The CrossPath Attack: Disrupting the SDN Control Channel via Shared Links

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Outline

1)Background

2)Motivation

3)Overview of the CrossPath Attack

4)Challenges

5)Adversarial Path Reconnaissance

6)Evaluation

7)Possible Defense

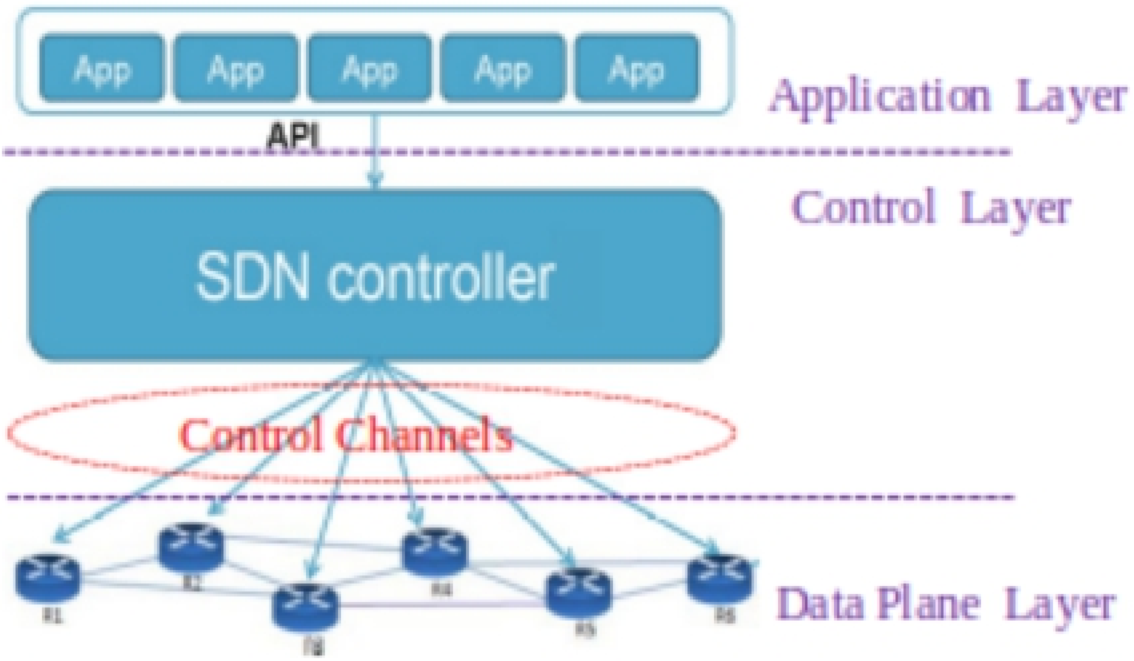
8)Pros and Cons

9)Conclusion

Software-Defined Networking (SDN)

1)Software-Defined Networking

- separate control and data planes
- take centralized network control
- enable network programmability



Three-Layer SDN Architecture

1)SDN Control Channels

- deliver all control traffic
- failure results in serious

Motivation

1)Software Defined Networks control and data channel security issues.

1)Control channel is susceptible to DoS attacks.

1)The impact of DoS on control channel is huge.

1)Existing studies focus on various other security issues in the Software Defined

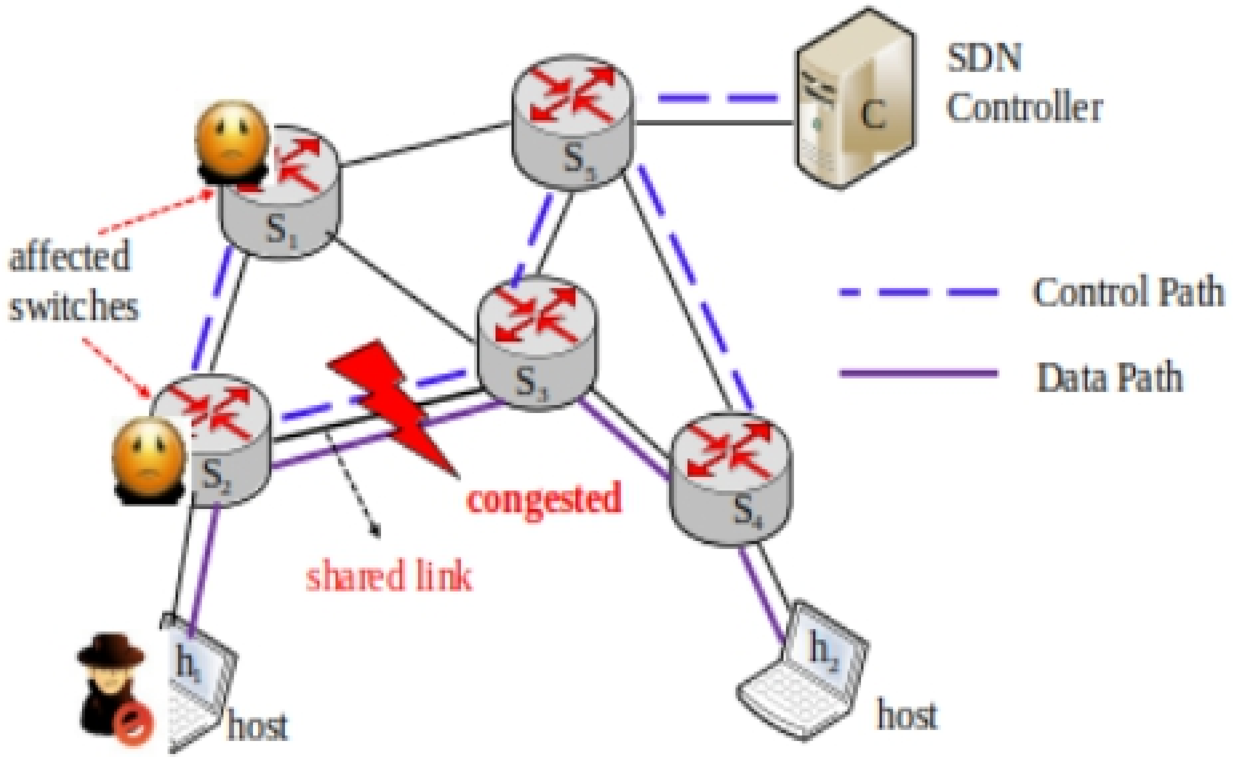
CrossPath Attack

1) We uncover a new attack to disrupt SDN control channels
   - leverage **shared links** between paths of control and data traffic
   - allow **data traffic** to disrupt **control traffic**
   - disrupt **a wide range of** SDN functionalities

1) Threat Model
   - an attacker compromises a host inside the target SDN
   - the target SDN applies **in-band** control

Example

A malicious host sends **data traffic** to congest **shared links** delivering **control traffic**



Challenges

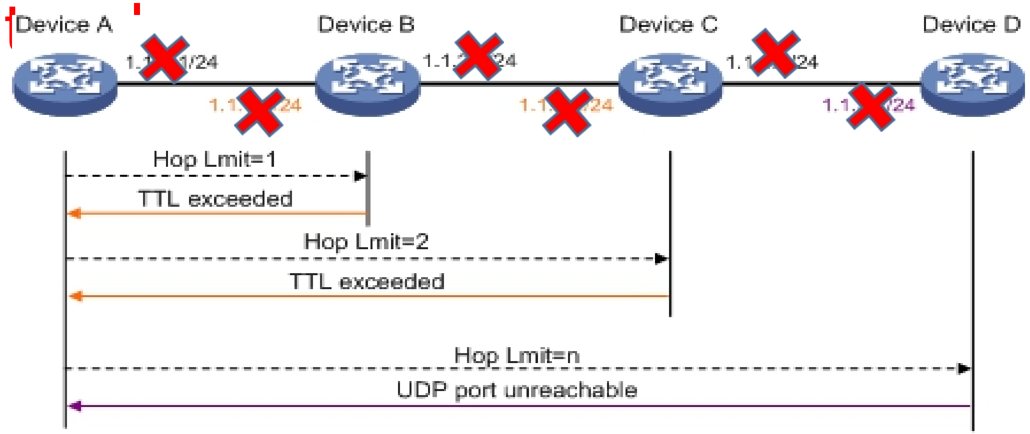
How to find a data path that contains shared links?

Randomly choose a data path to attack?

low success ratio due to only a few shared links

Apply existing scanning tools to find such a data path?

ineffectiveness due to unique SDN dat...



Assume m switches in total,

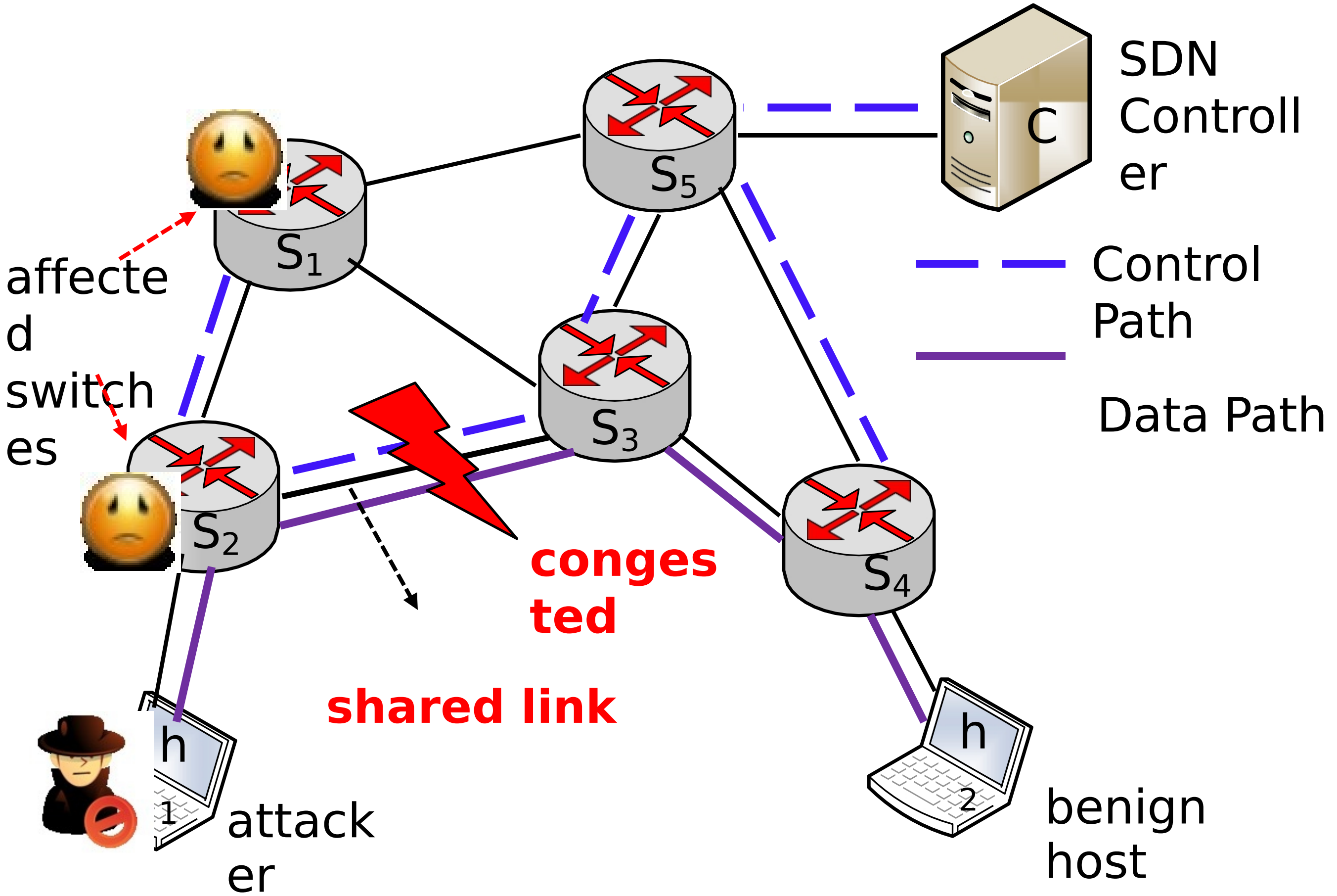
- $\boldsymbol{O}(\boldsymbol{m}^2)$ total links
- $\boldsymbol{O}(\boldsymbol{m})$ shared links connecting them with the controller

SDN

- **No IP** addresses in switch ports
- **No TTL decrease** for packets passing SDN switches

Adversarial Path Reconnaissance

Key Observation: **control path delays** can be an **indicator** on whether a data path contains shared links



- Control Path Delay between S_2 and C: $T_{S_2,C}$
- Case 1: a data path contains shared links
  - $T_{S_2,C} = 100\ ms$ due to congestion

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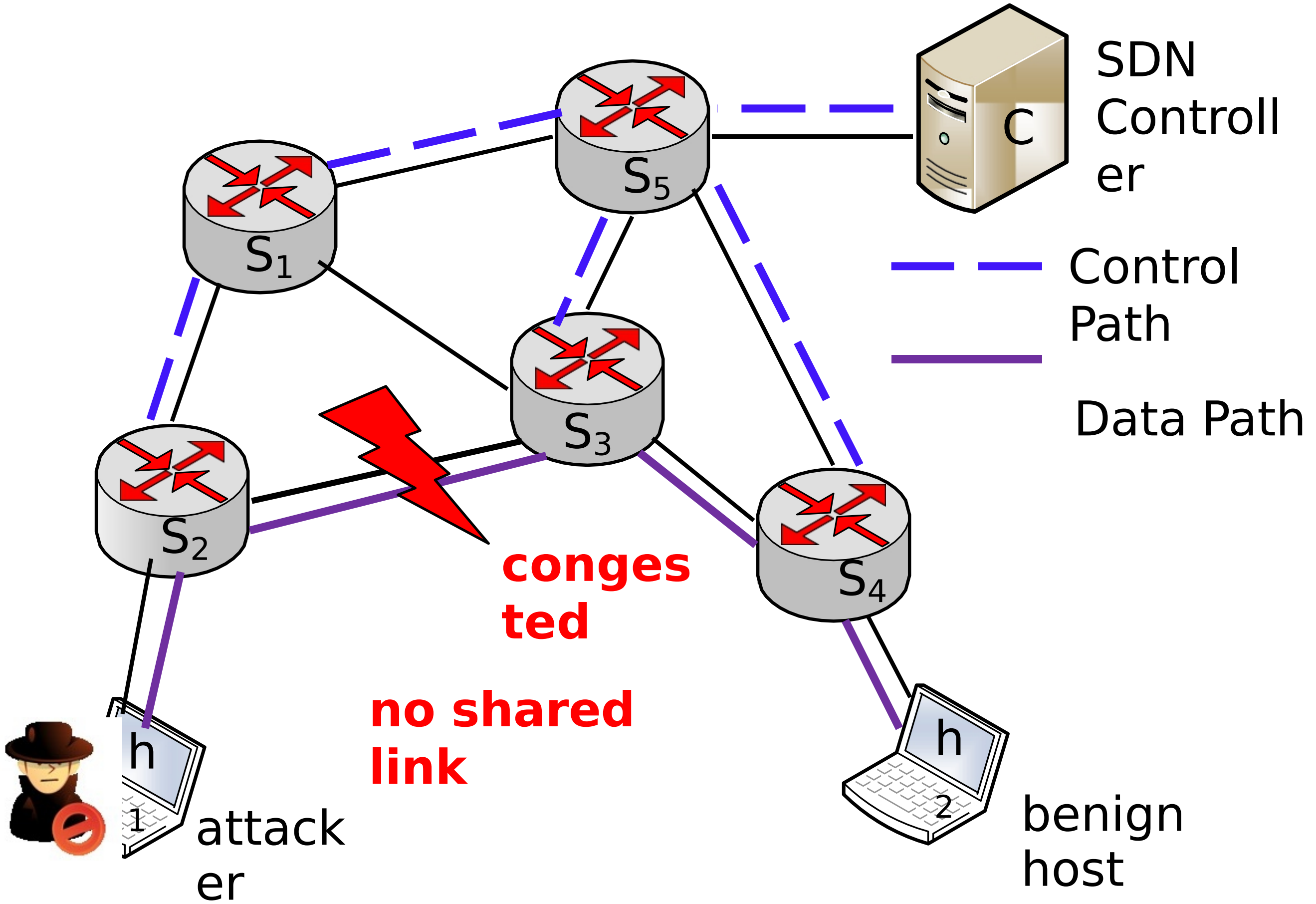

- Control Path Delay between S_2 and C: $T_{S_2,C}$
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- Case 2: a data path contains no shared links
  - $T_{S_2,C} = 10\ ms$

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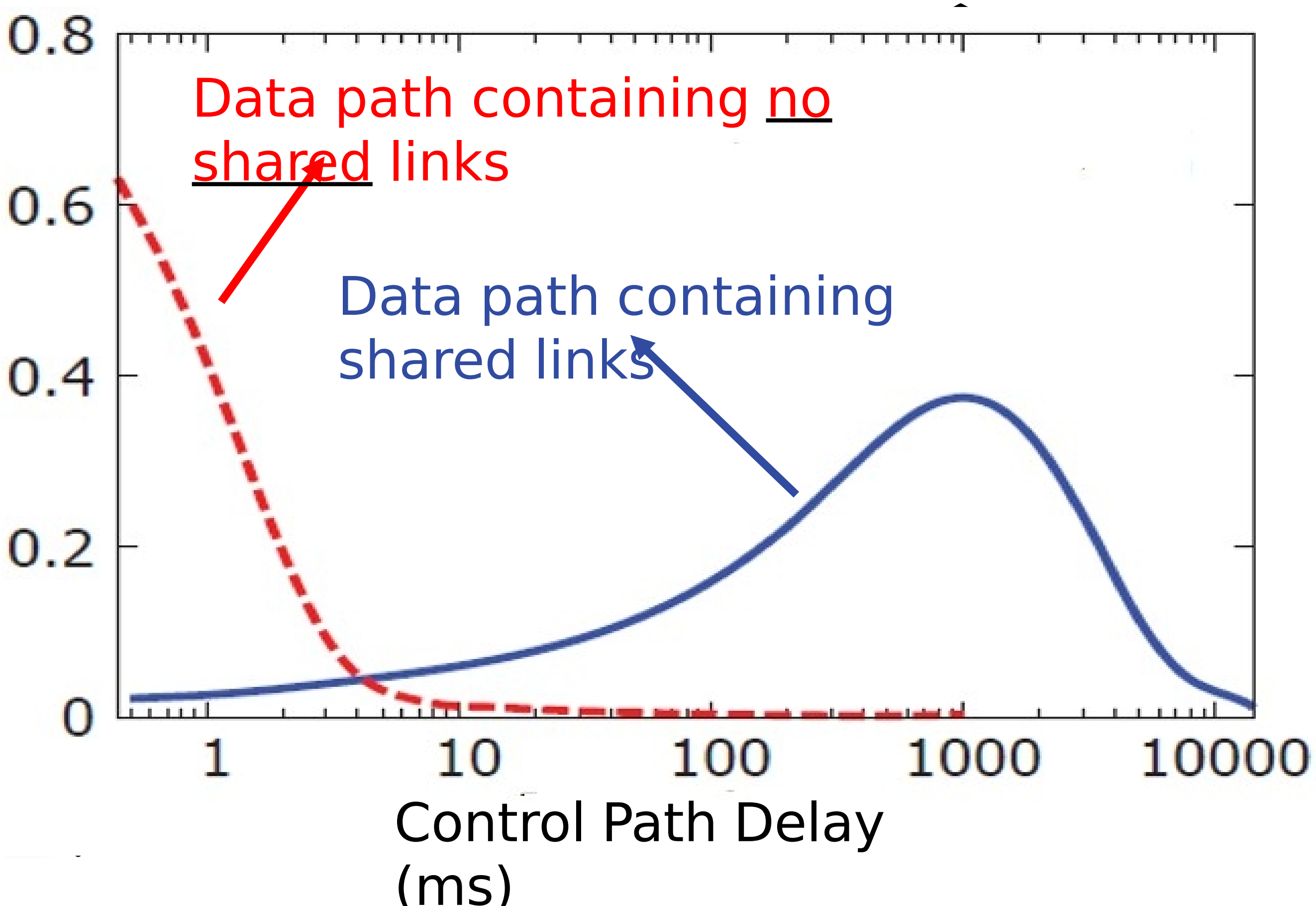

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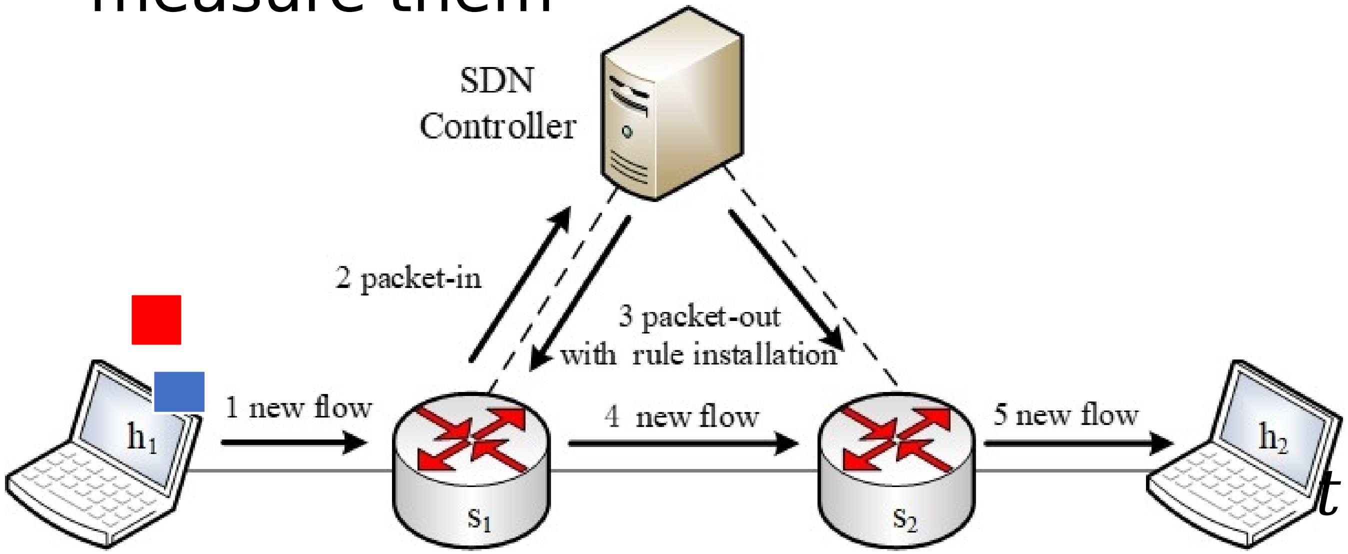
Control Path Delay Measurement

How to measure control path delays with an end host?

Leverage **side effects** of dynamic flow rule installation to measure them



$RTT_1 = t_{data} + t_{control}$

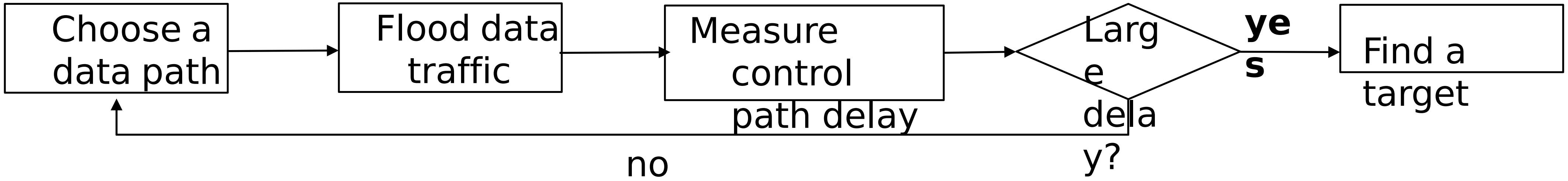
$RTT_2 = t_{data}$

$t_{control} = RTT_1 - RTT_2$

Control path delays can be calculated based on the first two packets of a new flow

Reconnaissance Algorithm

Algorithm



Optimization

Improve the accuracy of reconnaissance

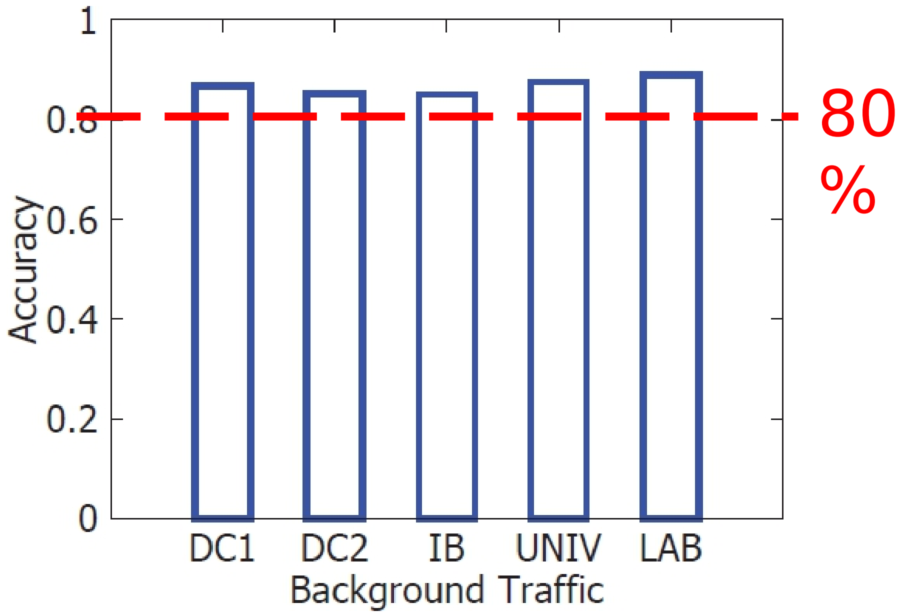
e.g., reduce the impacts of network jitters

e.g., enable concurrent reconnaissance

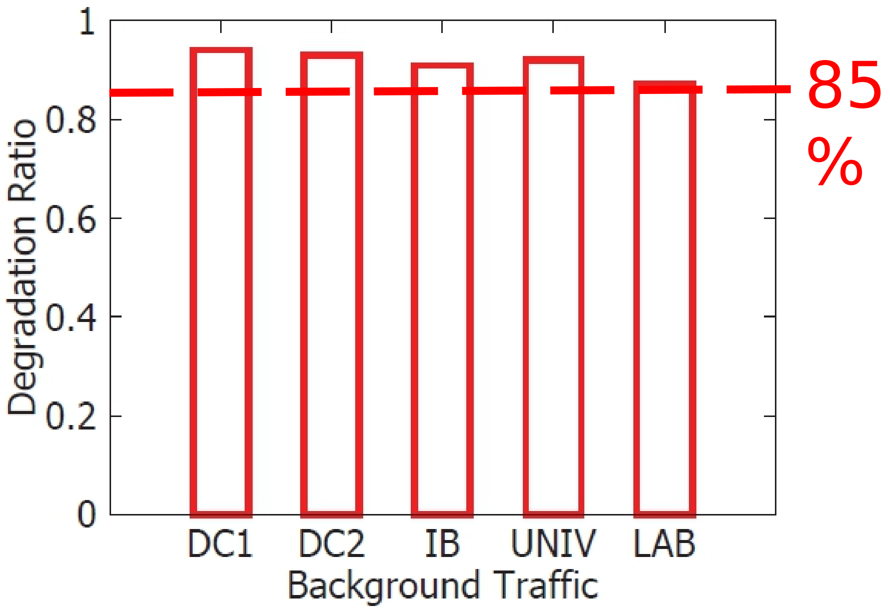
Experiment Setup

- A real SDN testbed consists of
  - commercial hardware SDN switches
  - an open source controller, Floodlight
  - physical hosts connecting to switches
- We replay five types of real traffic trace
  - traffic of two data centers
  - traffic of one university
  - traffic of one internet backbone
  - traffic of one computer lab
- We evaluate
  - the accuracy of adversarial path reconnaissance
  - the degradation ratio of control traffic

Accuracy and Effectiveness



reconnaissance accuracy degradation



control traffic

DC: datacenter traffic, **IB**: internet backbone traffic, **UNIV**: university traffic, **LAB**: our computer laboratory traffic

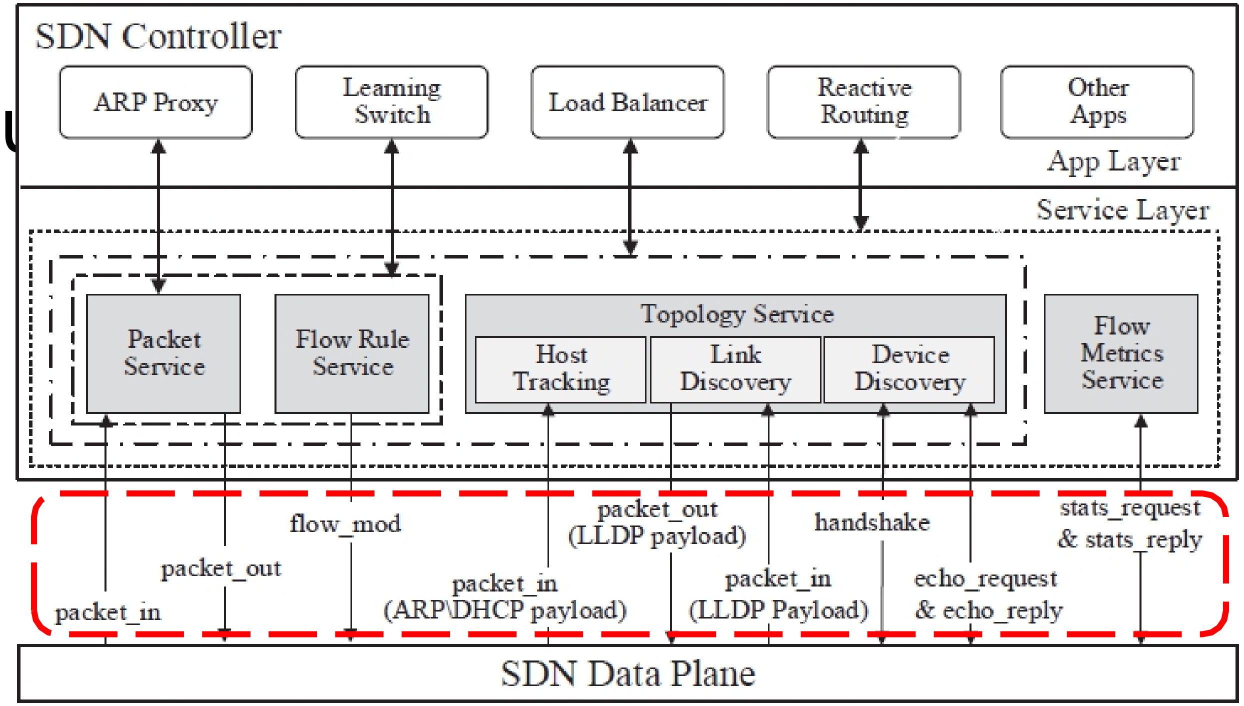
Attack Impacts on Network Functionalities

Almost all SDN applications depend on control messages delivered in control channels to enable network functionalities

We measure the impacts on popu

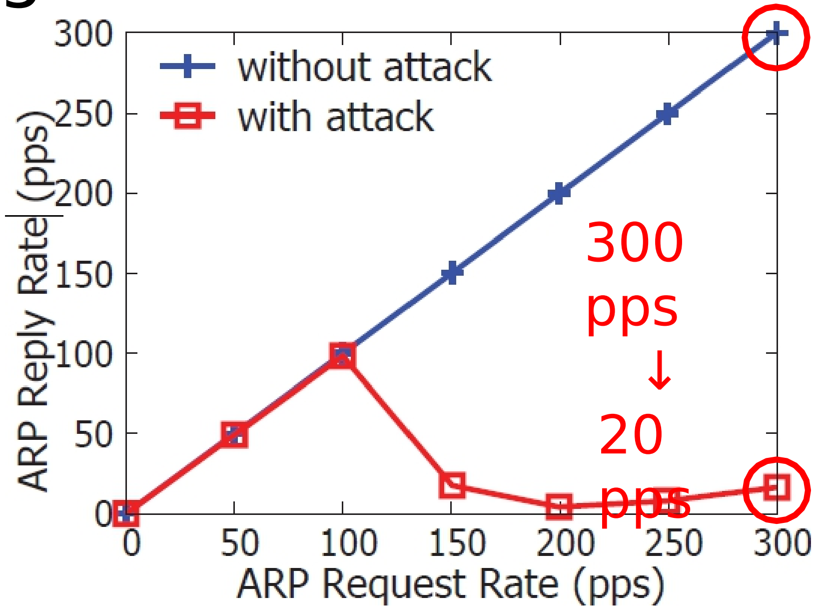
SDN APPs:

- ARP Proxy
- Learning Switch
- Reactive Routing
- Load Balancer

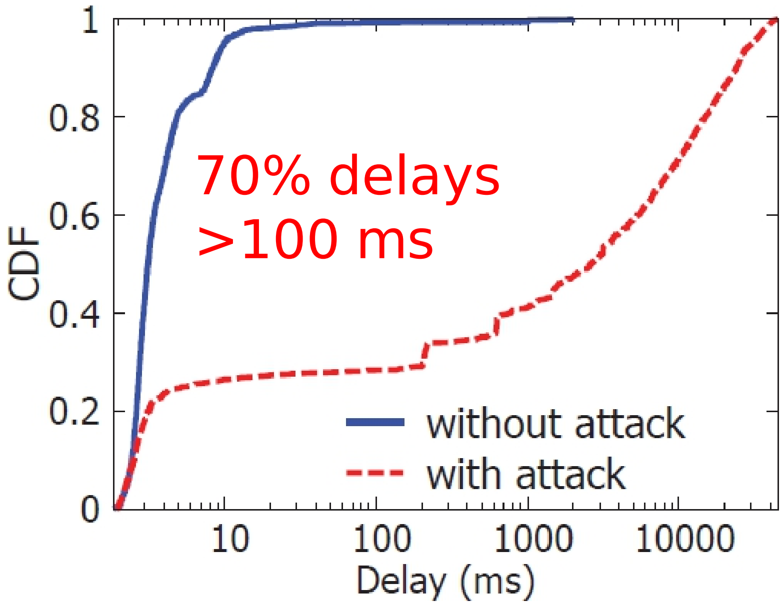


ARP Proxy

The performance of ARP Proxy significantly degrades



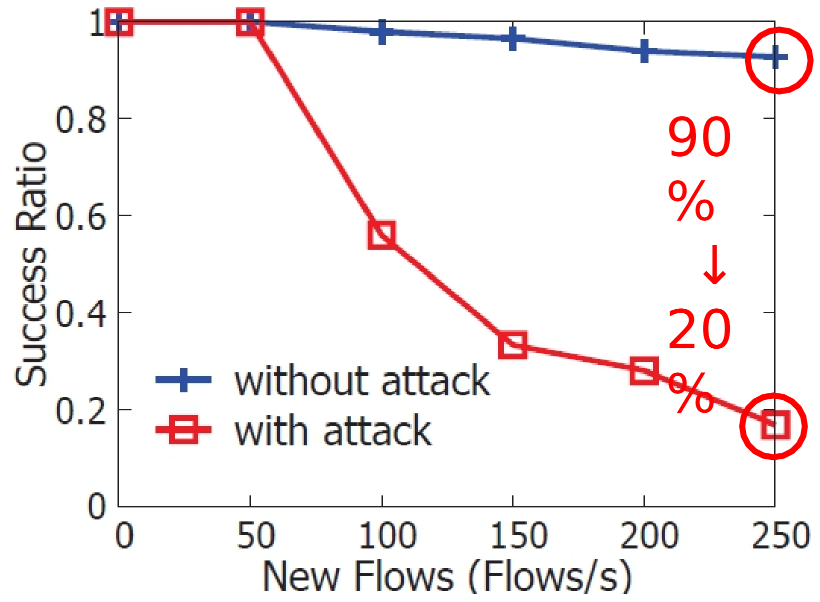
ARP throughput



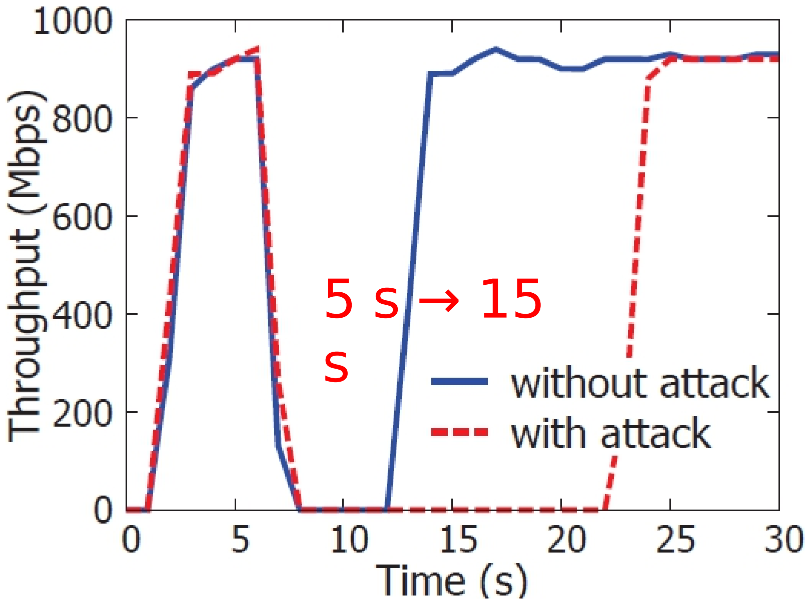
ARP query delay

Reactive Routing

Reactive Routing generates various anomalies



success ratio of rule installation



host migration time

Reactive Routing

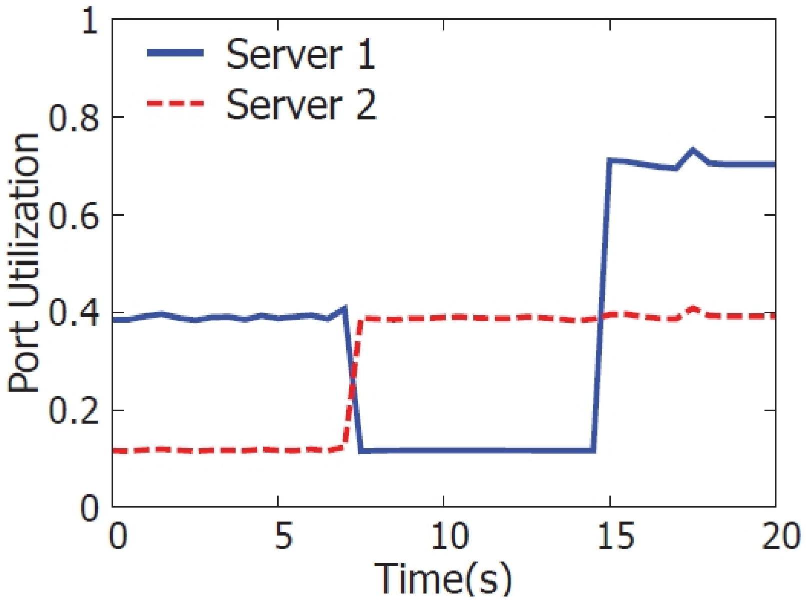
Reactive Routing generates various anomalies

```
17:37:46.344 INFO  [n.f.t.TopologyInstance] Route [id=RouteId [src=1c:48:cc:37:ab:a0:a8:41
dst=9d:54:cc:37:ab:a0:a8:41], switchPorts=[[id=1c:48:cc:37:ab:a0:a8:41, port=37],
[id=9d:54:cc:37:ab:a0:a8:41, port=31]]]
17:38:01.62 INFO  [n.f.l.i.LinkDiscoveryManager] Inter-switch link removed: Link
[src=a4:e7:cc:37:ab:a0:a8:41 outPort=38, dst=9d:54:cc:37:ab:a0:a8:41, inPort=42, latency=6]
17:38:01.95 INFO  [n.f.t.TopologyManager] Recomputing topology due to: link-discovery-
updates
17:38:01.345 INFO  [n.f.t.TopologyInstance] Route [id=RouteId [src=1c:48:cc:37:ab:a0:a8:41
dst=9d:54:cc:37:ab:a0:a8:41], switchPorts=[[id=1c:48:cc:37:ab:a0:a8:41, port=32],
[id=a4:e7:cc:37:ab:a0:a8:41, port=36], [id=a4:e7:cc:37:ab:a0:a8:41, port=38],
[id=9d:54:cc:37:ab:a0:a8:41, port=42]]]
```

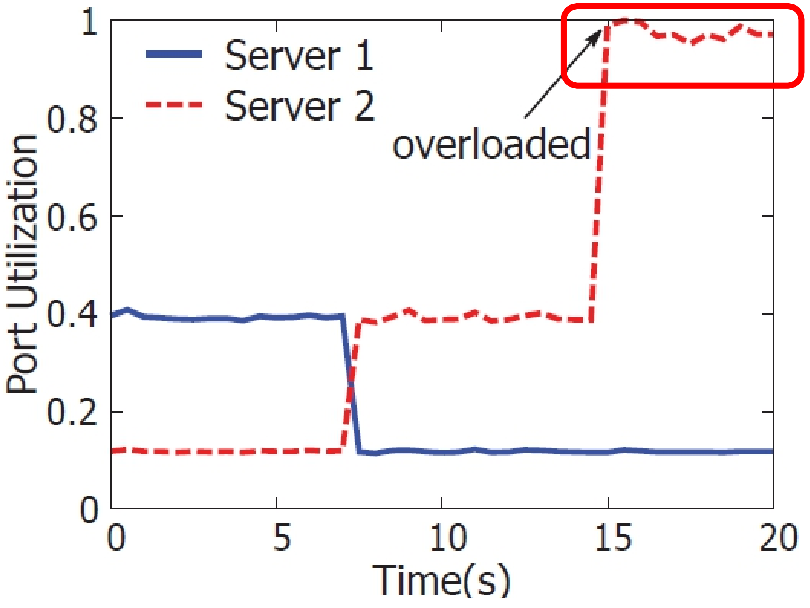
A routing path is evicted due to a deactivated link

Load Balancer

Load balancer incorrectly balances traffic among servers



without the attack



with the attack

Possible Defense

Deliver control traffic with a high priority

- implementation with priority queue or weighted round robin queue

Proactively reserve bandwidth for control traffic

- implementation with meter tables

Defense Strategy	Rule	Match	Actions
Control traffic delivery with high priority [1]	#1	control flows	OutPort(x), . . . , *SetQueue(ID=highPriQueue)*
	#2	data flows	OutPort(x), . . . , *SetQueue(ID=lowPriQueue)*
Proactive bandwidth reservation for control traffic [2]	#1	data flows	OutPort(x), . . . , *SetMeter(ID=RateLimit)*

[1] It requires SDN switches to support PQ or WRR queuing mechanism.
[2] It is used when SDN switches fail to enable PQ or WRR mechanism.

Pros and Cons

Pros:

- Adversarial Path Reconnaissance
- LDoS :- The low rate targeted TCP
- Impact of congesting the network with LDoS over shared links
- The paper is based on theoretical study supported with a strong experimental setup along with performance analysis of major SDN application.
- They have not supposed a network which is vulnerable – i.e. without any network security

Cons:

- The attacker needs to have control of one of the hosts in the SDN
- The solution proposed is an implementation scheduling algorithm – might create an overhead.
- If an attacker is trying to disrupt the entire SDN network by compromising more than 1 hosts to send the packets – there might be a possibility of the attacking host being compromised based on how

Conclusion

Data traffic passing shared links can congest control traffic to disrupt SDN control channels

A data path containing shared links can be found by measuring control path delays and leveraging side effects of dynamic rule installation

Network administrators should enable priority queue or reserve bandwidth for SDN control traffic to protect control channels

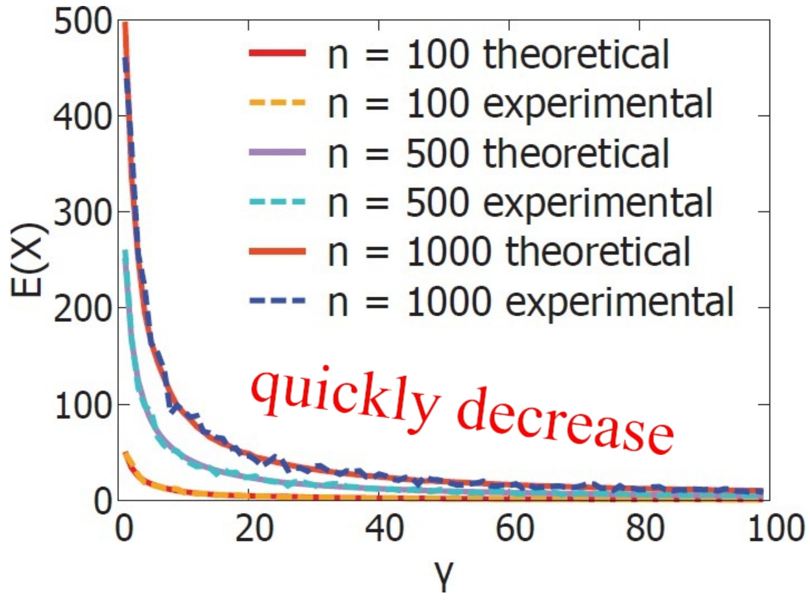
Thank you!

Slides by:- Jiahao Cao

Backup: Theoretical Analysis

The number of explored data paths to find a target data path containing a shared link

$$E(X) = \sum_{k=1}^{n-\gamma} \frac{k\gamma}{n-k} \prod_{j=0}^{k-2} \left(1 - \frac{\gamma}{n-1-j}\right)$$



n: The total number of hosts in SDN

γ: The total number of data paths containing shared links,
depending on the topology and the routing decision

Backup: Coverage

Simulation among 261 real network topologies

Connections between the controller and switches

- shortest path (SP)
- minimum spanning tree (MST)
- random (RS)