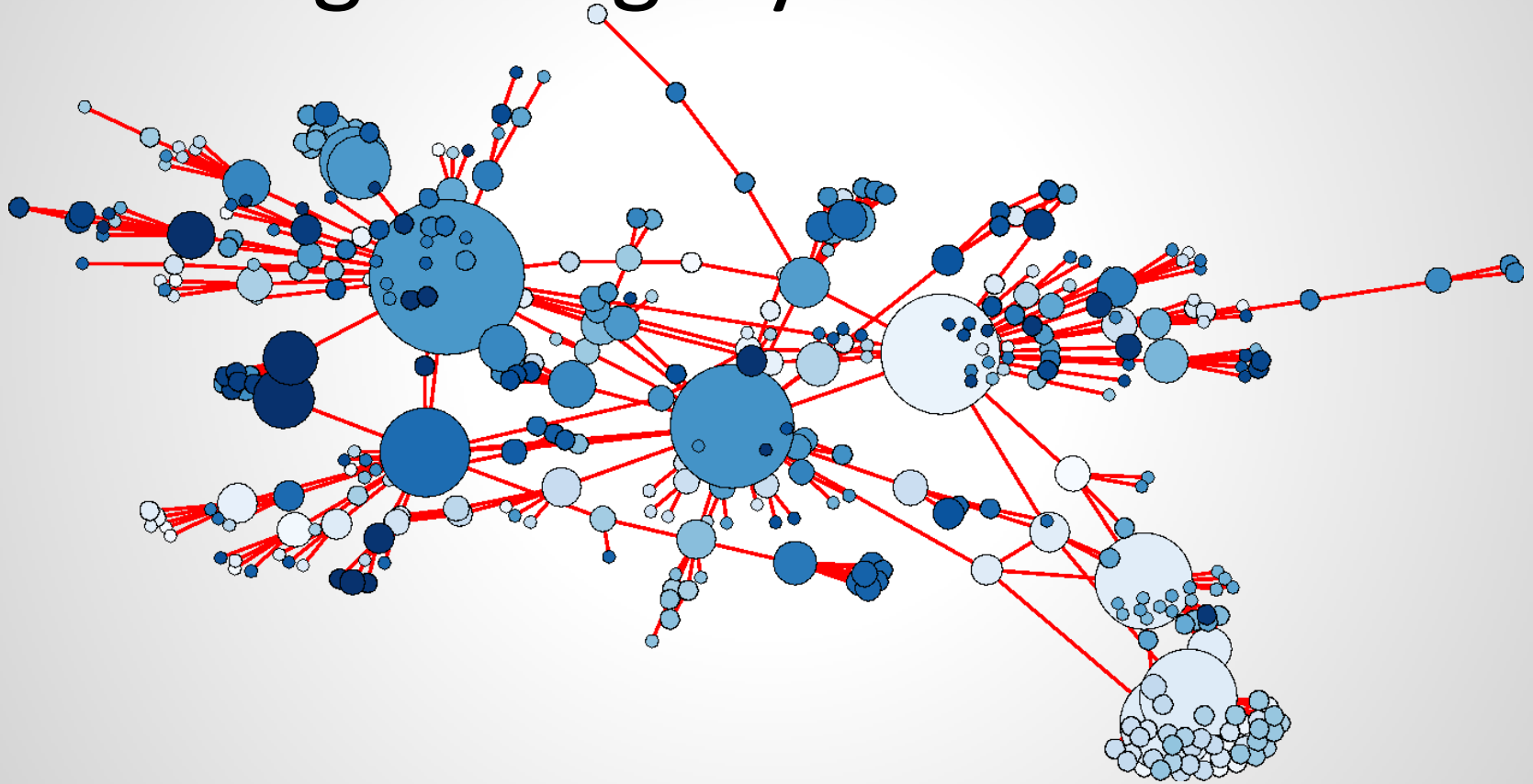


Dual-stack approach



Edge-only approach

The edge is legacy access switches

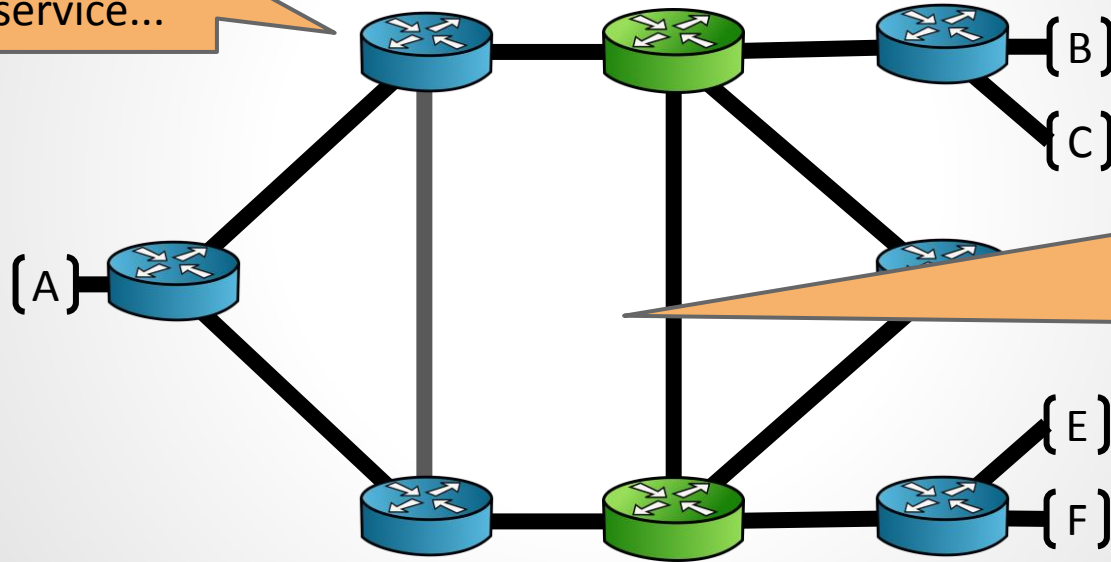


Hybrid SDN Use Cases

- **Automated Planned Maintenance Tool**
- Lightweight IP Subnet Mobility
- ACL refactorization
- Middle-box Traversal

Use Case: Planned Maintenance

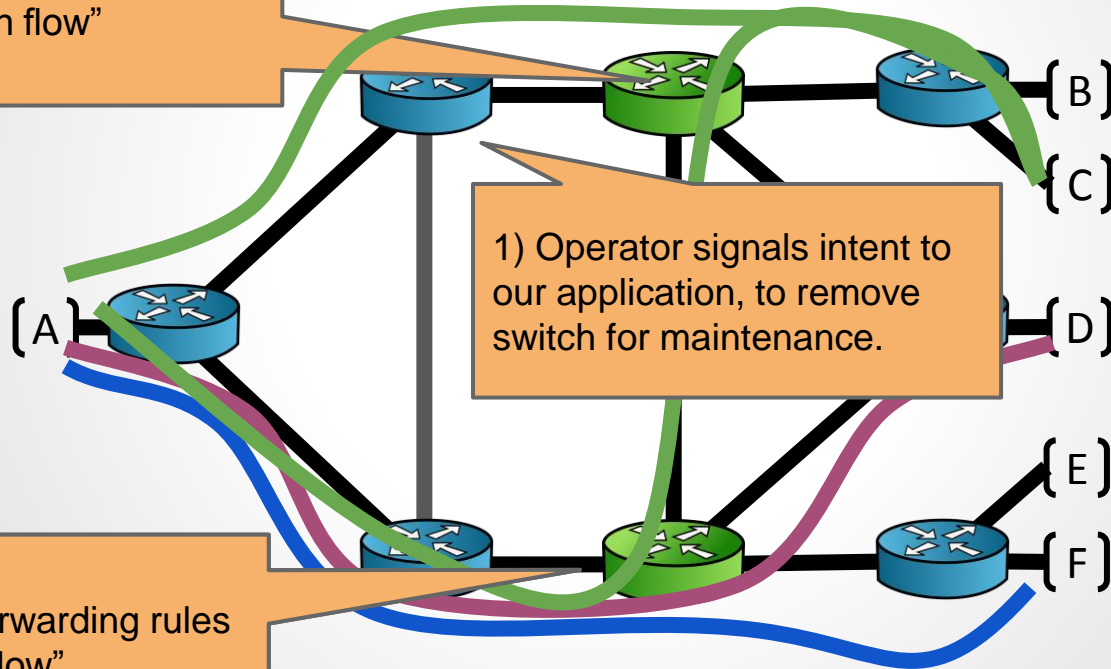
Operator says:
"You're Going
down for service..."



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

Use Case: Planned Maintenance

3) Update forwarding rules to re-route "green flow"



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

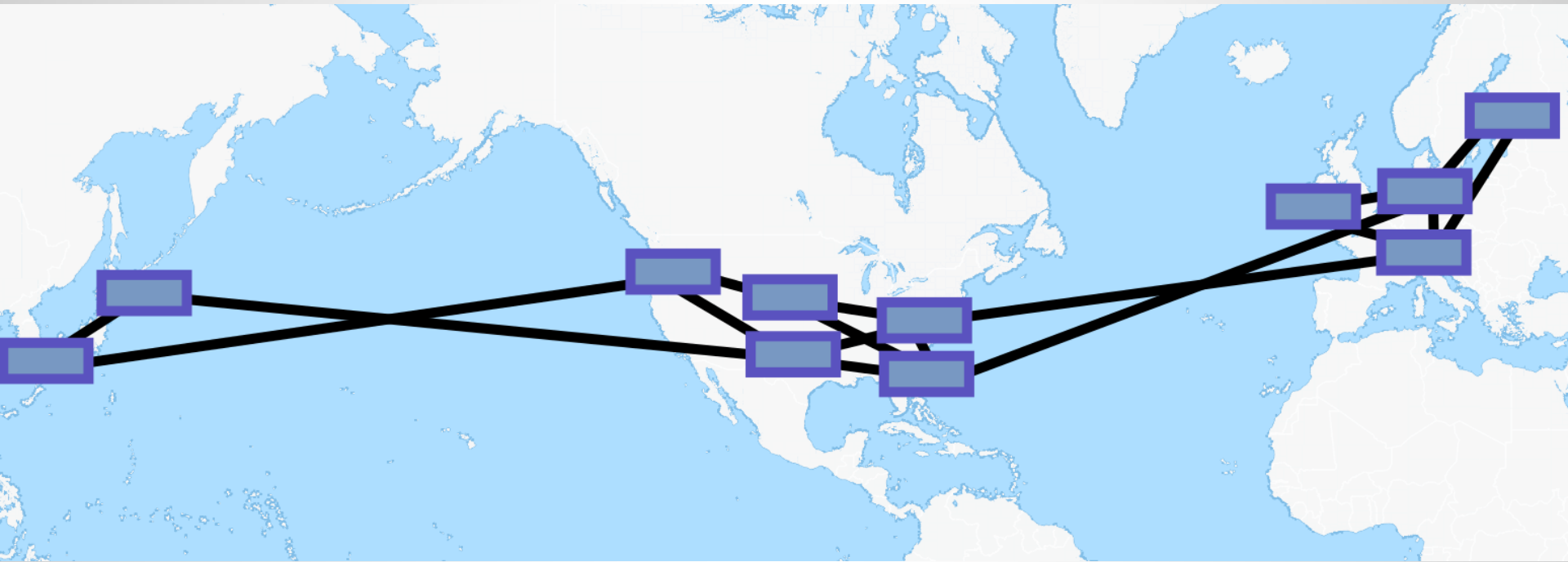
3x Cisco C2960G

2x HP 5406zl

1x Pica8 3290

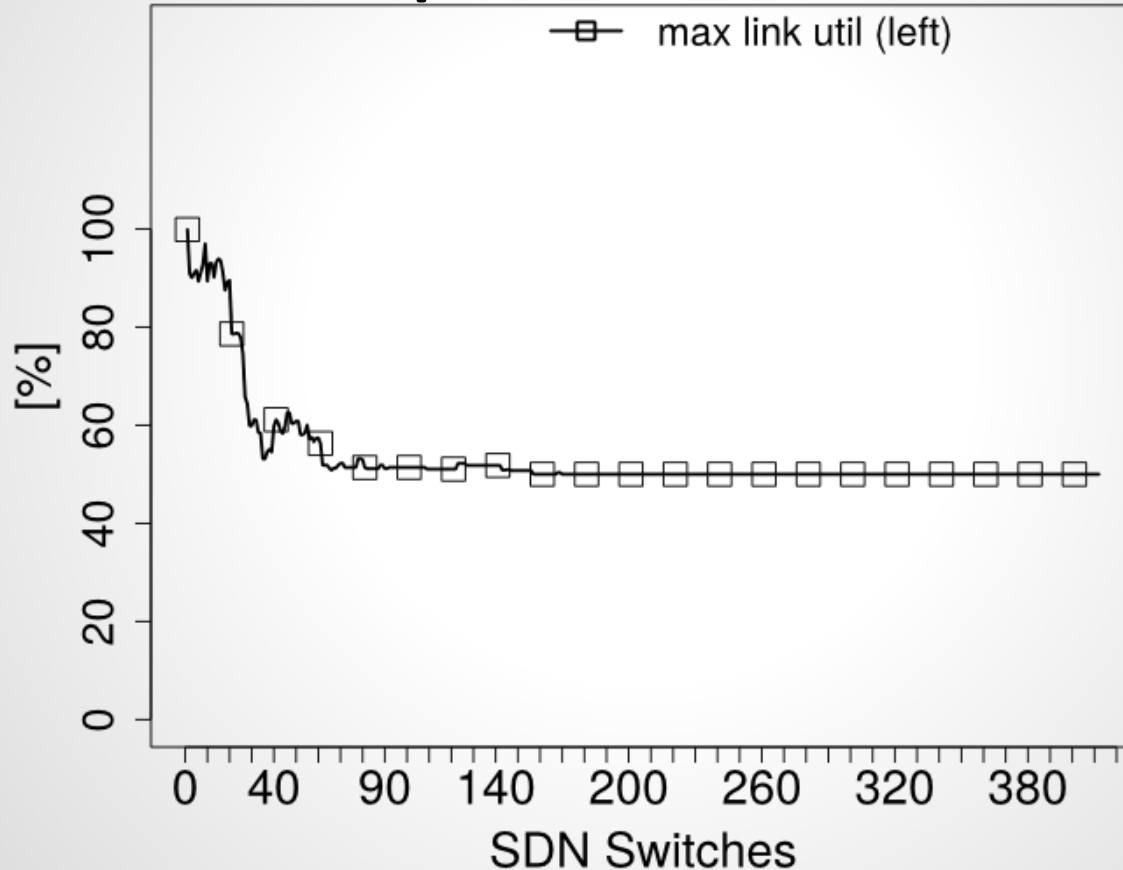


Google B4

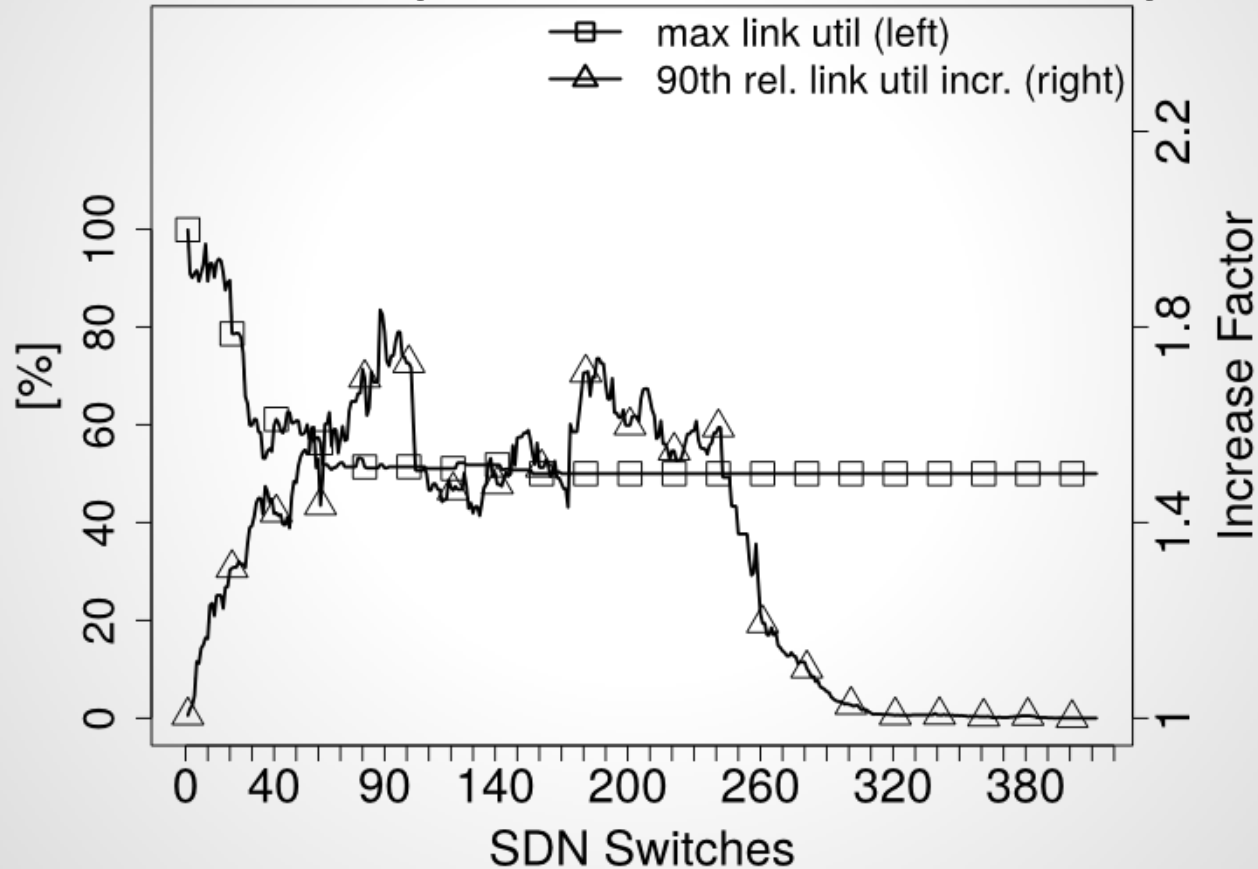


Functionally Equivalent Deployment

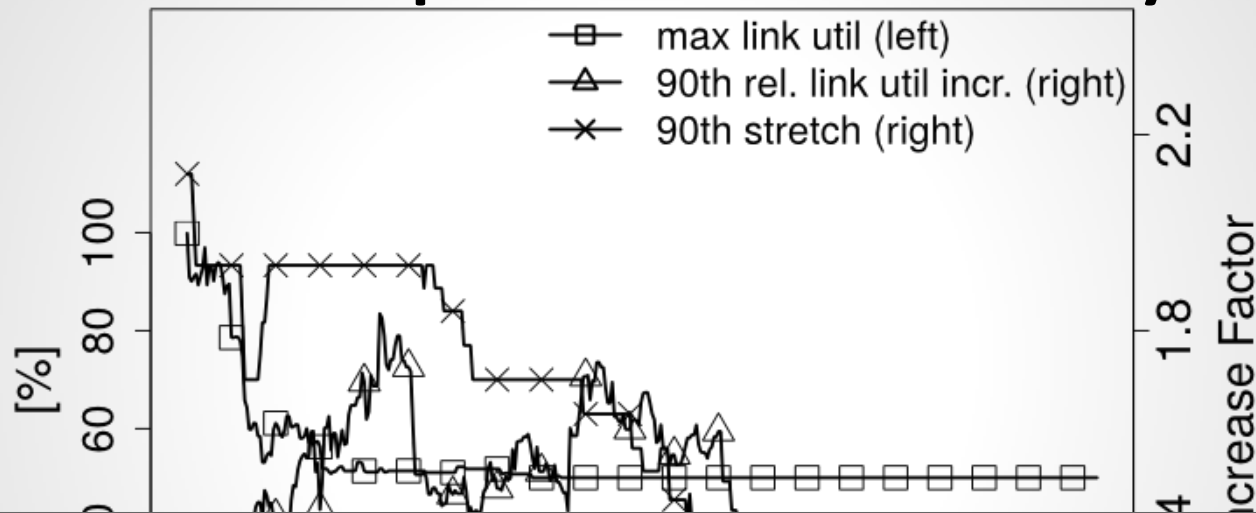
How will Panopticon affect my traffic?



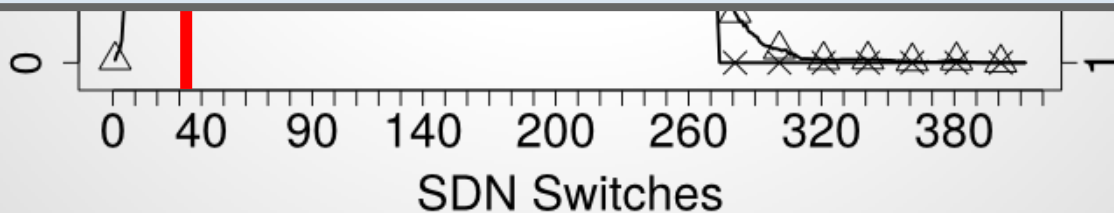
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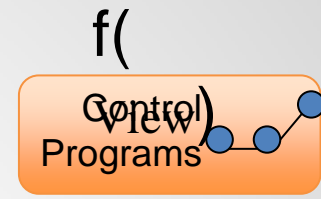
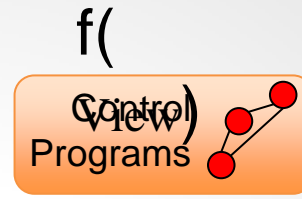
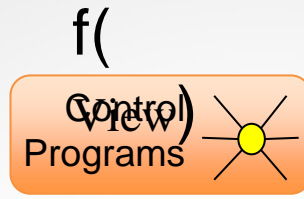
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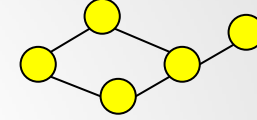
33 SDN switches \rightarrow 90th stretch $< 1.9x$ & max util. $< 60\%$



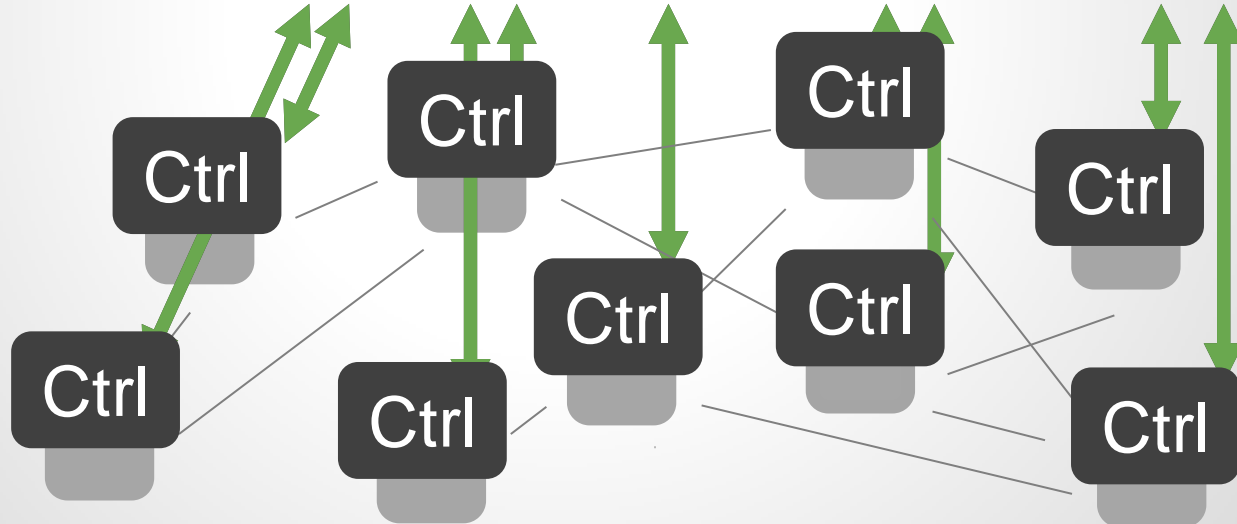
**SDN
Interface**



Global Network View



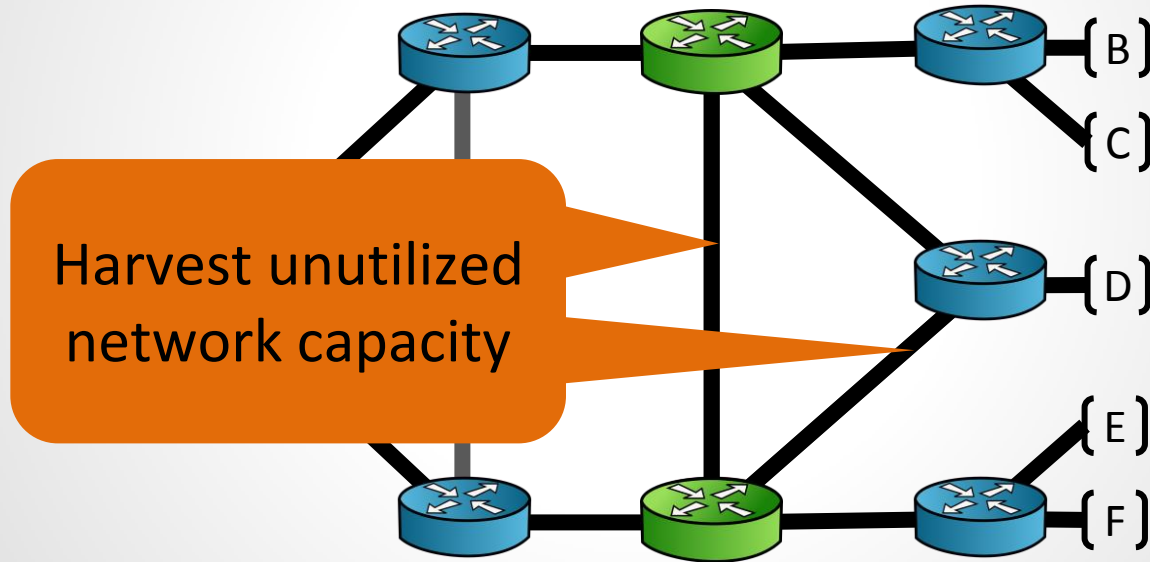
Controller Platform



Simulation Methodology

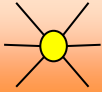
- Real network topology
 - 1296 Access / **412 Distribution** / 3 Core
- Traffic estimates from LBNL packet traces
 - Map randomly while preserving prefix locality
 - Scale traffic projection so that the most utilized link is 50%
- SDN deployment strategies: **RANDOM** vs. **VOL**
 - **VOL**: iteratively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

Benefits of Hybrid Deployment?



**SDN
Interface**

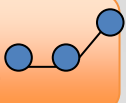
Control
Programs



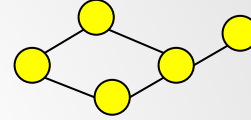
Control
Programs



Control
Programs



Global Network View



Controller Platform

