

# **Panopticon: Incremental SDN Deployment in Enterprise Networks**

**Stefan Schmid**

with

Dan Levin, Marco Canini, Fabian Schaffert, Anja Feldmann

<https://venture.badpacket.in>

**I  SDN!**

**How can I deploy it?**

# SDN: Where and why?

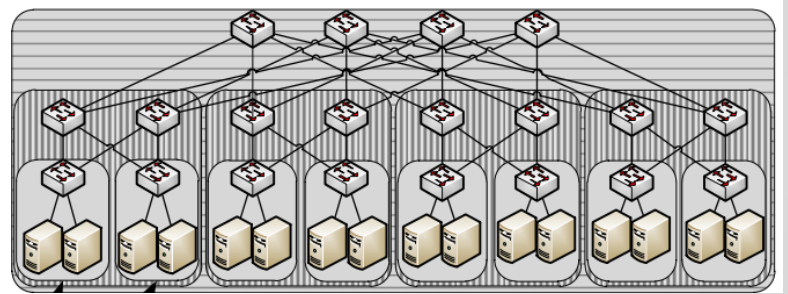
- Datacenters
- Wide-Area Networks (WANs)
- IXP
- ...

# SDN in Datacenters

- Characteristics?
- Why SDN?
- How to deploy?

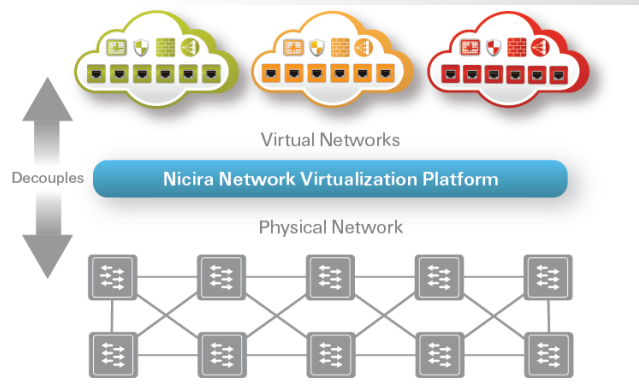
# SDN in Datacenters

- Characteristics?
  - Already highly virtualized
  - Quite homogeneous!



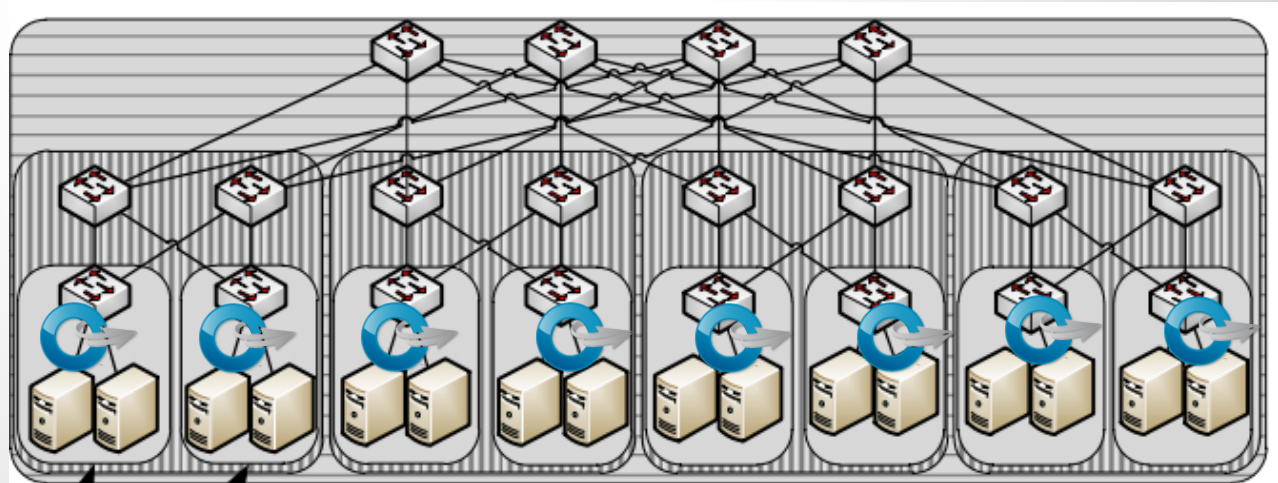
# SDN in Datacenters

- Why SDN?
  - Realize fabric abstraction
  - Decouple application from physical infrastructure
  - Own addresses for tenants, VM migration, ...
  - Improve performance



# SDN in Datacenters

- How to deploy?
  - Run Open VSwitch on servers!
  - Edge deployment (inside: MPEC)



# SDN in WANs

- Characteristics?
- Why SDN?
- How to deploy?



# SDN in WANs

- Characteristics?
  - Bandwidth precious (WAN traffic grows fastest)
  - Latency matters
  - Probably not so many sites
  - Many different applications and requirements

# SDN in WANs

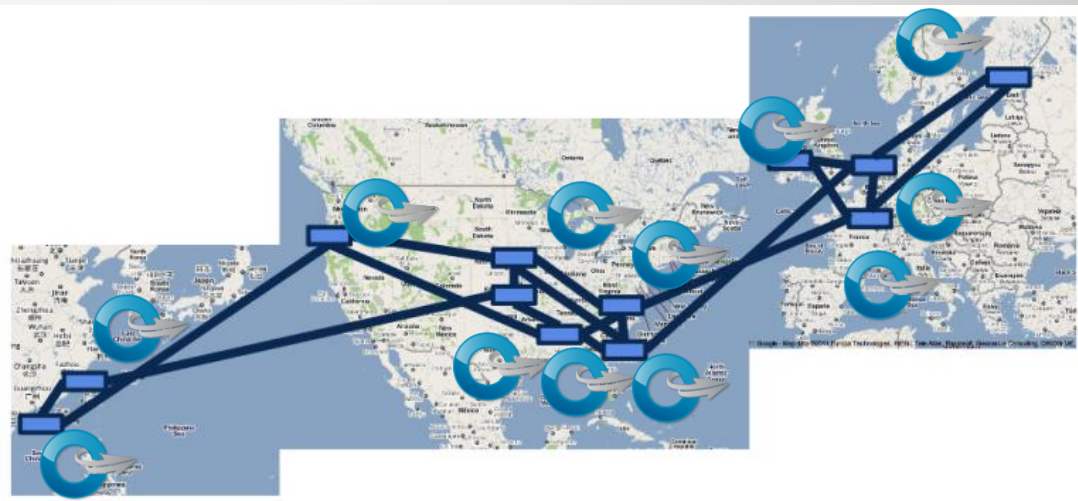
- Why SDN?
  - E.g., Google B4
  - Improve utilization
  - Differentiate applications (latency sensitive Google docs vs datacenter synchronization)



# SDN in WANs

- How to deploy?

- Replace IP “core” routers (running BGP) at border of datacenter (end of long-haul fiber)
- Gradually replace routers
- However, benefits arise only after complete hardware overhaul of network (after years)



# SDN in WANs

- How

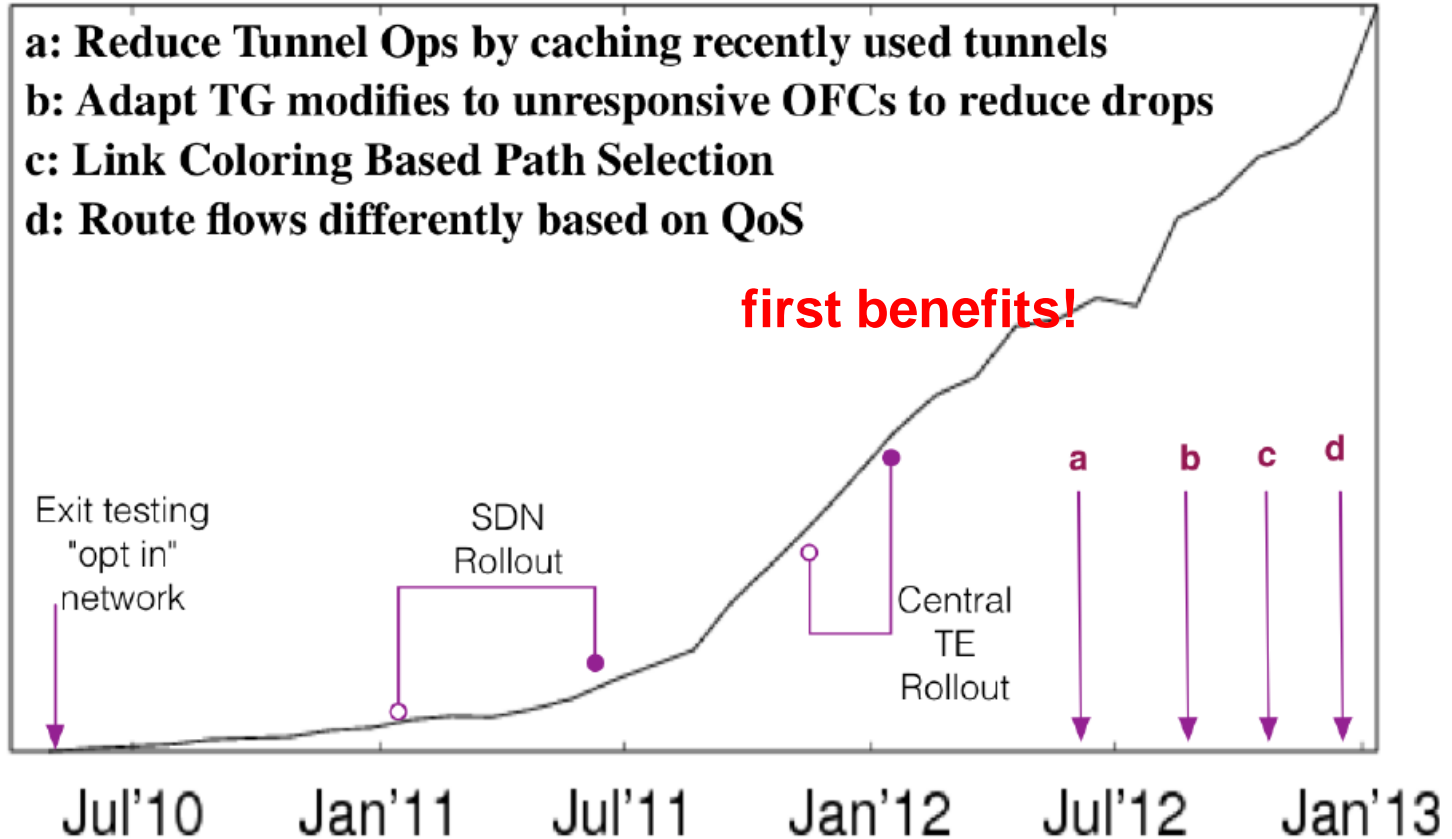
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Traffic  
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- G

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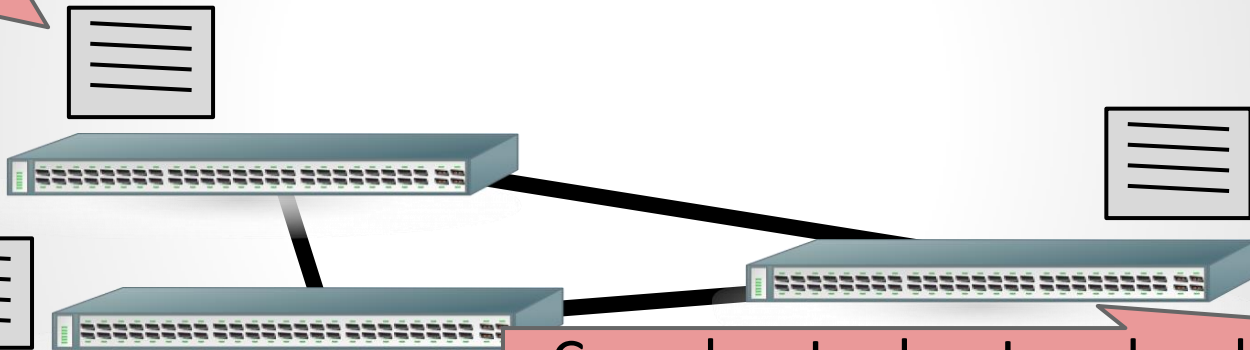
# Our Use Case: Enterprise Networks

- What's wrong with enterprise networks?

# Problems with traditional networks

Manual, Device-Centric  
Network Configuration  
*(CLI, LANmanager)*

Un-evolved Best Practices  
*(tcpdump, traceroute - from the 1990s)*

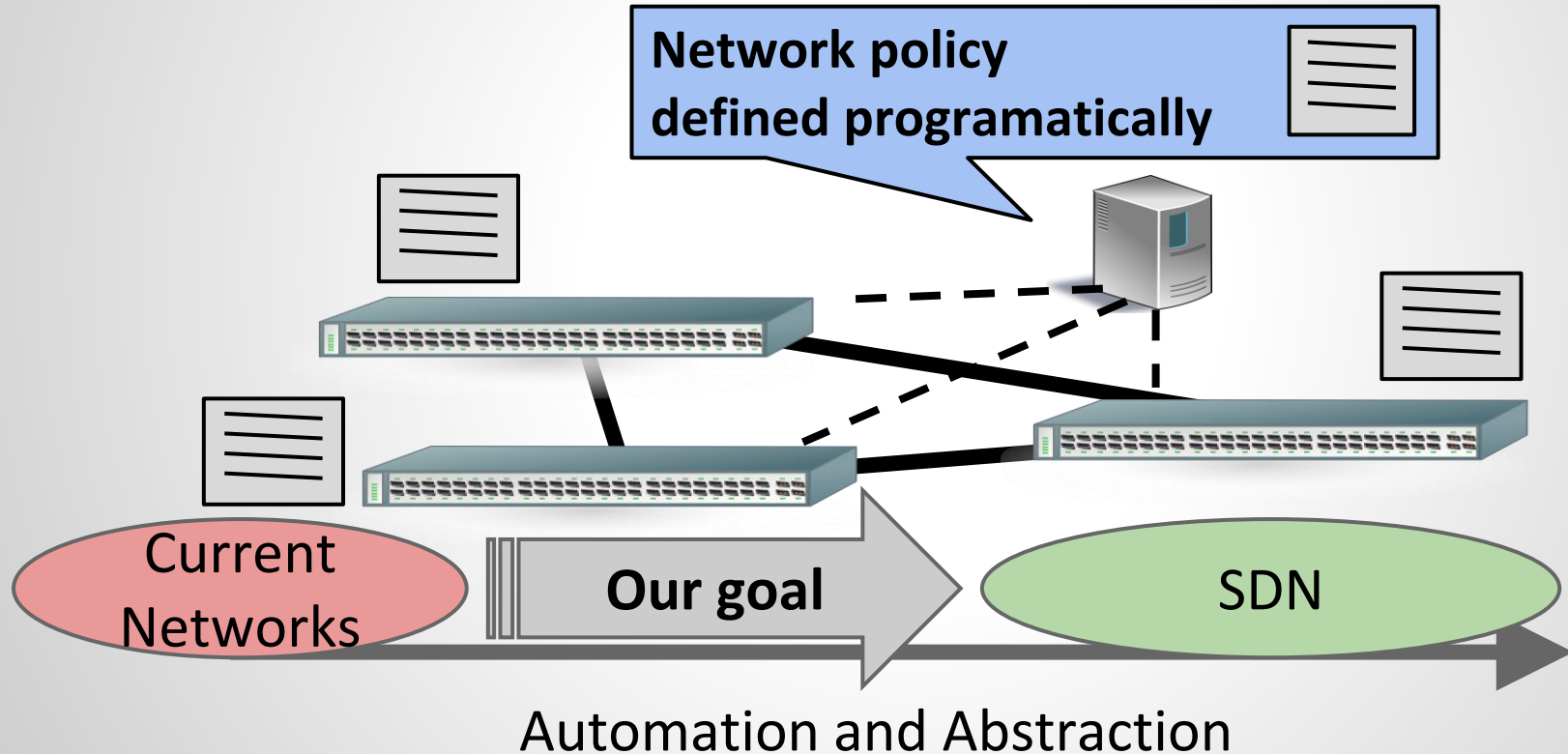


Current  
Networks

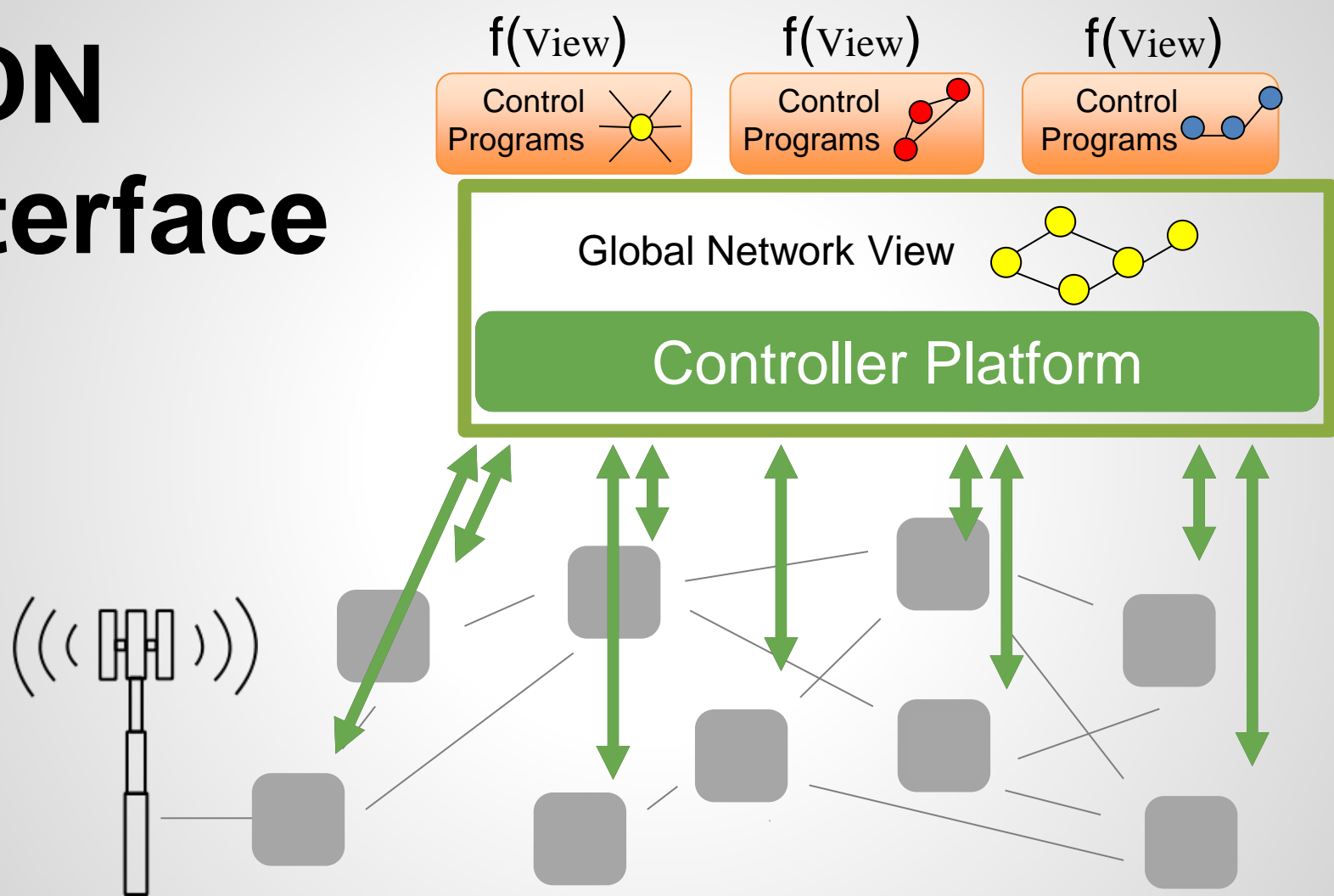
Complex, Leaky, Low-level Interfaces  
*(VLANs, Spanning Tree, Routing)*

# Software Defined Networking

Automation und Abstraction for Networks

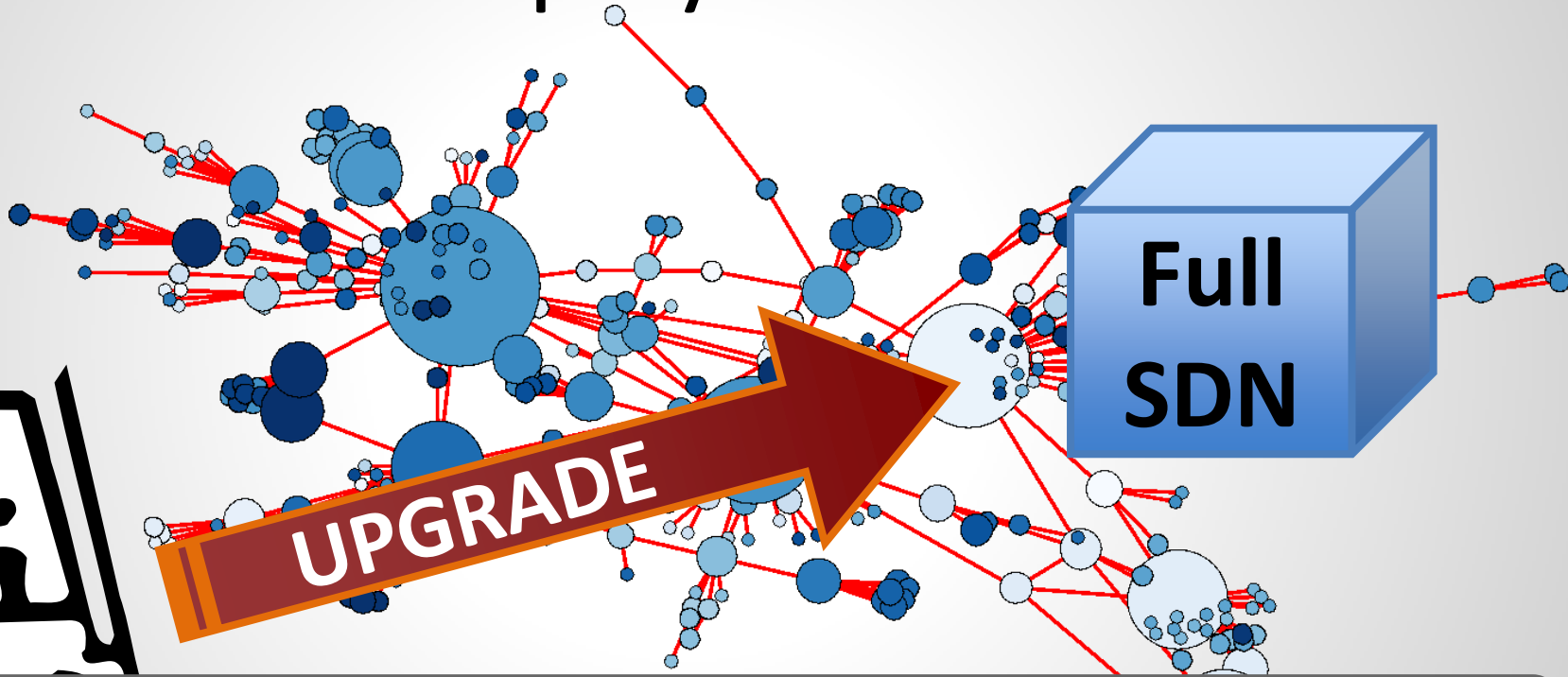


# SDN Interface





# The SDN Deployment Problem

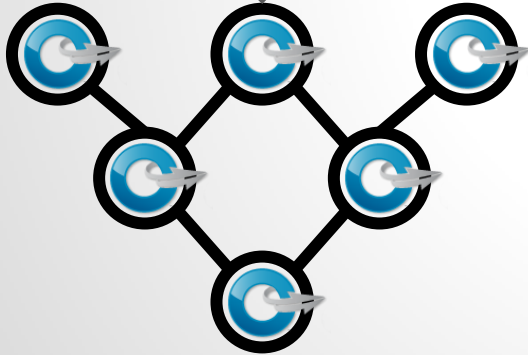
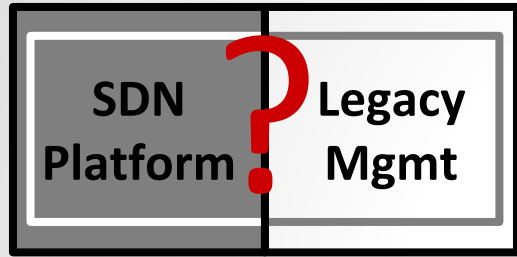


**Must upgrade to SDN incrementally**

# Key Questions

- How can we **incrementally deploy SDN** into enterprise campus networks?
- What **SDN benefits** can be realized in a hybrid deployment?

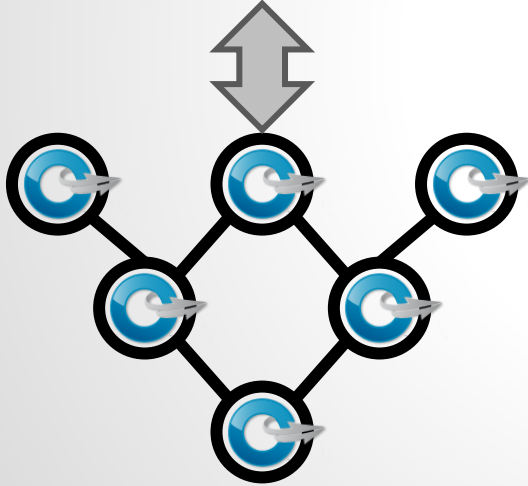
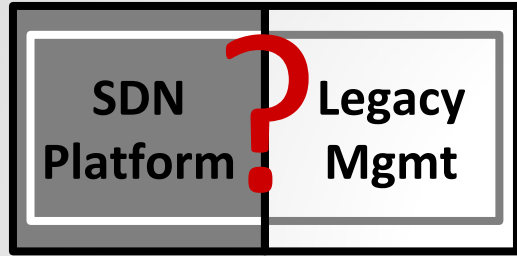
# Current Hybrid Networks



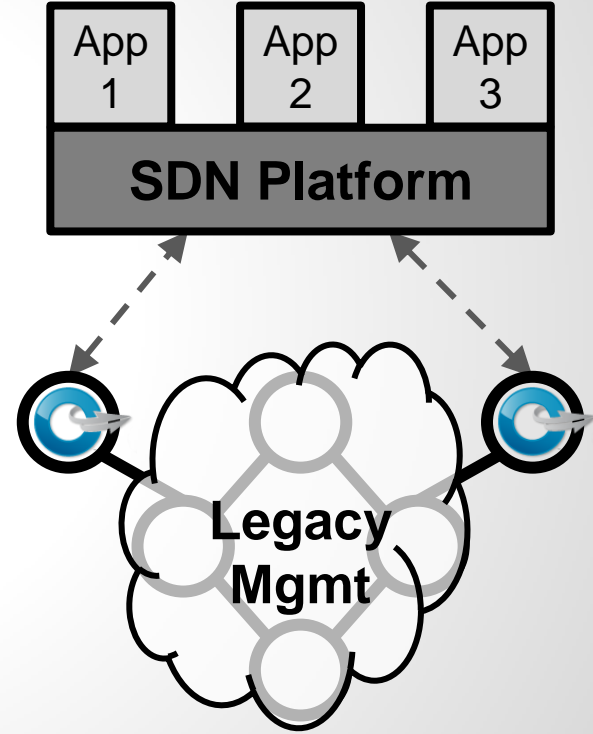
Dual-stack approach

E.g., part of the  
Stanford network.

# Current Hybrid Networks

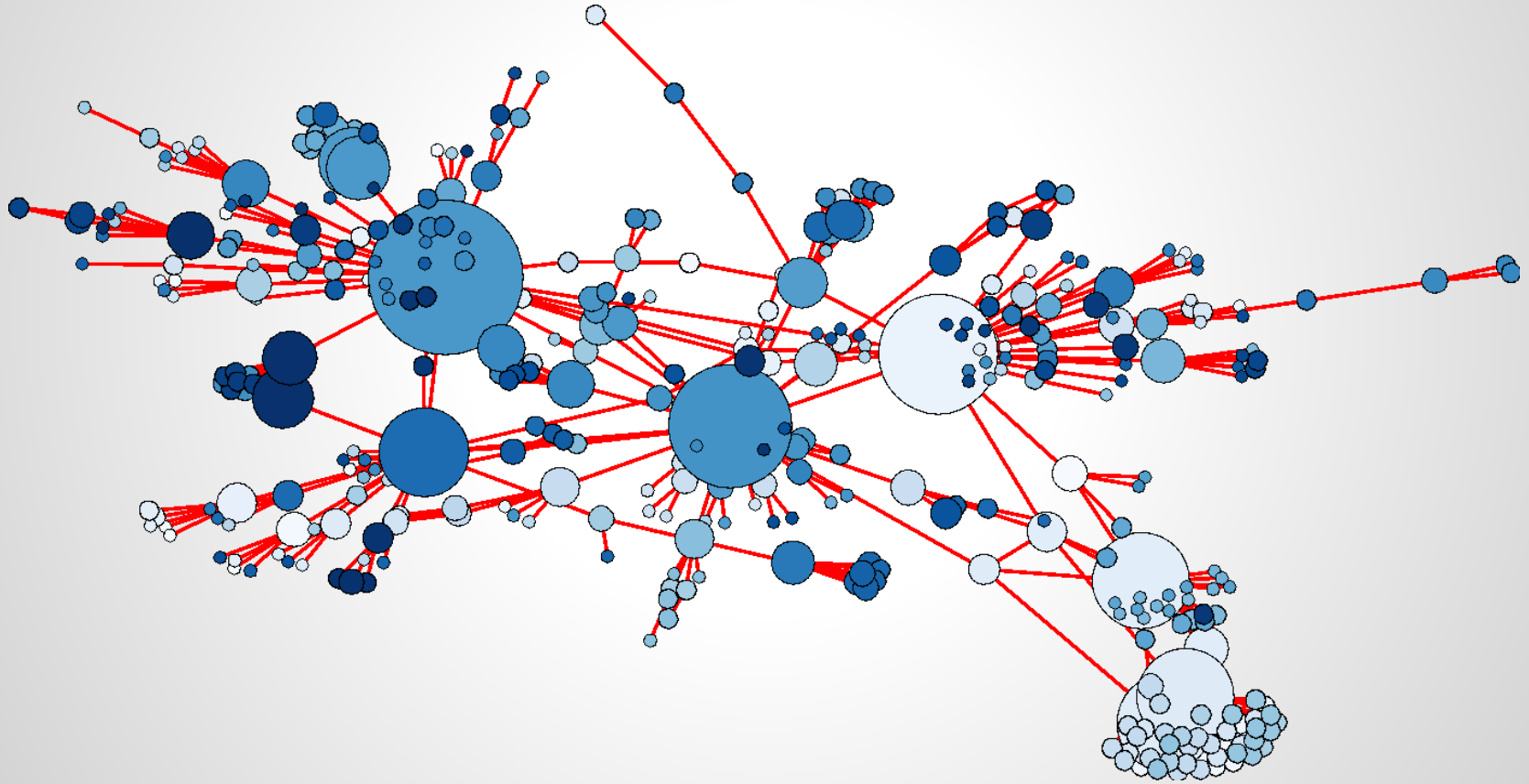


Dual-stack approach

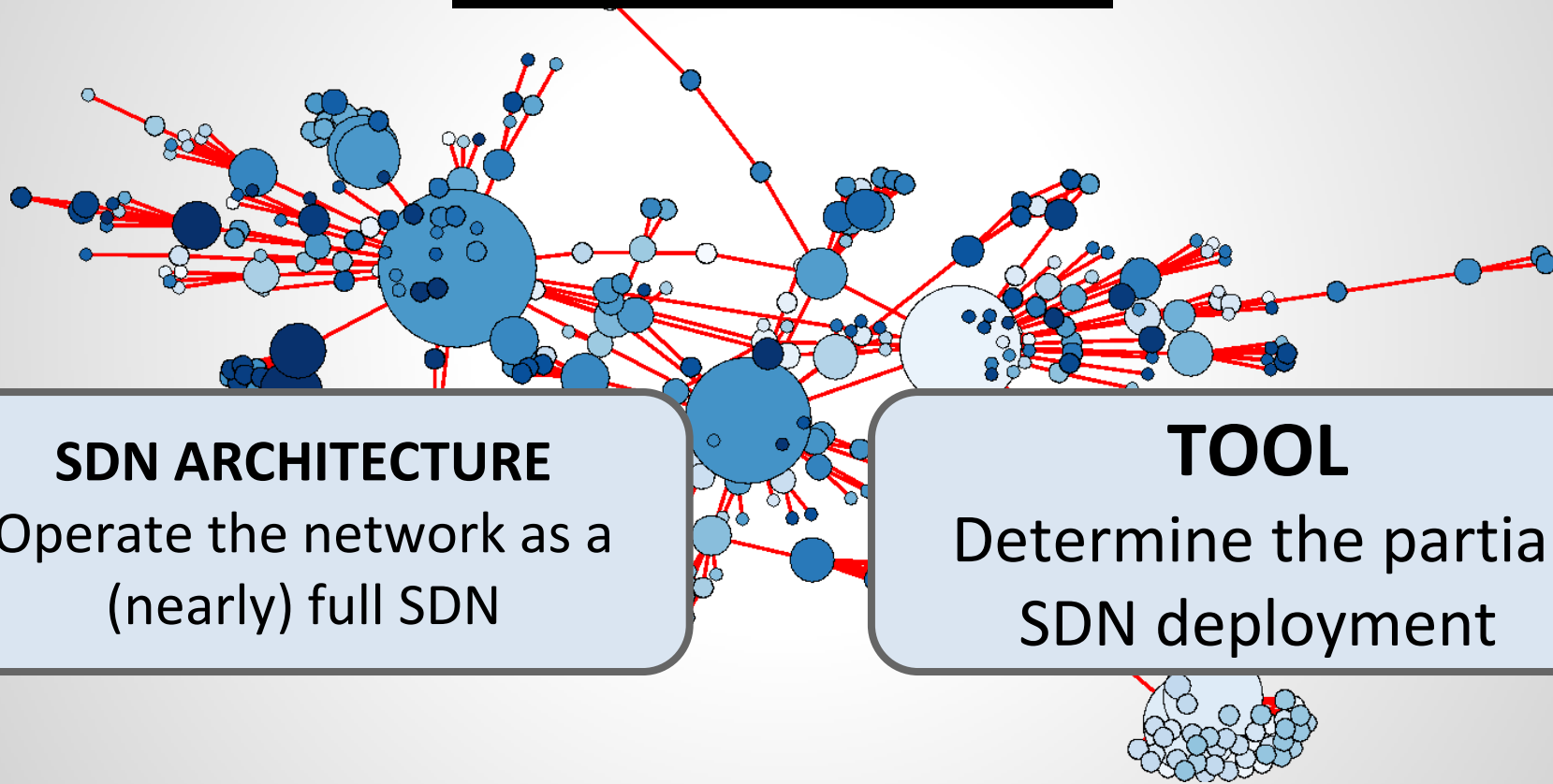


Edge-only approach

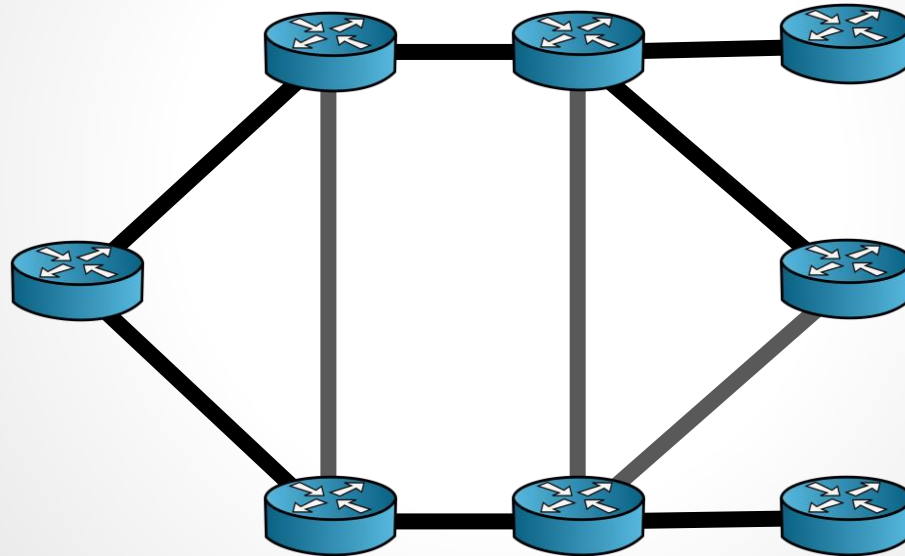
# The edge is legacy access switches



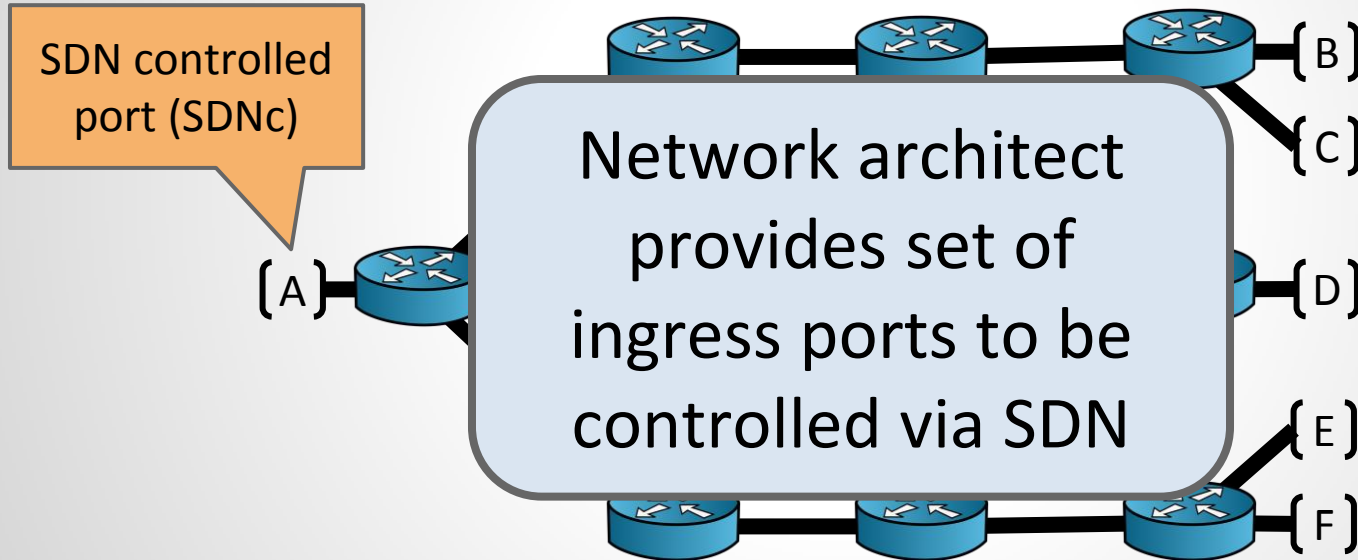
# PANOPTICON



# The Existing Network

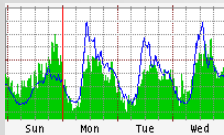
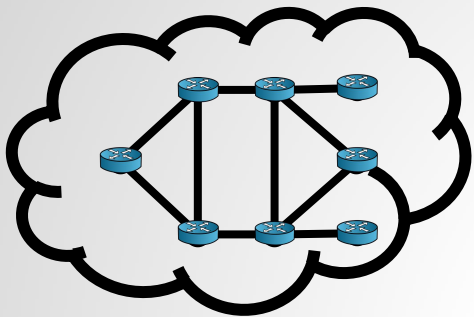


# 1. Planning the SDN Deployment





# Network topology



## Traffic estimates



## Objectives

- Upgrade budget
- Path delay

## Tunable parameters

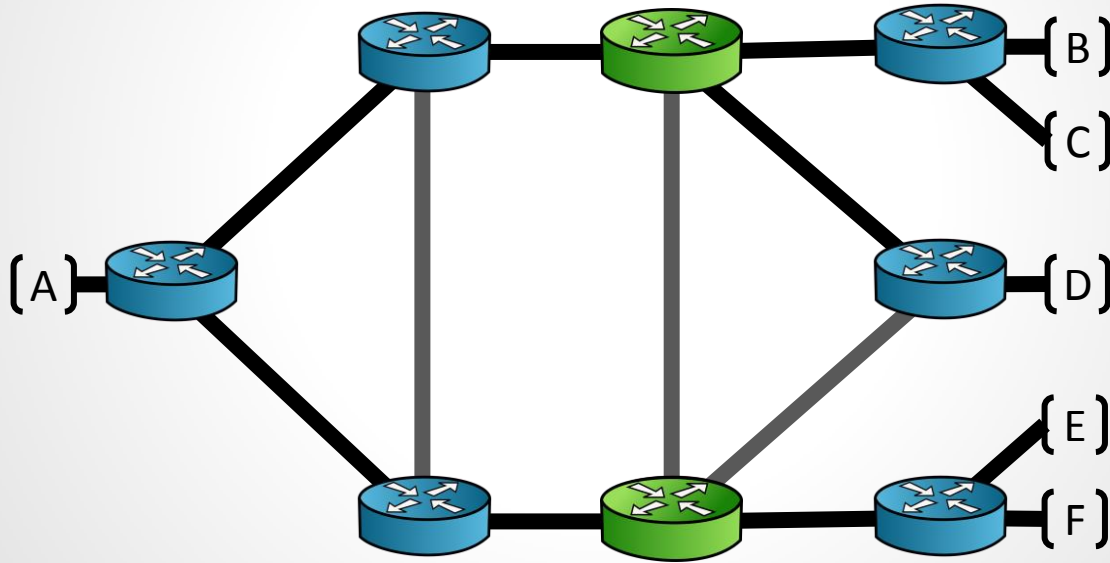
- Price model
- Utilization thresholds  
(link utilization, VLANs, etc.)



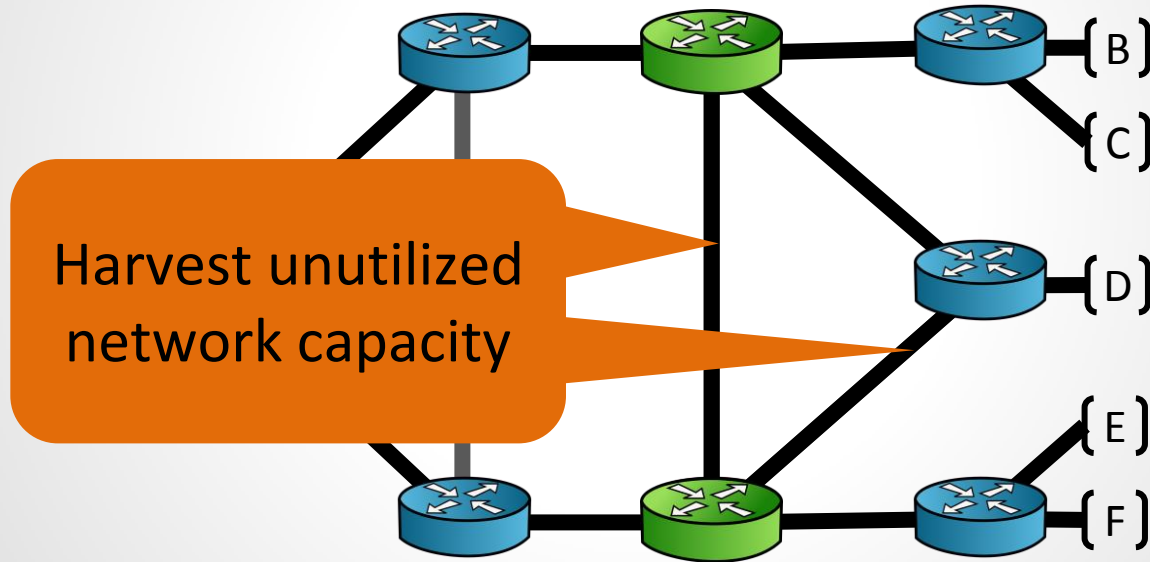
resource  
aware  
optimizer

Partial SDN  
deployment

# The Partial SDN Deployment ( )



# Benefits of Partial SDN Deployment?



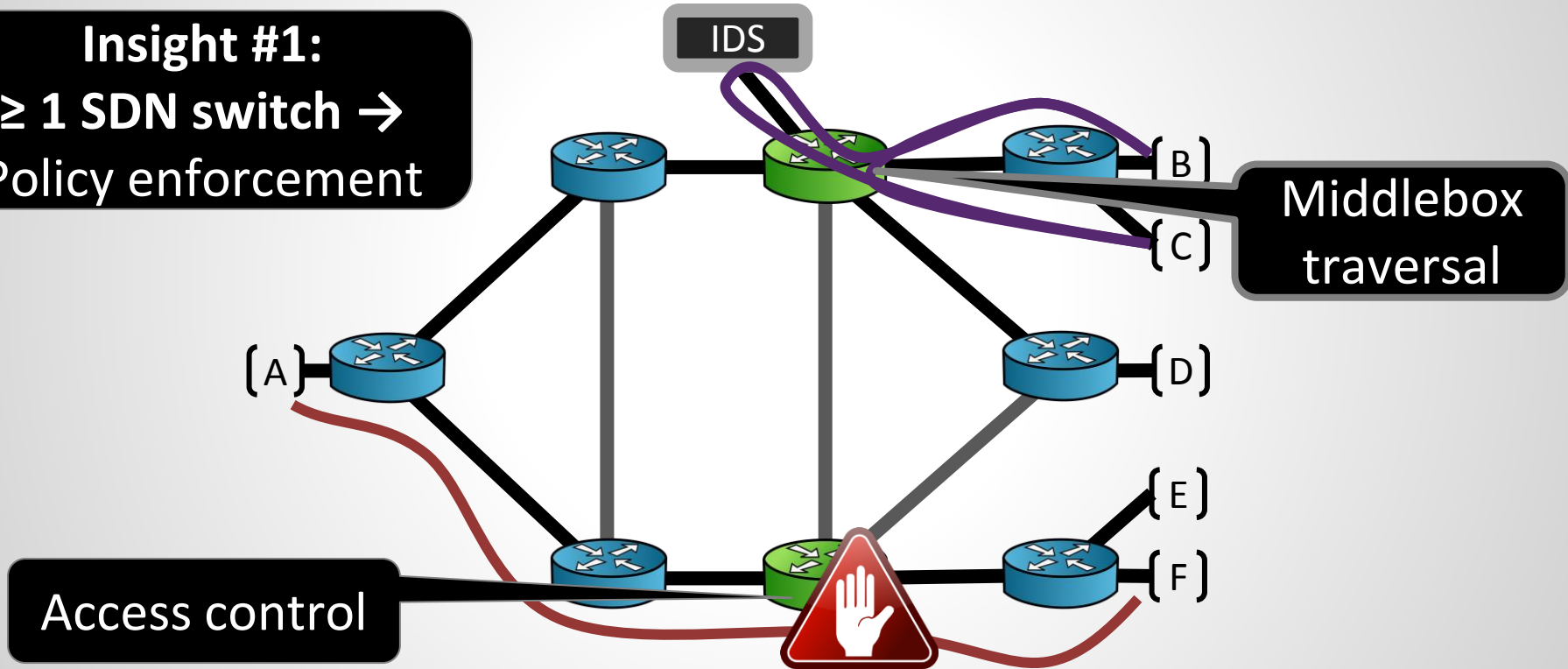
Main benefits of **SDN**=  
Principled orchestration of  
the network policy

Can partial SDN deployment  
still take advantage of *principled  
network orchestration*



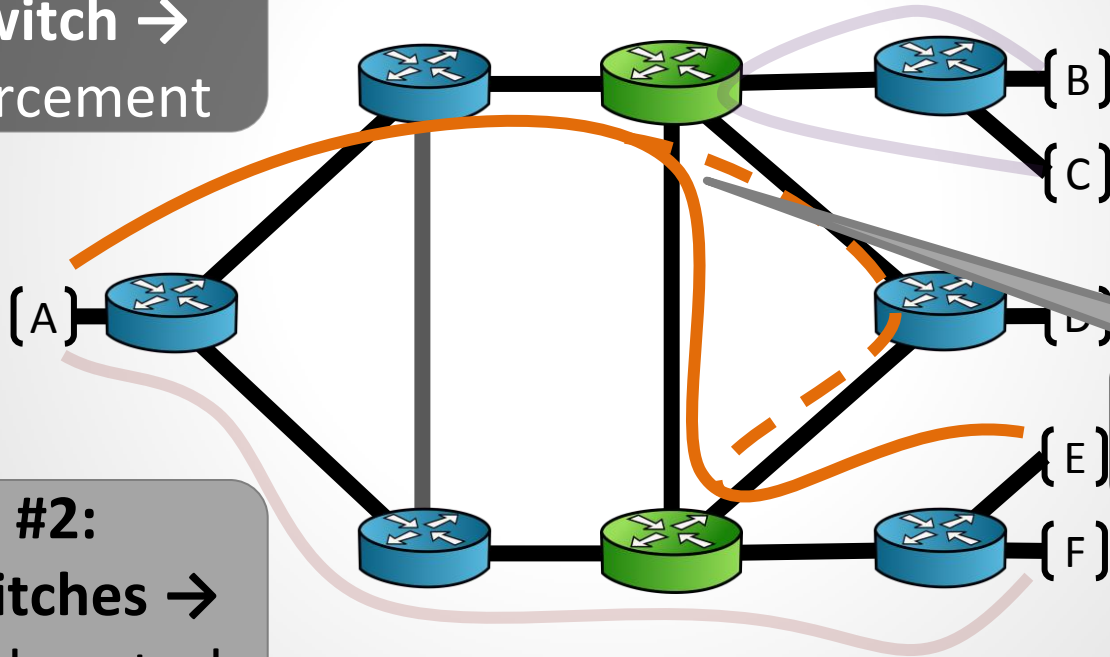
## 2. Realizing the Benefits of SDN

**Insight #1:**  
 $\geq 1$  SDN switch  $\rightarrow$   
Policy enforcement



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**Insight #1:**  
 $\geq 1$  SDN switch  $\rightarrow$   
Policy enforcement



**Insight #2:**  
 $\geq 2$  SDN switches  $\rightarrow$   
Fine-grained control

Traffic  
load-balancing

**Insight #1:**  
 **$\geq 1$  SDN switch  $\rightarrow$**   
**Policy enforcement**

**Insight #2:**  
 **$\geq 2$  SDN switches  $\rightarrow$**   
**Fine-grained control**

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

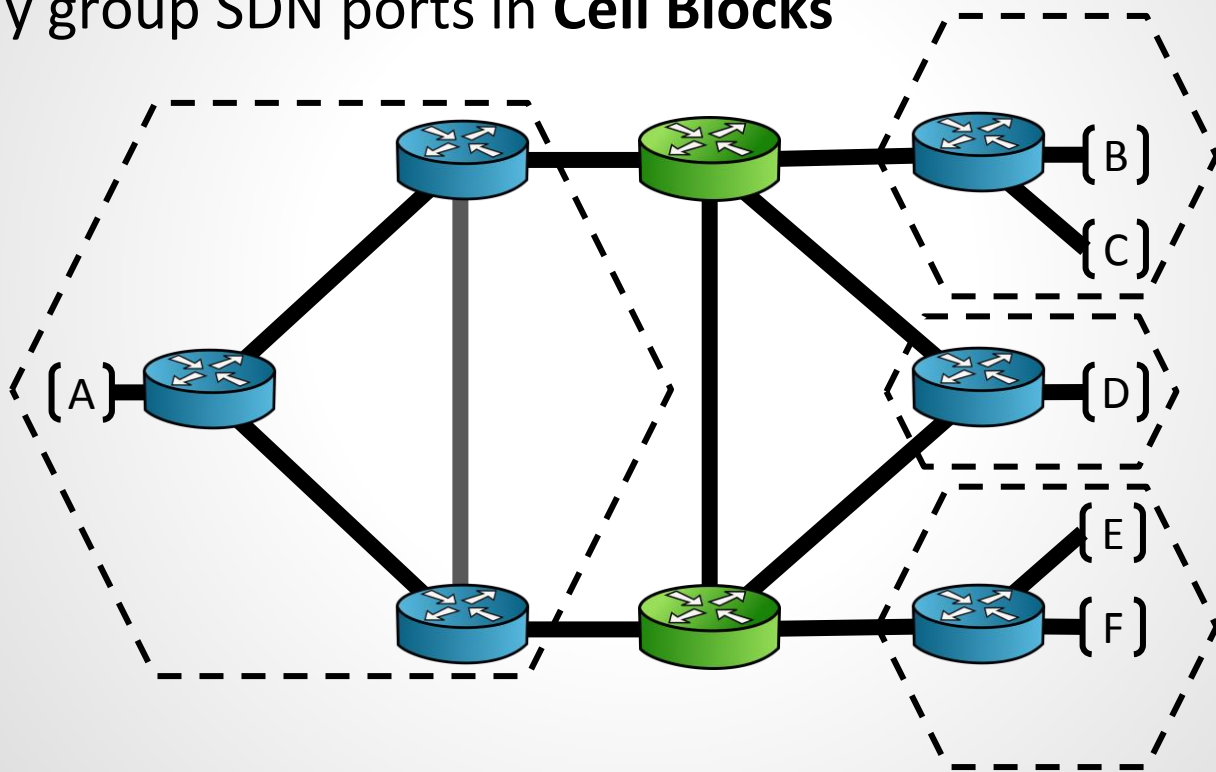
## SDN Waypoint Enforcement

**Legacy devices must direct traffic to SDN switches**



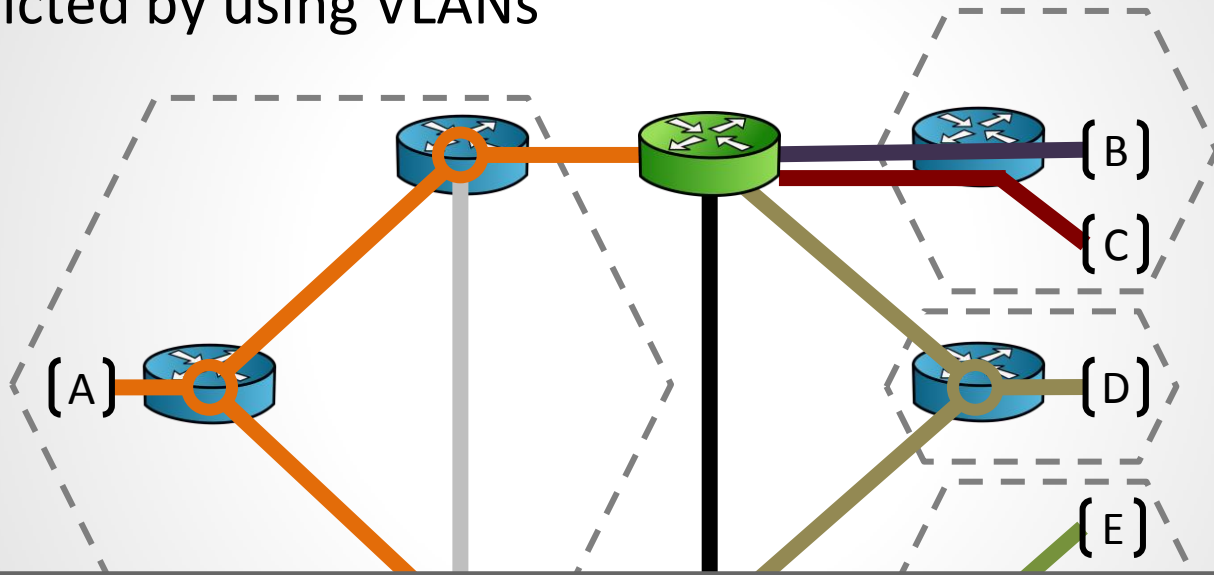
# The **PANOPTICON** SDN Architecture

## Conceptually group SDN ports in **Cell Blocks**



# The **PANOPTICON** SDN Architecture

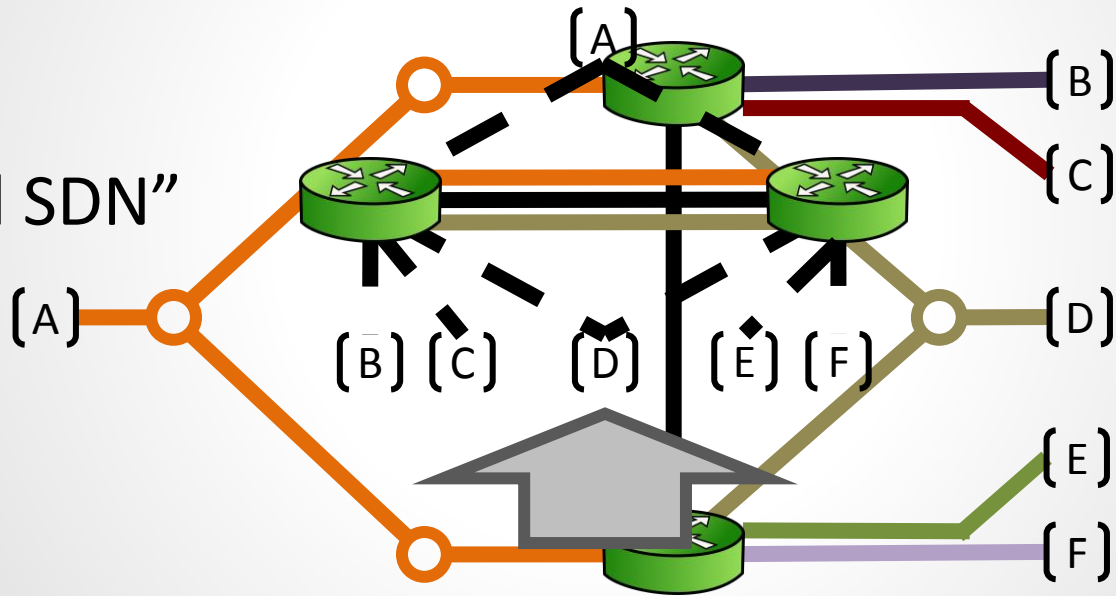
Traffic restricted by using VLANs

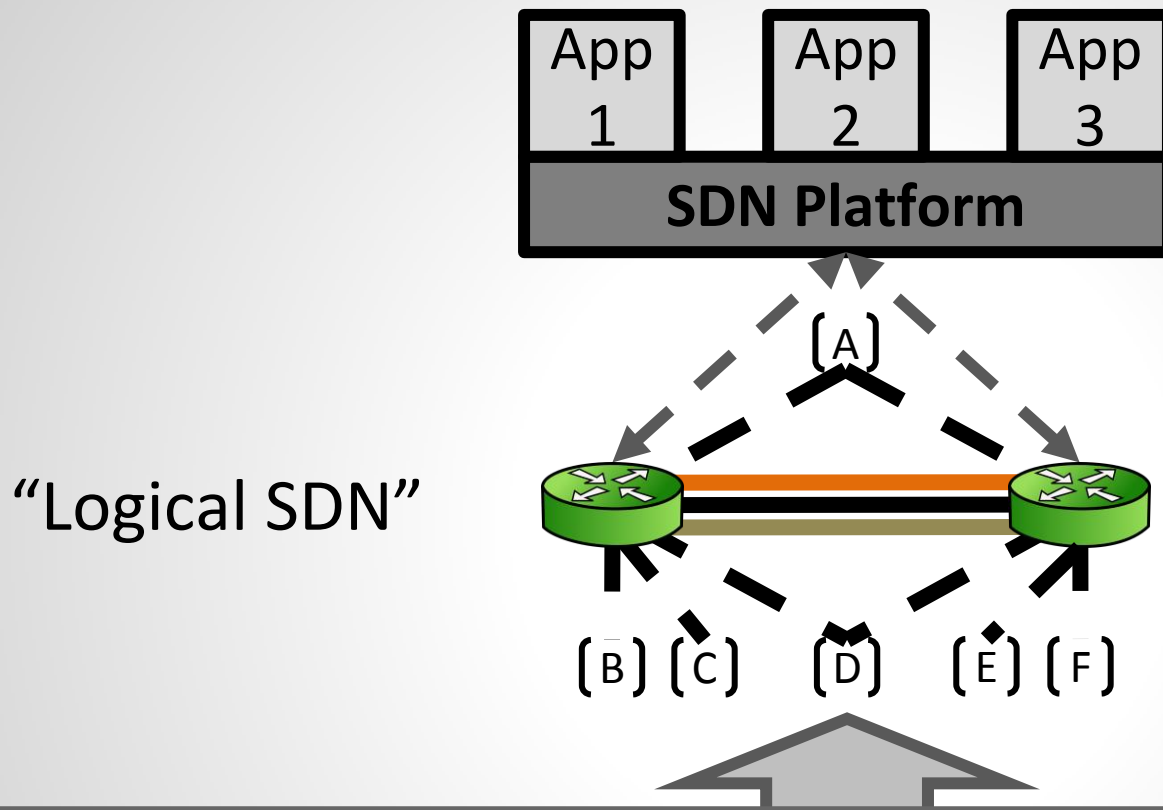


**Per-port spanning trees that  
ensure waypoint enforcement**

# PANOPTICON

“Logical SDN”





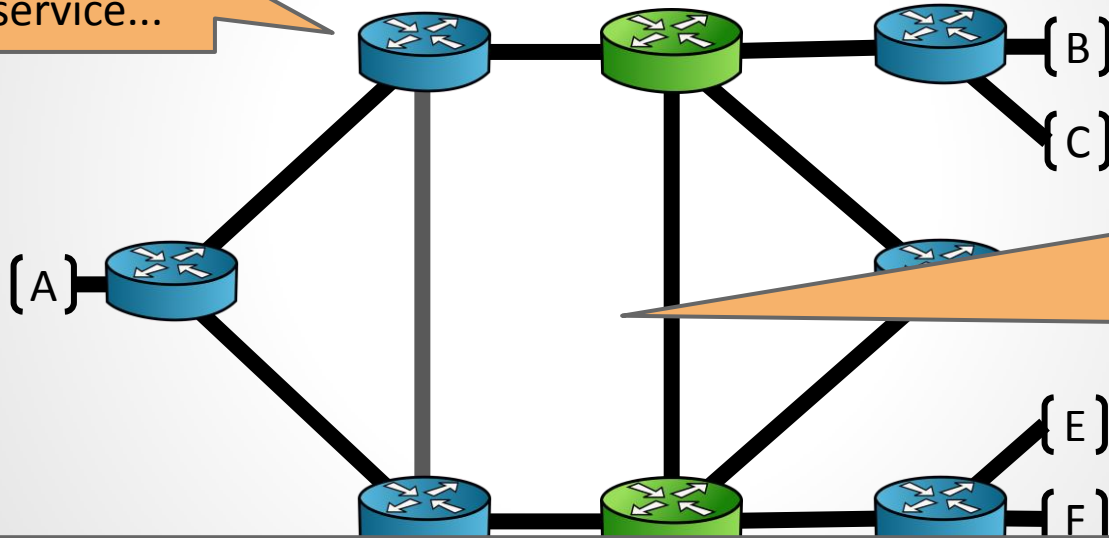
**PANOPTICON provides the abstraction of a (nearly) fully-deployed SDN in a partially upgraded network**

What is the value of  
a logical SDN



# Use Case: Planned Maintenance

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



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

**Let software worry about the dependencies,  
not the human operator!**

# Use Case Testbed Evaluation

2x NEC IP8800 (OF 1.0)

1x Cisco C3550XL

3x Cisco

2x HP 54

1x Dell R3200

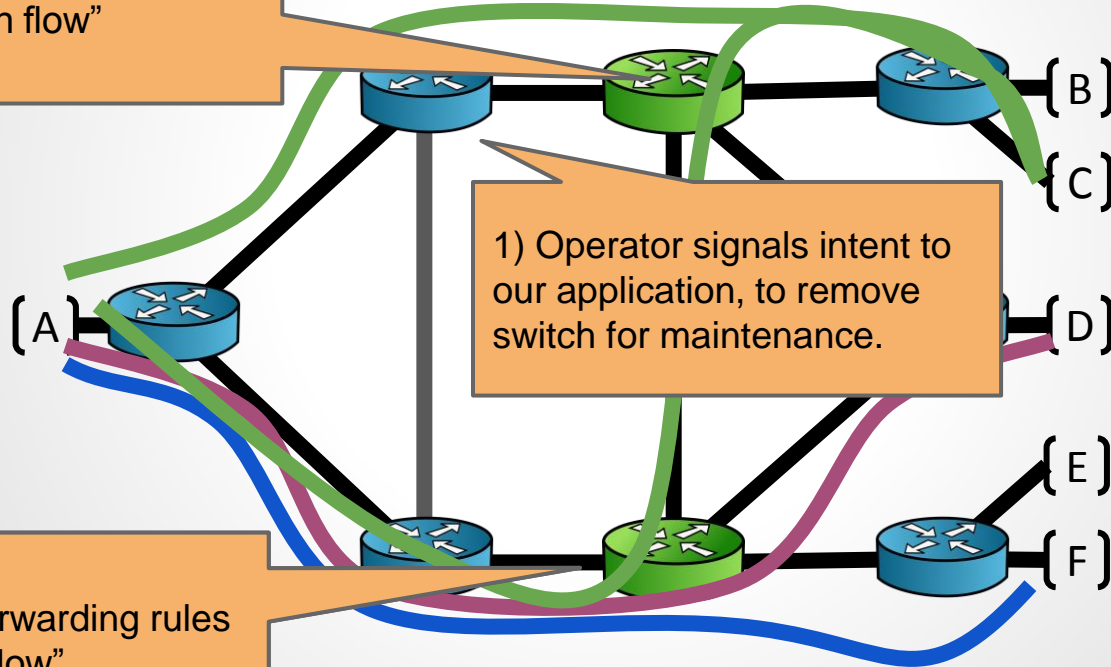
TCP Connection  
Recovery Time

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



# Use Case: Planned Maintenance

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



2) Install forwarding rules for "green flow"



# Use Case Testbed Evaluation

2x NEC IP8800 (OF 1.0)

1x Cisco C3550XL

3x Cisco C2960G

2x HP 5406zl

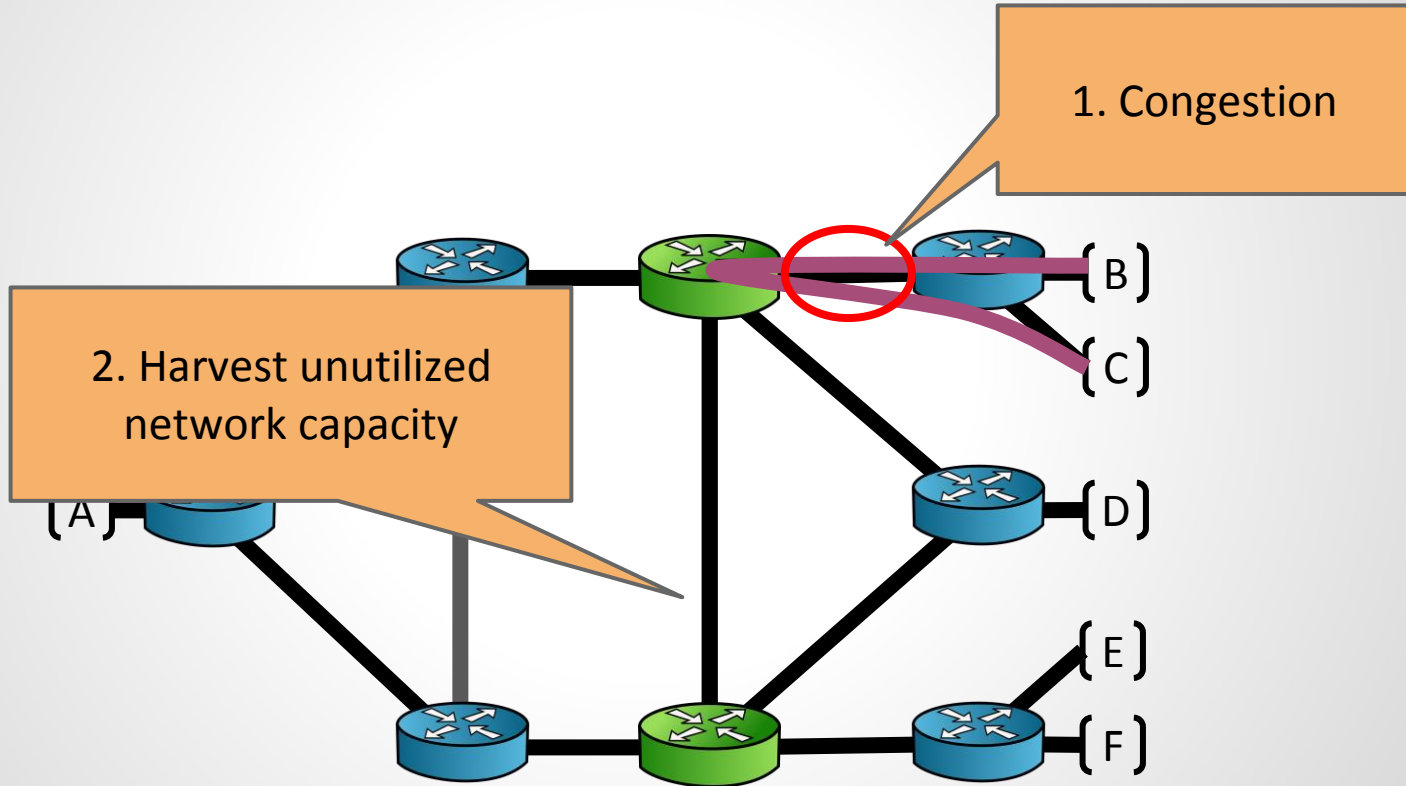
1x Pica8 3290



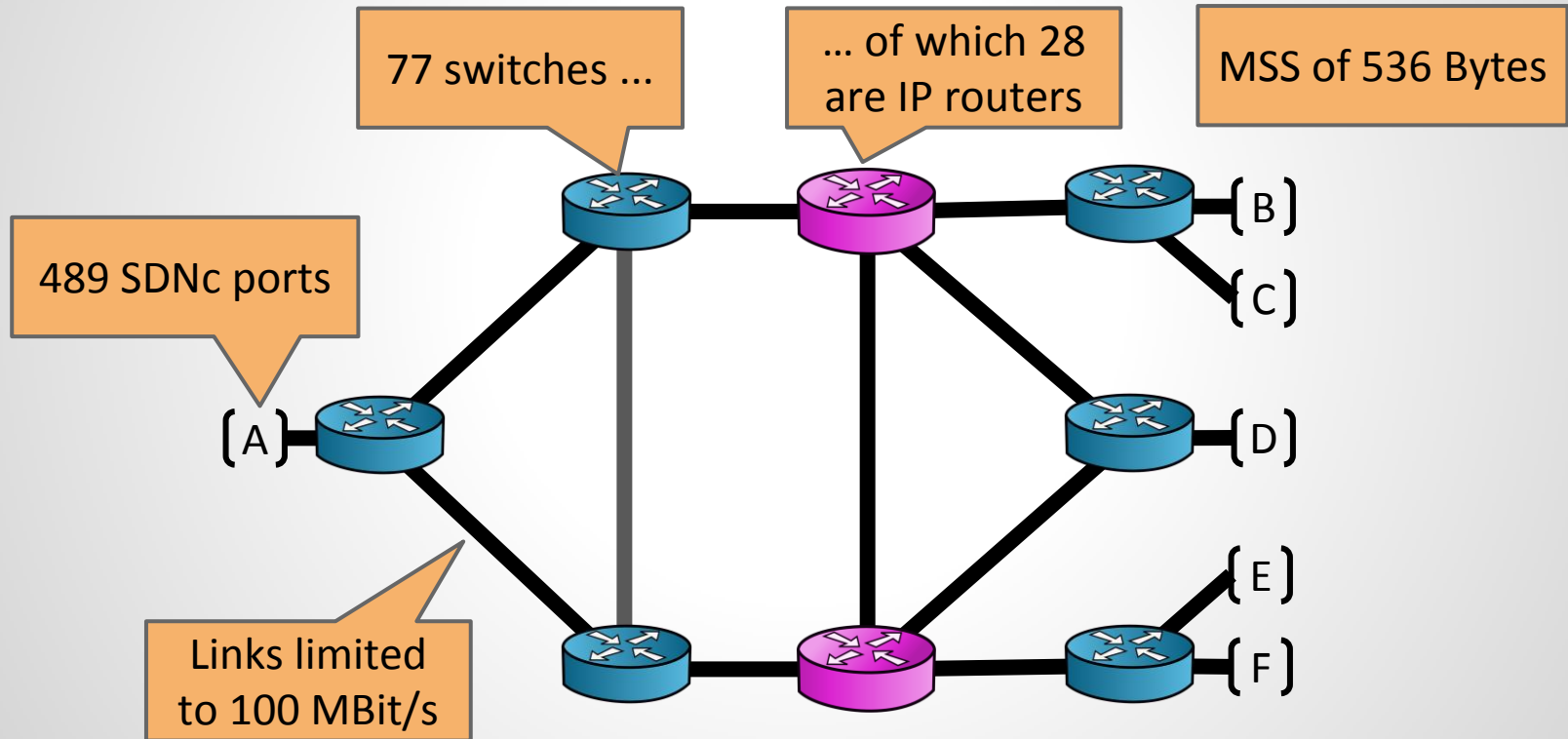
What is the impact of  
partial SDN deployment on the  
**network traffic**



# Potential Impact on Traffic

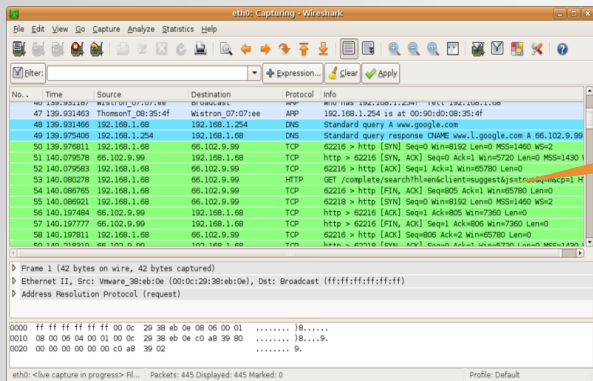


# Network Emulation Experiments



# Workload

Packet-level enterprise  
network traffic traces



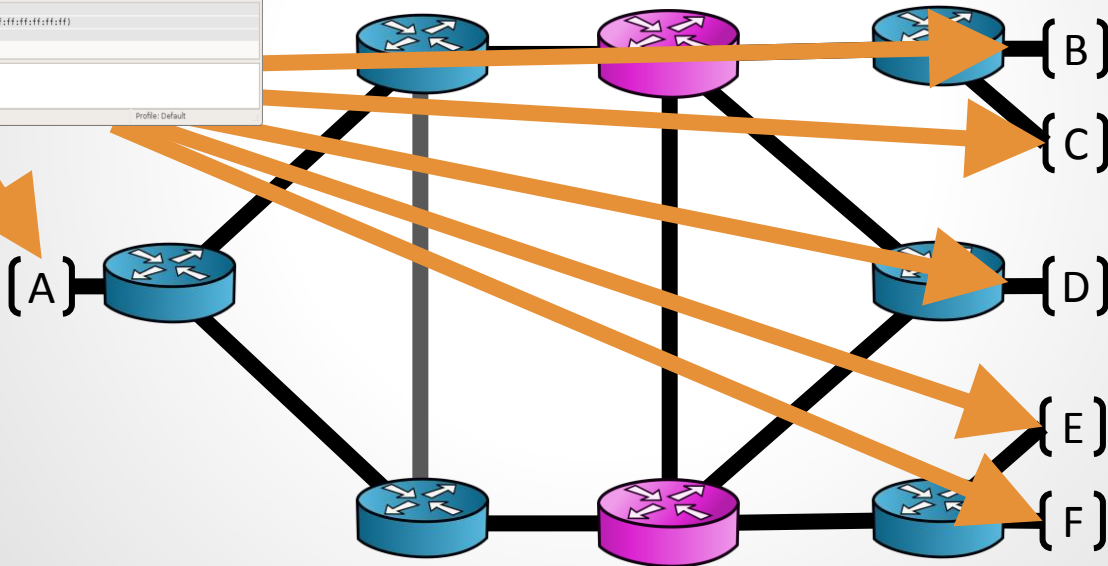
No.	Time	Source	Destination	Protocol	Info
47	139.931463	ThomsonT_08:35:4f	192.168.1.254	ARP	192.168.1.254 is at 00:90:40:08:35:4f
48	139.931468	192.168.1.68	192.168.1.254	DNS	Standard query 1 www.google.com
49	139.975406	192.168.1.254	192.168.1.68	DNS	Standard query response CNAME www.l.google.com A 66.102.9.99
50	139.979811	192.168.1.68	66.102.9.99	TCP	62216 > http [RST] Seq=0 Win=0 Len=0 MSS=1460 W54
51	140.079078	66.102.9.99	192.168.1.68	TCP	http > 62216 [RST, ACK] Seq=0 Ack=1 Win=0 Len=0 MSS=1460
52	140.079563	192.168.1.68	66.102.9.99	TCP	62216 > http [ACK] Seq=1 Ack=1 Win=0 Len=0
53	140.080278	192.168.1.68	66.102.9.99	HTTP	GET /complete/search?hl=en&client=suggest&jsr=... HTTP/1.1
54	140.080765	192.168.1.68	66.102.9.99	TCP	62216 > http [FIN, ACK] Seq=805 Ack=1 Win=0 Len=0
55	140.080921	192.168.1.68	66.102.9.99	TCP	62216 > http [FIN] Seq=0 Win=0 Len=0 MSS=1460 W54
56	140.107484	66.102.9.99	192.168.1.68	TCP	http > 62216 [ACK] Seq=1 Ack=805 Win=7960 Len=0
57	140.107777	66.102.9.99	192.168.1.68	TCP	http > 62216 [FIN, ACK] Seq=1 Ack=805 Win=7960 Len=0
58	140.107811	192.168.1.68	66.102.9.99	TCP	62216 > http [ACK] Seq=805 Ack=2 Win=65790 Len=0
59	140.107815	66.102.9.99	192.168.1.68	FIN	62216 > 62216 [ACK] Seq=1 Ack=2 Win=0 Len=0

Frame 1 (42 bytes on wire, 42 bytes captured)  
Ethernet II, Src: VMware\_38:eb:0e (00:0c:29:38:eb:0e), Dst: Broadcast (ff:ff:ff:ff:ff:ff)  
Address Resolution Protocol (request)

0000 ff ff ff ff ff ff 00 0c 29 38 eb 0e 08 06 00 01 ..... 18.....  
0010 08 00 06 04 00 01 00 0c 29 38 eb 0e c0 a8 39 80 ..... 18....9.  
0020 00 00 00 00 00 00 c0 a8 39 02 ..... 9.

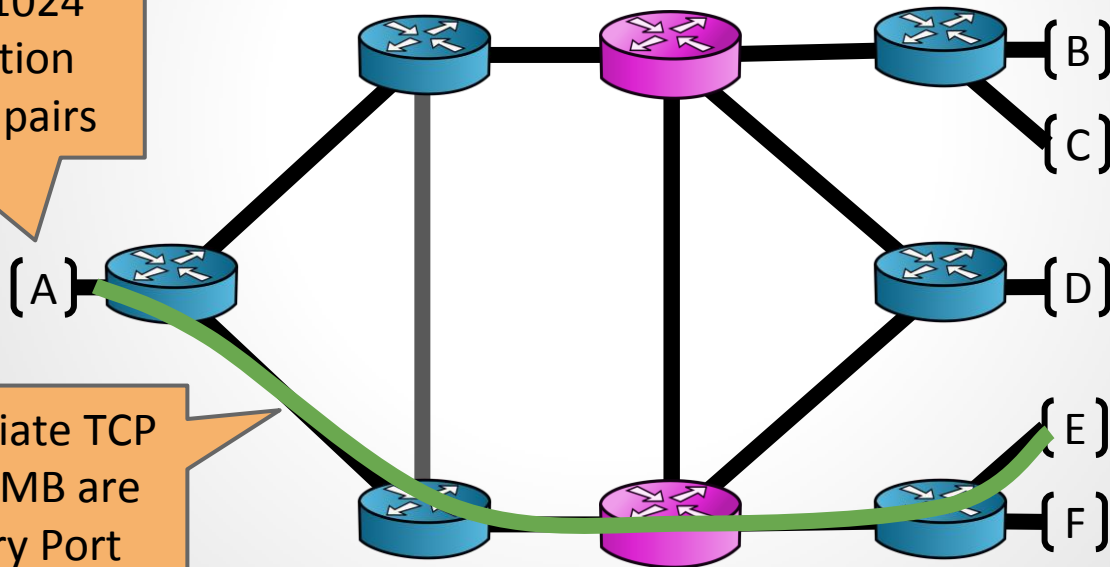
eth0: -live capture in progress> R... Packets: 445 Displayed: 445 Marked: 0 Profile: Default

Defines a  
traffic  
matrix



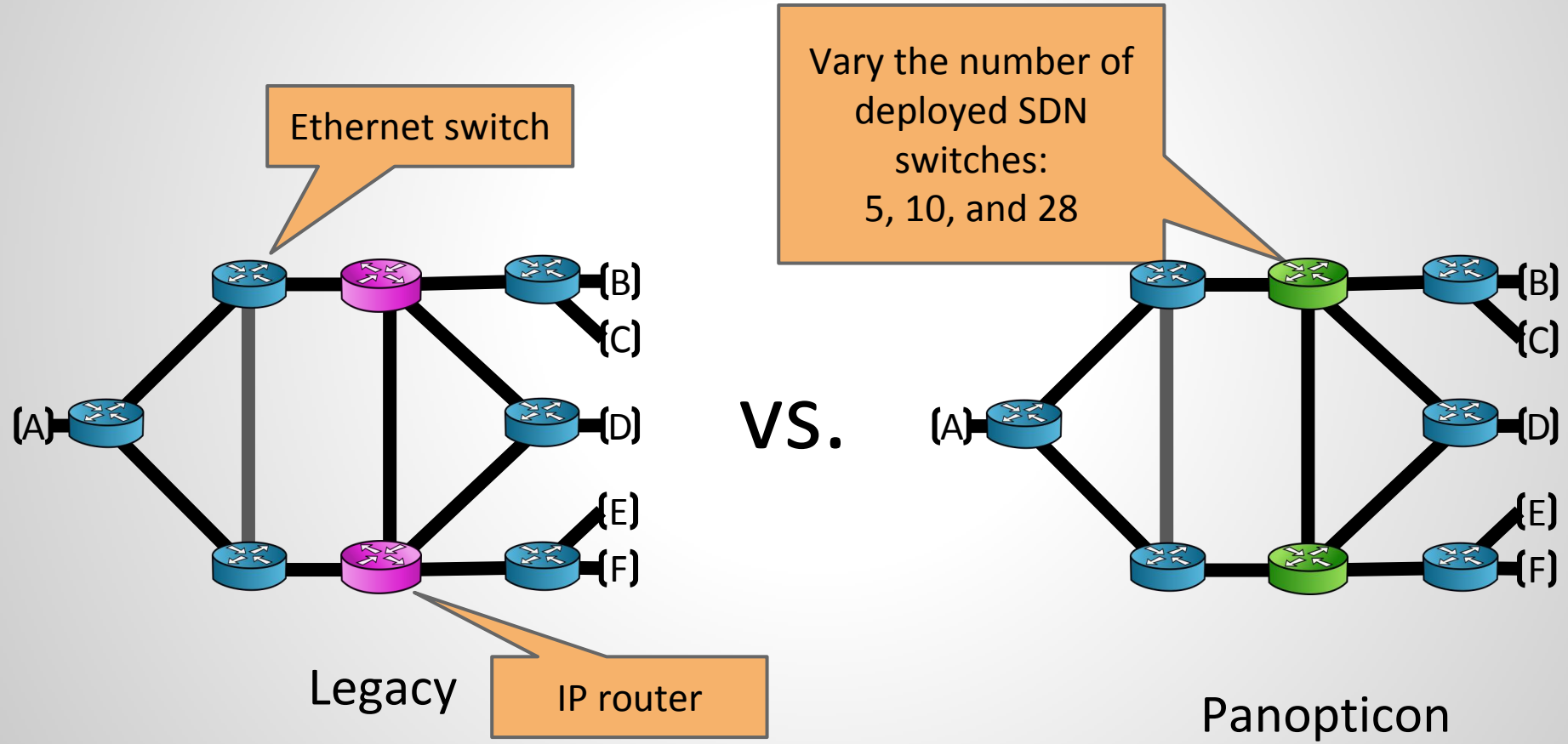
# Workload

Traffic Matrix: 1024  
source-destination  
communication pairs

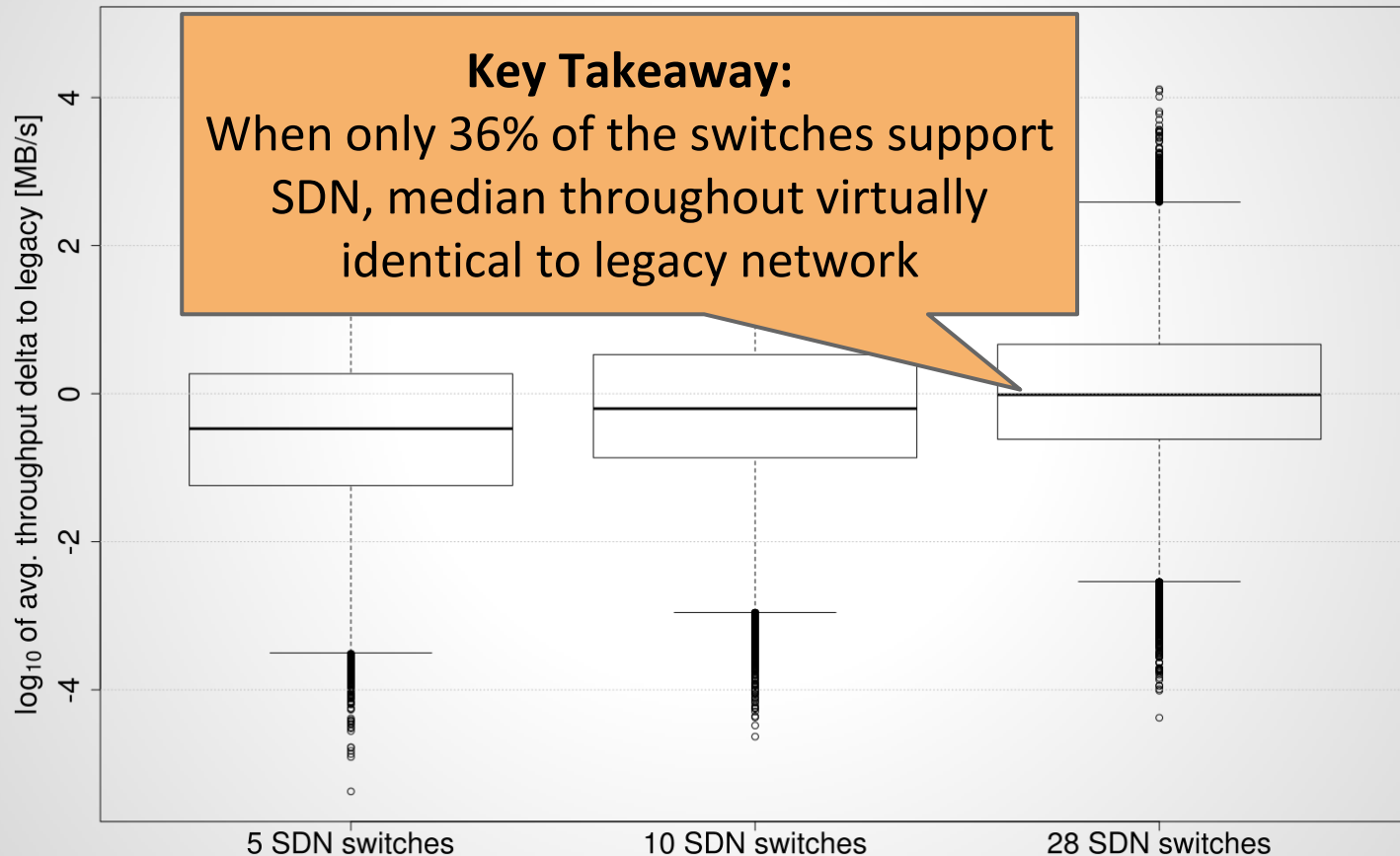


Sequentially initiate TCP  
flows until 100 MB are  
sent from every Port

# TCP Throughput Comparison



# SDN Deployment Size vs. Performance





# Key Results Highlights

- Evaluated a large campus network (1500+ switches)
- Real topologies and real traffic traces
- Upgrade **2%** of the switches/routers →
  - 100% SDN-controlled ingress ports
  - avg. path stretch < 50%
  - 90th percentile link util. < 25% increase

# Summary

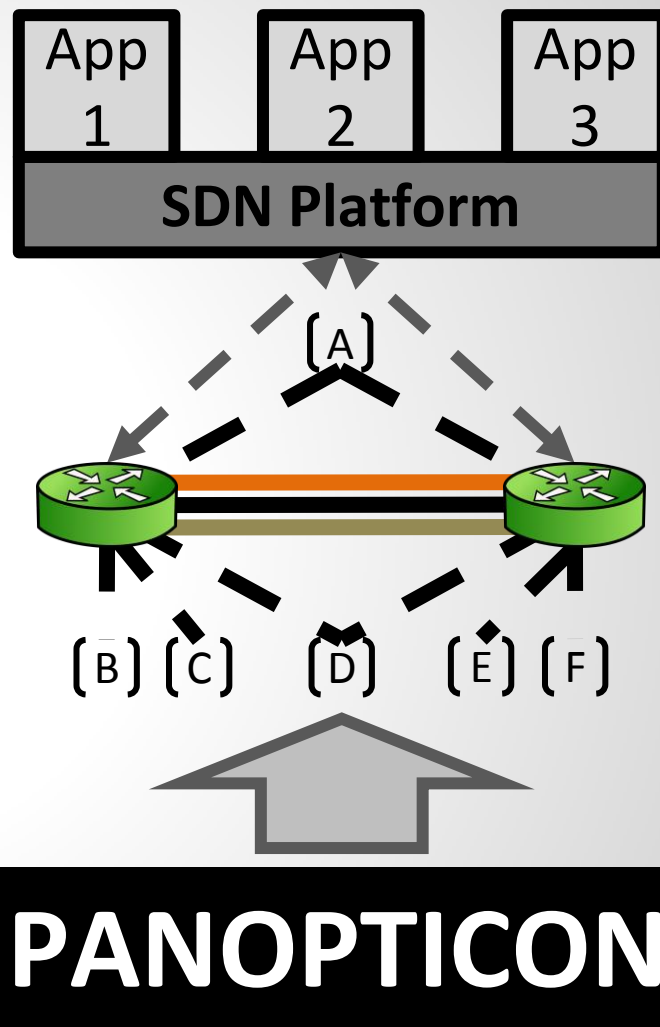
## SDN ARCHITECTURE

Operate the network as  
a (nearly) full SDN

## TOOL

Determine the partial  
SDN deployment

<https://venture.badpacket.in>

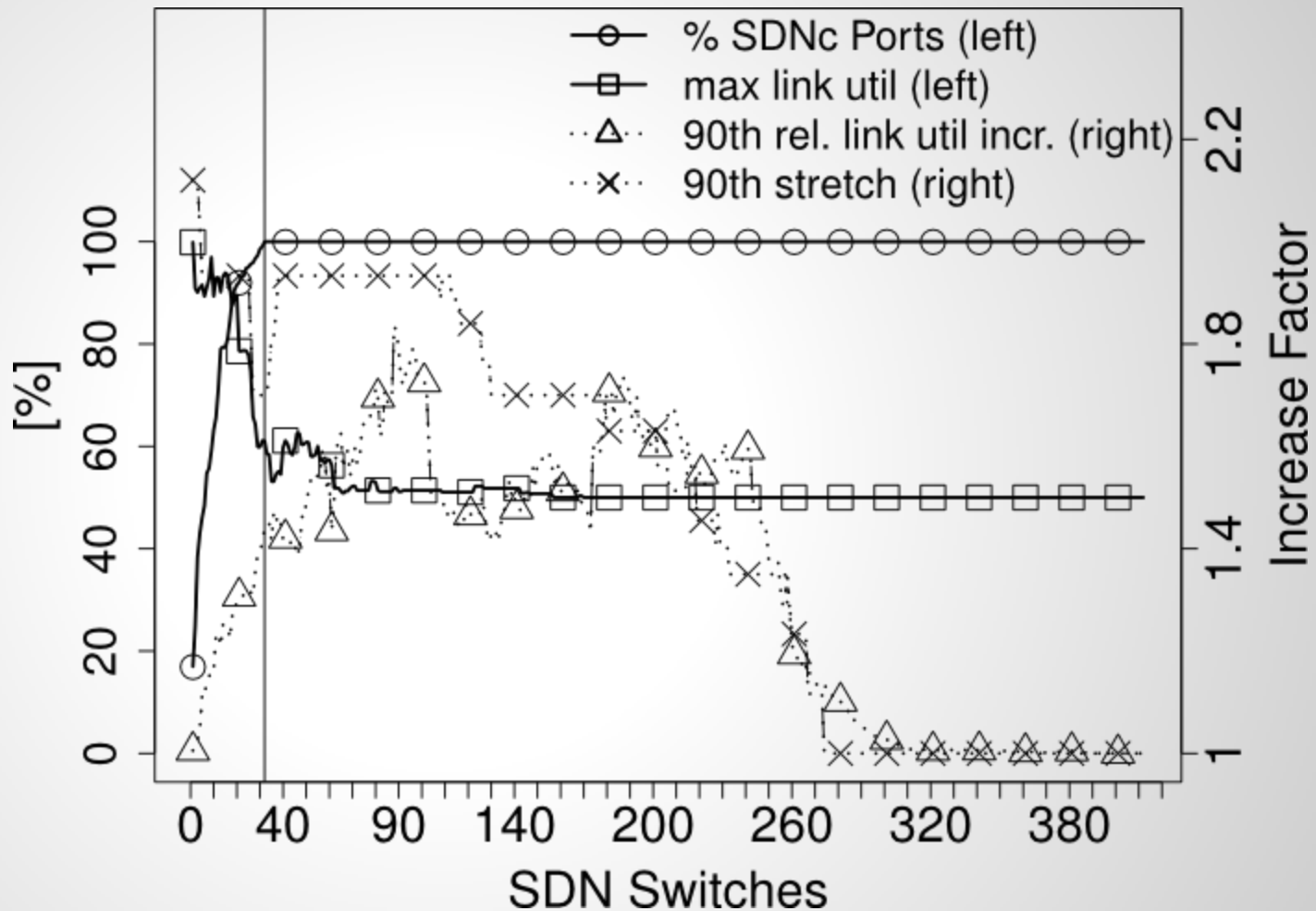


Median values of  
10 random TM  
permutations

1296 SDNc Ports

10 policy rules per  
port (avg)

1024 VLANs



# Other Ongoing Projects

- STN: Concurrent Control Plane
- Provably Dataplane Connectivity
- Consistent Network Updates
- AeroFlux: Wifi SDN with near-sighted control