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

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Enterprise Network Management

Policy changes

Scheduled maintenance

Heterogeneity

Device life cycle management

Resource allocation

Troubleshooting
Software Defined Networking

Controller Platform

Global Network View

SDN Interface

Control Programs

RIP

OSPF

ISIS

EIGRP
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?
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?

3. What limitations or performance costs?
The Existing Network

SDN-controlled “SDNc Ports”
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 → Policy enforcement

Access control

Middlebox traversal
2. Realizing the Benefits of SDN

**Insight #1:**
≥ 1 SDN switch → Policy enforcement

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

Traffic load-balancing
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**
Traffic restricted to **Solitary Confinement Trees**

**The PANOPTICON SDN Architecture**

Per-port spanning trees that ensure waypoint enforcement
**The PANOPTICON SDN Architecture**

1. One VLAN ID per SDNc port
2. Reuse VLAN ID space across cell blocks
3. SCTs can be pre-installed
"Logical SDN"
PANOPTICON provides the abstraction of a (nearly) fully-deployed SDN in a partially upgraded network
## Evaluation

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<td>How will Panopticon Affect Network Traffic?</td>
<td>TCP Wyvernment</td>
<td>Fault Tolerance</td>
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See our Paper
Simulation Methodology

**Topology: Real Enterprise Network**
- 1296 Access Switches
- 412 Distrib. Switches

**Workload: Packet-level Traces $\rightarrow$ 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

Flow Table Capacity (100K entries)

Link Capacities

# Supported VLANs (256, 512, 1024)
How many SDNc ports do I get?

Switch Placement Heuristic

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

Accommodate 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

2% of network switches (33 SDN switches)

100% SDN-controlled ports

Optimistic Conditions

Conservative Conditions
How will Panopticon affect my traffic?

Recall: Baseline traffic scaled so that max-utilized link is 50%
How will Panopticon affect my traffic?
How will Panopticon affect my traffic?

- 33 SDN switches (2% of network)
- 90th path stretch < 1.9x
- max util. < 60%
# Key Evaluation Results

<table>
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<tr>
<th>Optimistically at 2% deployed SDN switches</th>
<th>Conservatively at 10% deployed SDN switches</th>
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<tr>
<td>- Every access port controlled via SDN</td>
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<tr>
<td>- Moderate Path Stretch</td>
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<tr>
<td>- Moderate increase in link utilization</td>
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<td>- Traffic Emulation: results support simulations</td>
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<td>- Testbed: validate system and fault-tolerance</td>
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Summary

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

**Planning TOOL** Determine the partial SDN deployment

https://panoptisim.badpacket.in
Packet Forwarding

Inter-Switch Fabric provides transit between SCTs
Current Hybrid Networks

SDN Platform

Legacy Mgmt

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

1) Operator signals intent to our application, to remove switch for maintenance.

2) Install forwarding rules for “green flow”

3) Update forwarding rules to re-route “green flow”

Gratuitous ARP for destination C.
Use Case Testbed Evaluation

2x NEC IP8800 (OF 1.0)
1x Cisco C3550XL
3x Cisco C2960X
2x HP 5406zl
1x Pica8

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

TCP Connection Recovery Time
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?
How will Panopticon affect my traffic?
How will Panopticon affect my traffic?

33 SDN switches → 90\textsuperscript{th} stretch < 1.9x & max util. < 60\%
SDN Interface

Global Network View

Controller Platform

f( )

Control Programs

f( )

Control Programs

f( )

Control Programs
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?

Harvest unutilized network capacity
SDN Interface

Controller Platform

Global Network View