Security as an App and Security as a Service: New Killer Applications for Software Defined Networking?

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Credits

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Roadmap

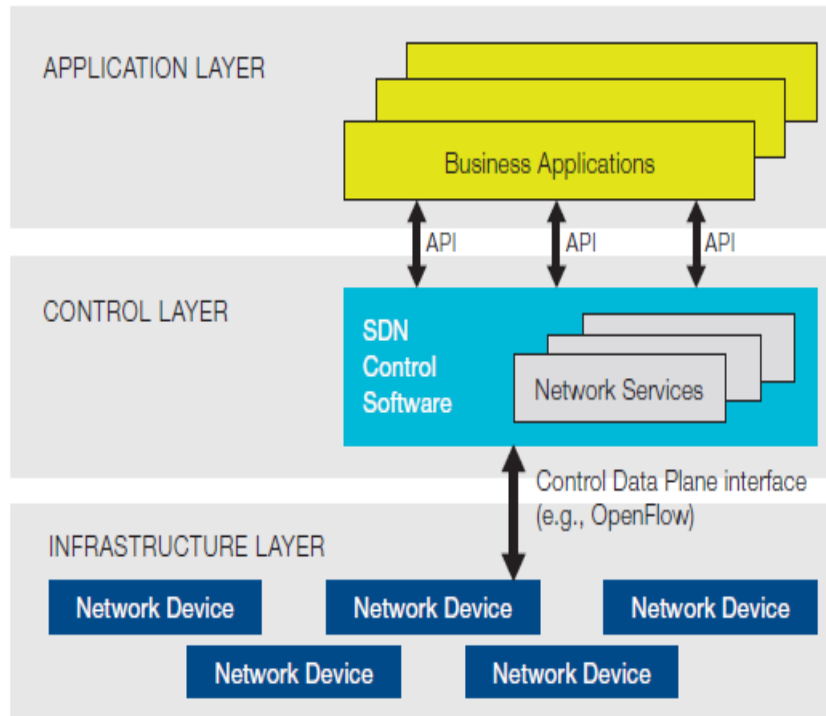
- Security in the paradigm of SDN/OpenFlow
- Security as an App (SaaA)
  - New app development framework: FRESCO
  - New security enforcement kernel: FortNOX
- Security as a Service (SaaS)
  - New security monitoring service for cloud tenants: CloudWatcher
- Summary

Problems of Legacy Network Devices

- Too complicated
  - Control plane is implemented with complicated S/W and ASIC
- Closed platform
  - Vendor specific
- Hard to modify (nearly impossible)
  - Hard to add new functionalities

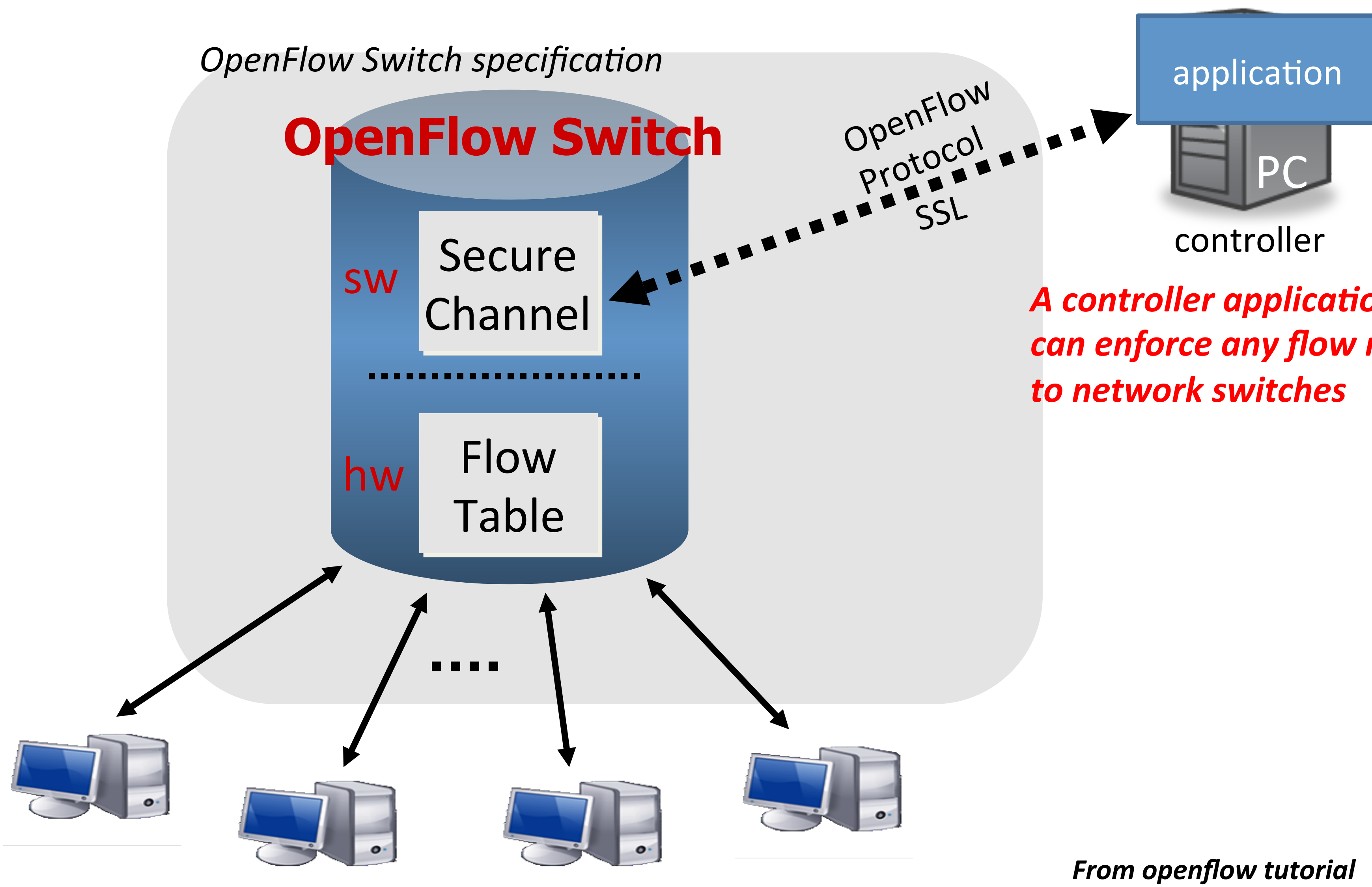
Software Defined Networking (SDN)

- Three layer
  - Application layer
    - Application part of control layer
    - Implement logic for flow control
  - Control layer
    - Kernel part of control layer
    - Run applications to control network flows
  - Infrastructure layer
    - Data plane
    - Network switch or router



SDN architecture from ONF

OpenFlow Architecture



A controller application can enforce any flow rules to network switches

From openflow tutorial

Killer Applications of SDN?

- Reducing Energy in Data Center Networks (load balancing)
- WAN VM Migration
- …
- How about security?
  – We are going to talk about this, more specifically:
  – Security as an App (SaaA)
  – Security as a Service (SaaS)

Software App Store Today

Security as an App

- SDN naturally has an application layer
- Security functions can be apps on top of SDN/networking OS
  - Firewall
  - Scan detection
  - DDoS detection
  - Intrusion detection/prevention
  - …
- Why SaaA?
  - Cost efficiency
  - Easy deployment/maintenance
  - Rich, flexible network control

Security as a Service

- Clouds are large, complicated, and dynamic
- How do tenants deploy security devices/ functions?
    - Tenant can use some pre-installed fixed-location security devices
        - Not able to keep up with the high dynamisms in network configurations
    - Tenant can Install security devices for themselves
        - Difficult
- Need a new **Security Monitoring as a Service** mechanism for a cloud network

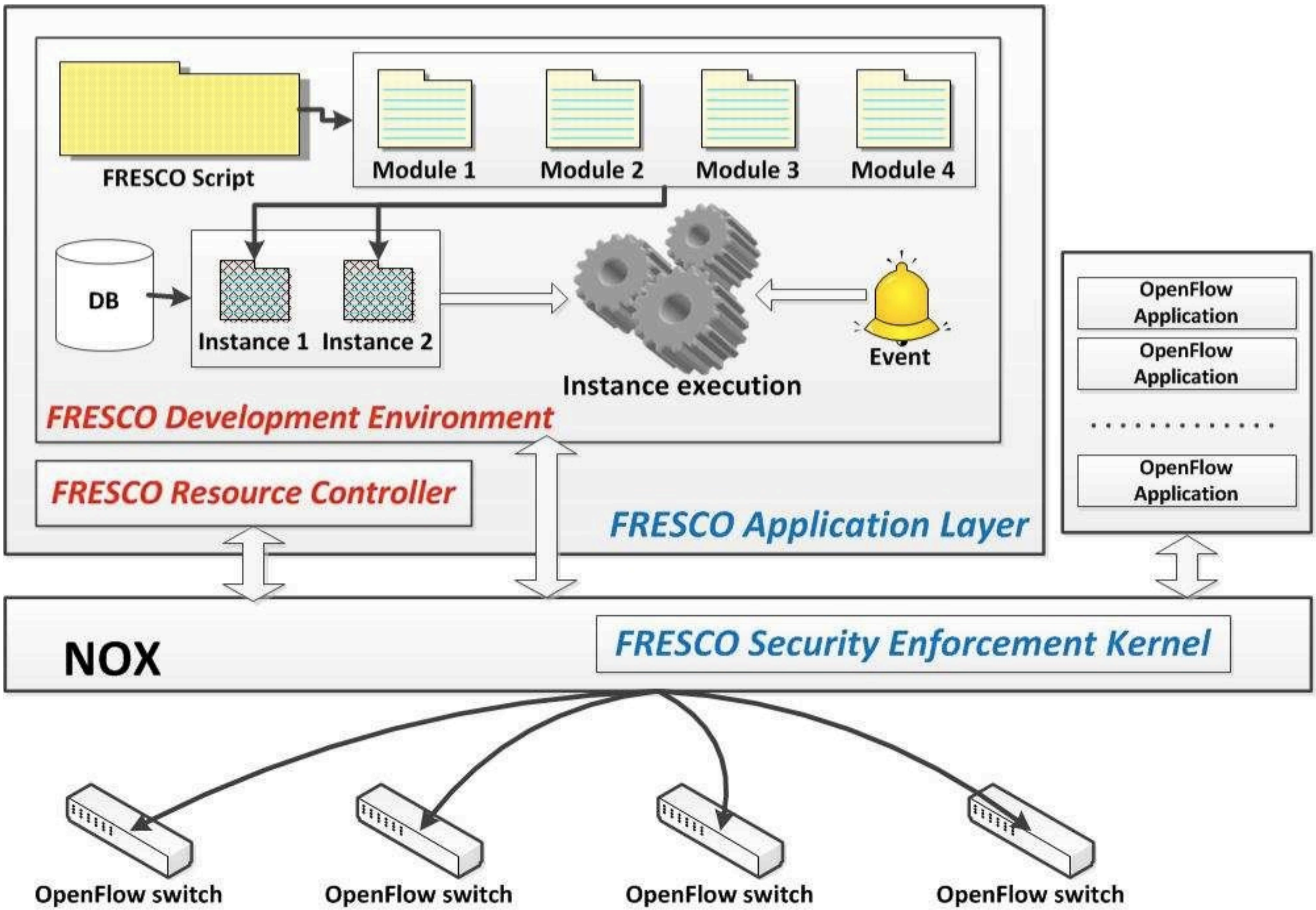
Challenges and Our Contributions

- *It is not easy to develop security apps*
  - FRESCO: a new app development framework for modular, composable security services
- *It is not secure when running buggy/vulnerable/ multiple security apps (e.g., policy conflict/ bypass)*
  - FortNOX: a new security enforcement kernel
- *It is not convenient to install/use security devices for cloud tenants*
  - CloudWatcher: a new security monitoring service model based on SDN

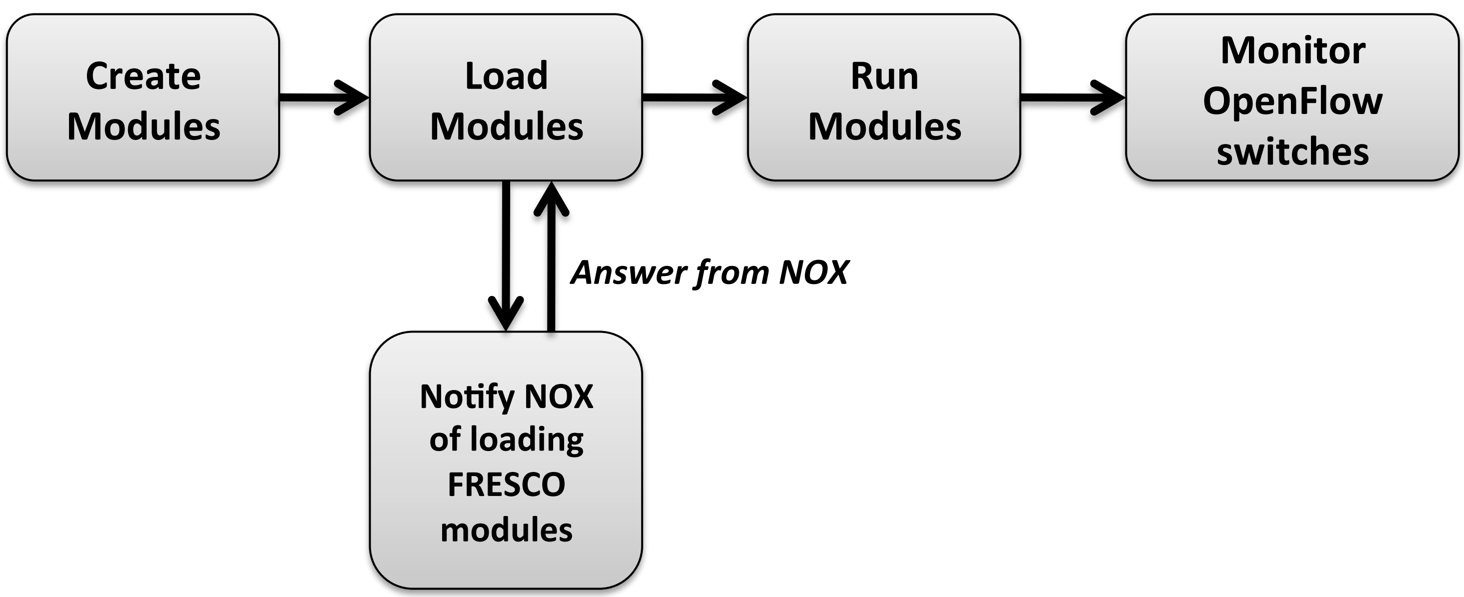
FRESCO:
Framework for Enabling Security Controls in OpenFlow networks

What is FRESCO?

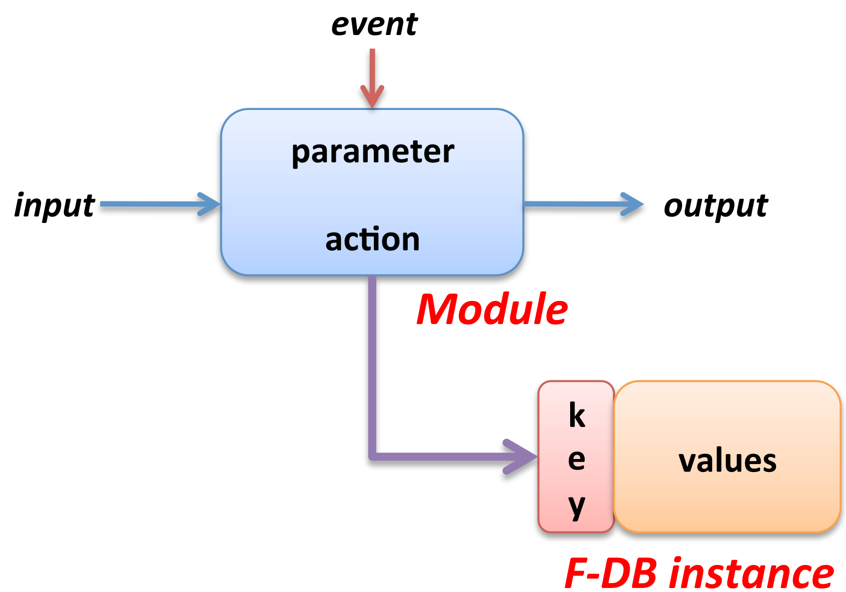
- A new framework
  - Enables to compose diverse network security functions easily (with combining multiple modules)
  - Enables to create own network security functions easily (without requiring additional H/Ws)
  - Enables to deploy network security functions easily and dynamically (without modifying the underlying network architecture)
  - Enable to add more intelligence to current network security functions

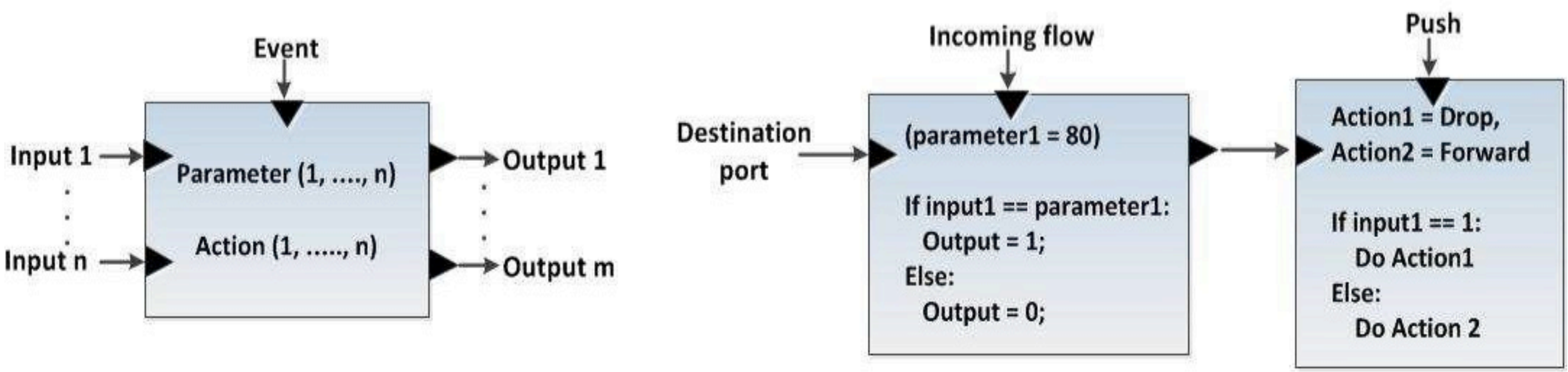

FRESCO Script
Module 1
Module 2
Module 3
Module 4
DB
Instance 1
Instance 2
Instance execution
Event
FRESCO Development Environment
FRESCO Resource Controller
FRESCO Application Layer
OpenFlow Application
OpenFlow Application
OpenFlow Application
NOX
FRESCO Security Enforcement Kernel
OpenFlow switch
OpenFlow switch
OpenFlow switch
OpenFlow switch

FRESCO – Overall Operation



FRESCO Modular Design





FRESCO – Script Language

- Goal
  - Define interfaces, actions, and parameters
  - Connect multiple modules
  - Similar to C/C++ function, start with { and end with }
- Format
  - Instance name (# of input) (# of output)
    - denotes the module name and the number of input and output variables
  - INPUT: a_1,a_2,
    - denotes input items for a module a_n may be set of flows, packets or integer values
  - OUTPUT: b_1,b_2,
    - denotes output items for a module b_n may be set of flows, packets or integer values
  - PARAMETER: c_1,c_2,
    - denotes configuration values of a module c_n may be real numbers or strings
  - EVENT: d_1,d_2,
    - denotes events that will be delivered to a module d_n may be any predefined string
  - ACTION : condition ; action,
    - denotes actions that will be performed based on condition

Simple Working Example: Reflector Net

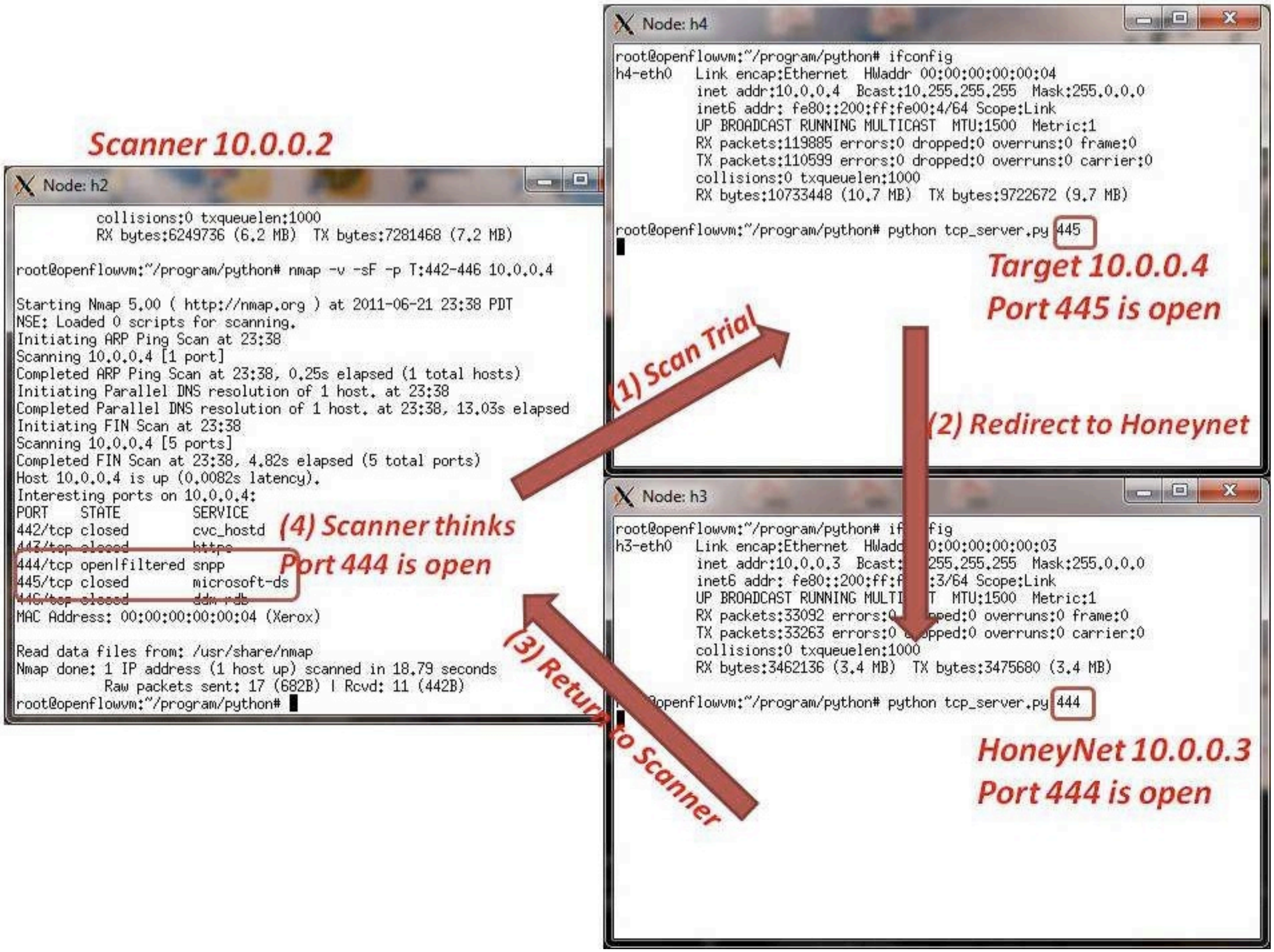
find_scan (1) (2) {
 TYPE: ScanDetector
 EVENT:TCP_CONNECTION_FAIL
 INPUT: SRC_IP
 OUTPUT: SRC_IP, scan_result
 PARAMETER: 5
 ACTION: -
/* no actions are defined */
}

Module 1

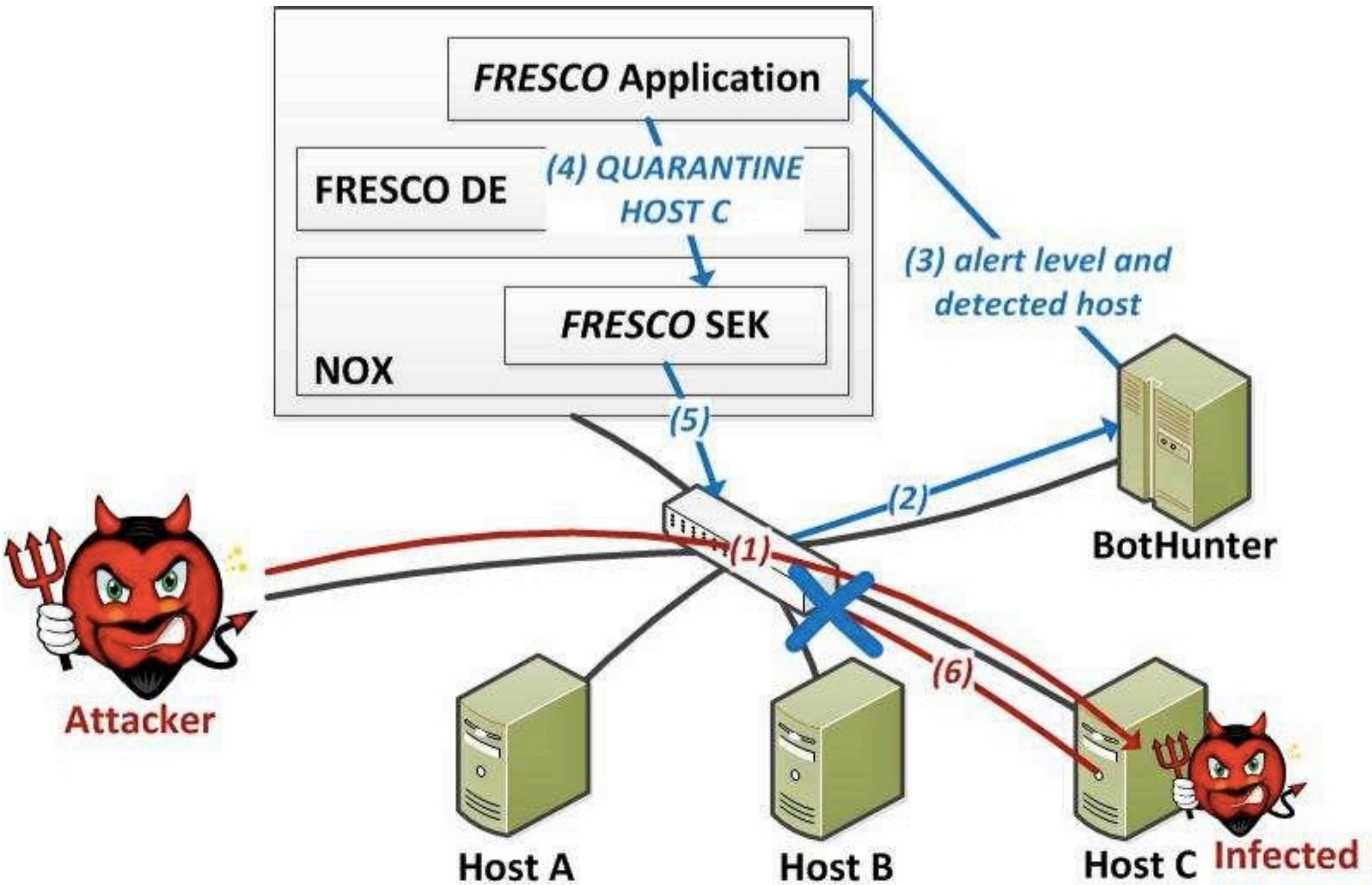
do_redirect (2) (0) {
 TYPE: ActionHandler
 EVENT:PUSH
 INPUT:SRC_IP, scan_result
 OUTPUT: -
 PARAMETER: -
 ACTION: scan_result == 1? REDIRECT: FORWARD
/* if scan_result equals 1, redirect; otherwise, forward */
}

Module 2

Reflector Net



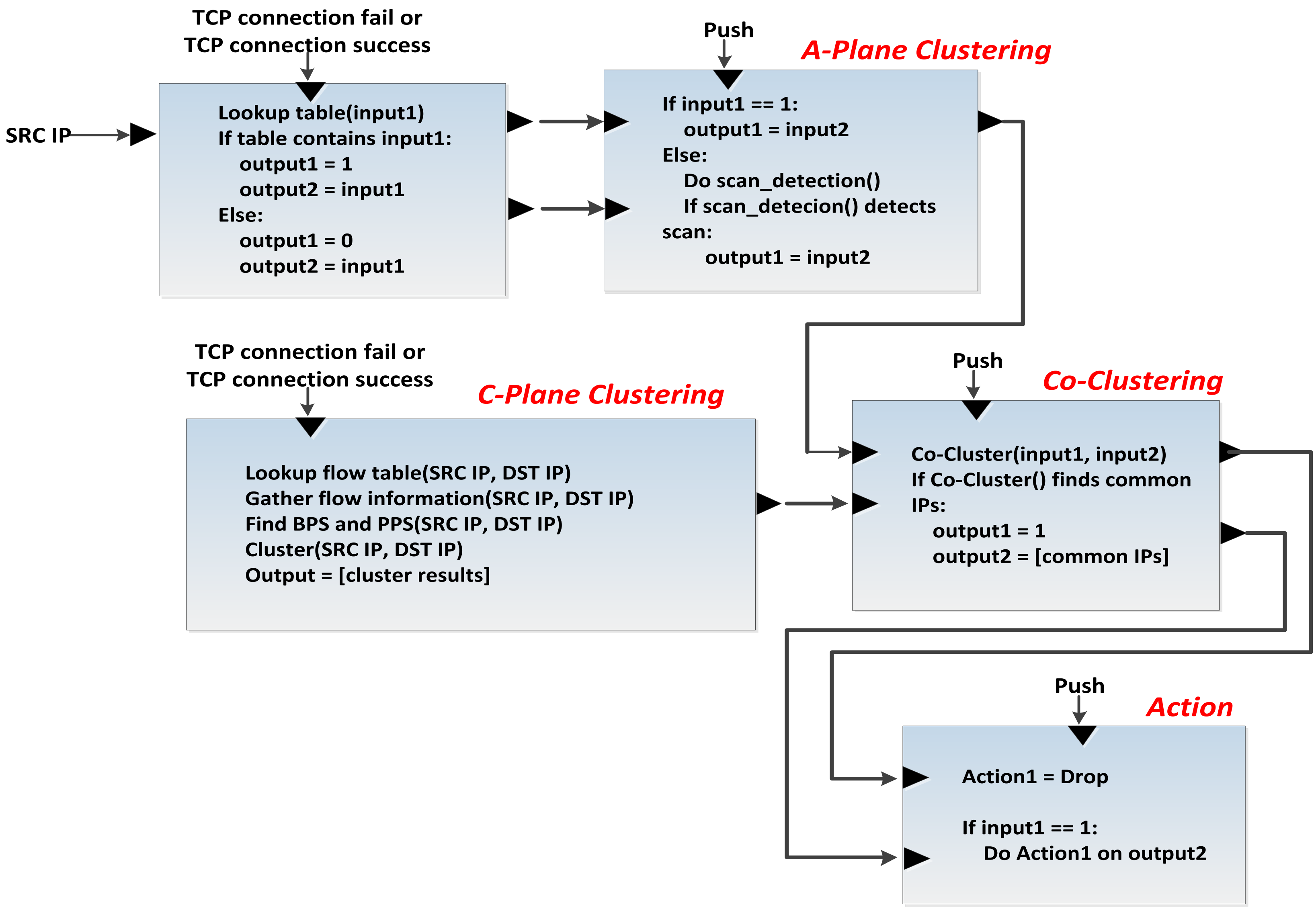
Cooperating with Legacy Security Applications



BotMiner - Overview

- How to detect botnet C&C channels
  - Find C-plane
    - Who is talking to whom?
      - Flow: SRC IP, DST IP, DST Port, Protocol
      - Features
        - » BPS (bytes per second), FPH (flows per hour)
        - » BPP (bytes per packet), PPF (packets per flow)
      - Clustering based on features
  - Find A-plane
    - Who is doing what?
      - Clients perform malicious activities
        - » E.g., scanning, spam activity and etc
      - Clustering based on malicious actions
        - » E.g., scan cluster
  - Co-Clustering
    - Combine results of two clusters to find botnet C&C channels
    - Channels showing similar C-plane patterns and performing malicious actions

BotMiner in FRESCO (Diagram)



BotMiner in FRESCO (Script)

```
BM1 (1) (2) {
  EVENT:TCP_CONNECTION_FAIL,
  TCP_CONNECTION_SUCCESS
  INPUT: Source IP
  OUTPUT: Result, Input1
  PARAMETER: -
  ACTION: -
}
```

```
BM2 (2) (1) {
  EVENT:PUSH
  INPUT:BM1-0, BM1-1
  OUTPUT: Result
  PARAMETER:10
  ACTION: -
}
```

A-Plane Clustering

```
BM3 (0) (1) {
  EVENT:TCP_CONNECTION_FAIL,
  TCP_CONNECTION_SUCCESS
  INPUT: -
  OUTPUT: Result
  PARAMETER: -
  ACTION: -
}
```

C-Plane Clustering

```
BM4 (2) (2) {
  EVENT:PUSH
  INPUT:BM2-0, BM3-0
  OUTPUT: Result1, Result2
  PARAMETER:-
  ACTION: -
}
```

Co-Clustering

```
BM5 (2) (0) {
  EVENT:PUSH
  INPUT:BM4-0, BM4-1
  OUTPUT: -
  PARAMETER:-
  ACTION: BM4-0 == 1 ?Drop
}
```

Action

More …

- Tarpits
- White Holes
- Scan detector
- P2P detector (P2P Plotter)
- Botnet detector (BotMiner)
- …
- Over 90% reduction in lines of code compared with their standard implementations
- Already include more than 16 commonly reusable modules (expending over time)

"FRESCO: Modular Composable Security Services for Software-Defined Networks." NDSS'13

FortNOX:
A Security Enforcement Kernel for OpenFlow

New Threat

- SDN apps can compete, contradict, override one another, incorporate vulnerabilities
- Worst case: an adversary can use a vulnerable and deterministic SDN app to control the state of all SDN switches in the network

SDN/OpenFlow Evasion Scenario

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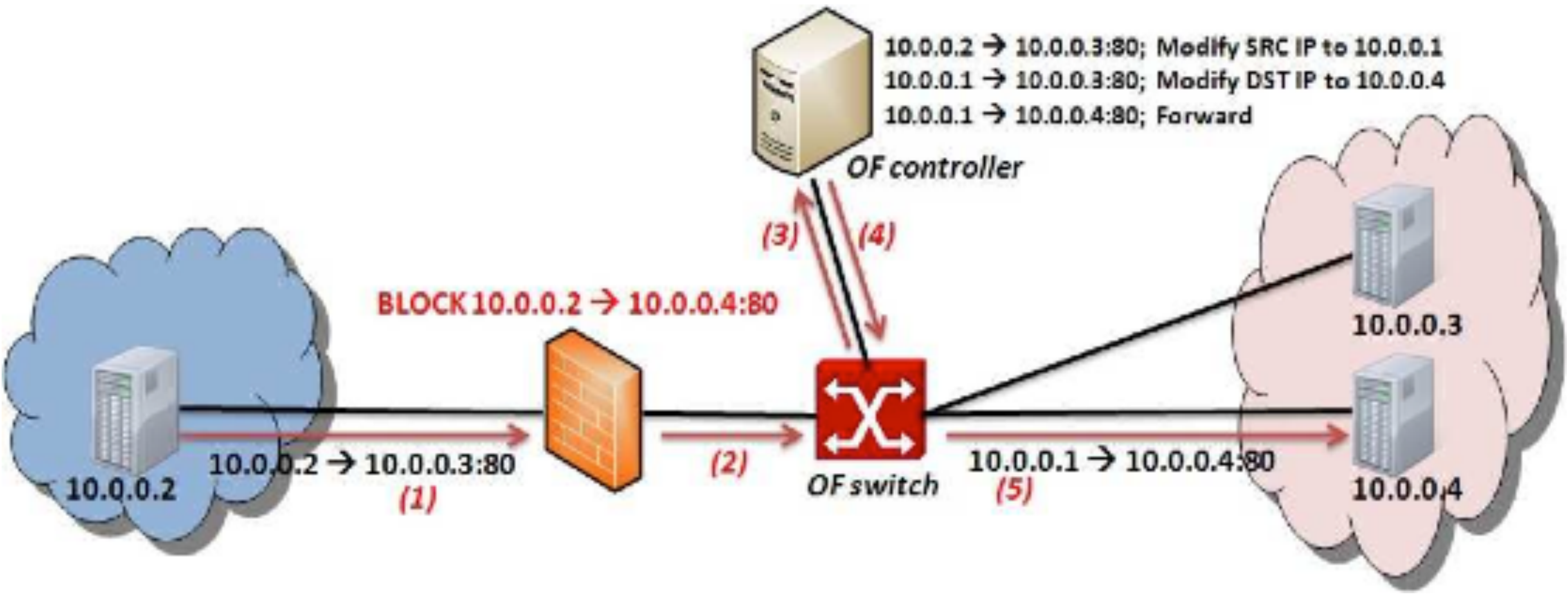
Dynamic Flow Tunneling



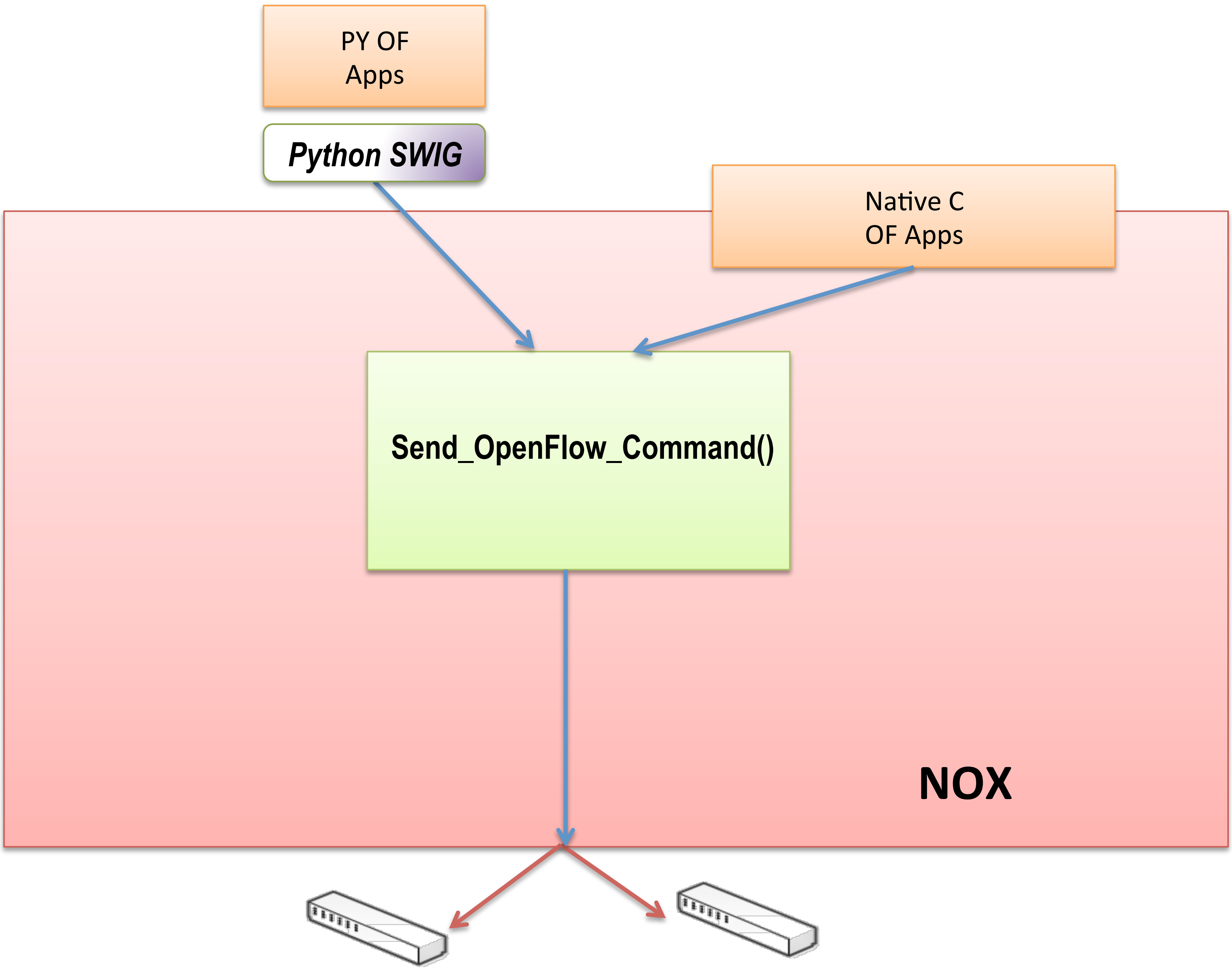
Prerequisites for a Secure OpenFlow Platform

- Must be resilient to
  - Vulnerabilities in OF applications
  - Malicious code in 3rd party OF apps
  - Complex interaction that arise between OF app interactions
  - State inconsistencies due to switch garbage collection or policy coordination across distributed switches
  - Sophisticated OF applications that employ packet modification actions
  - Adversaries who might directly target our security services to harm the network

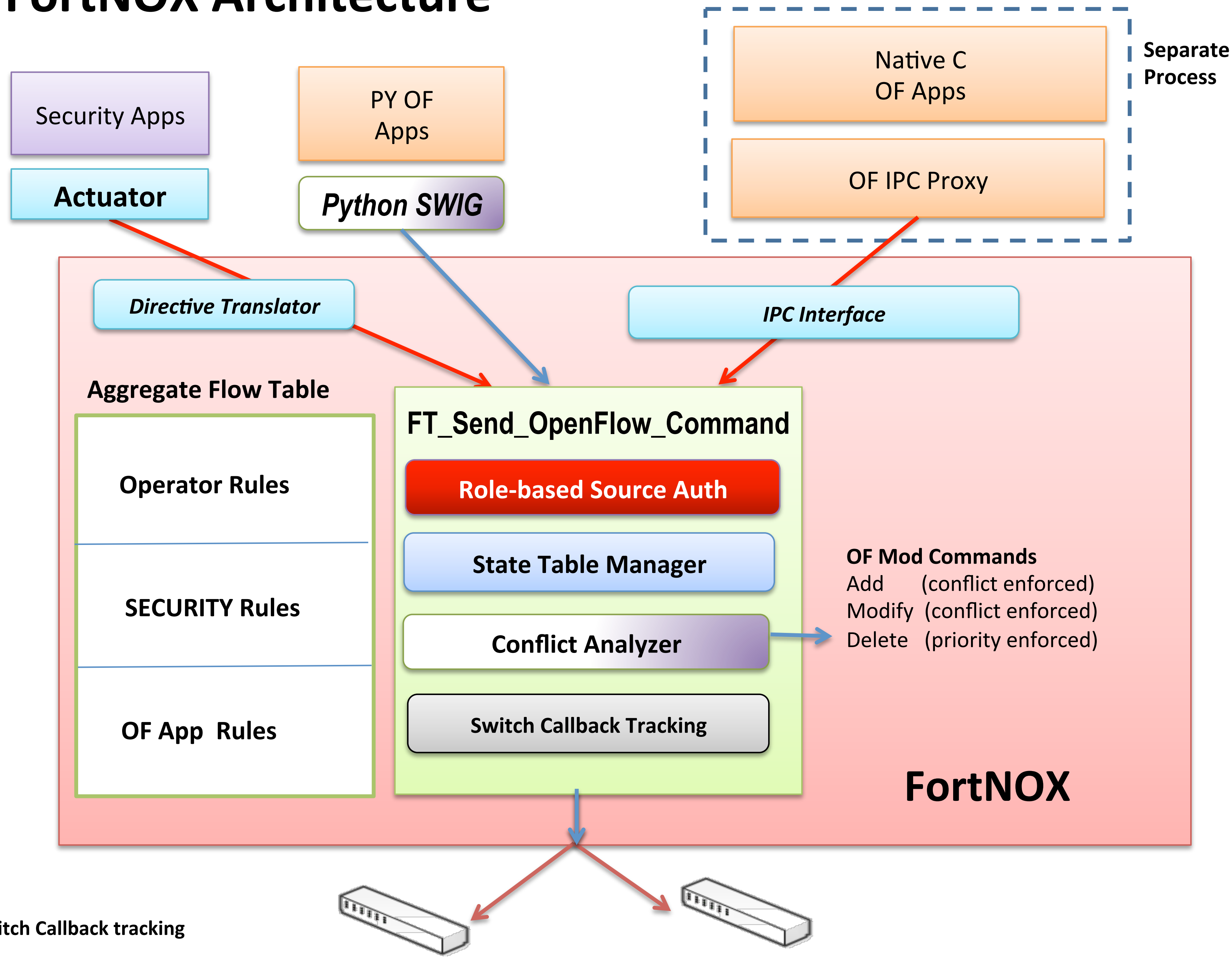
Our Contributions

- Development of a security enforcement kernel for the NOX OpenFlow controller
- Role-based authorization
- Rule conflict detection
- Security directive translation

Classic NOX Architecture



FortNOX Architecture



Switch Callback tracking

Summary of FortNOX

- FortNOX – A new security enforcement kernel for OF networks
  - Role-based Authorization
  - Rule-Authentication
  - Conflict Detection and Resolution
  - Security Directive Translation
- Ongoing Efforts and Future Work
  - Prototype implementations for newer controllers (Floodlight, POX)
  - Security enforcement in multicontroller environments
  - Improving error feedback to OF applications
  - Optimizing rule conflict detection

"A Security Enforcement Kernel for OpenFlow Networks". HotSDN'12

Some Demonstrations

- **www.openflowsec.org**
  - Some technical reports and publications
  - DEMO videos
    - Demo 1: **Constraints Enforcement** [high res .mov or Youtube!]
    - Demo 2: **Reflector Nets** [high res .mov or Youtube!]
    - Demo 3: **Automated Quarantine** [high res .mov or Youtube!]
  - FRESCO/FortNOX beta to be released soon

CloudWatcher:
Network Security Monitoring Using OpenFlow in Dynamic Cloud Networks

or: How to Provide Security Monitoring as a Service in Clouds?

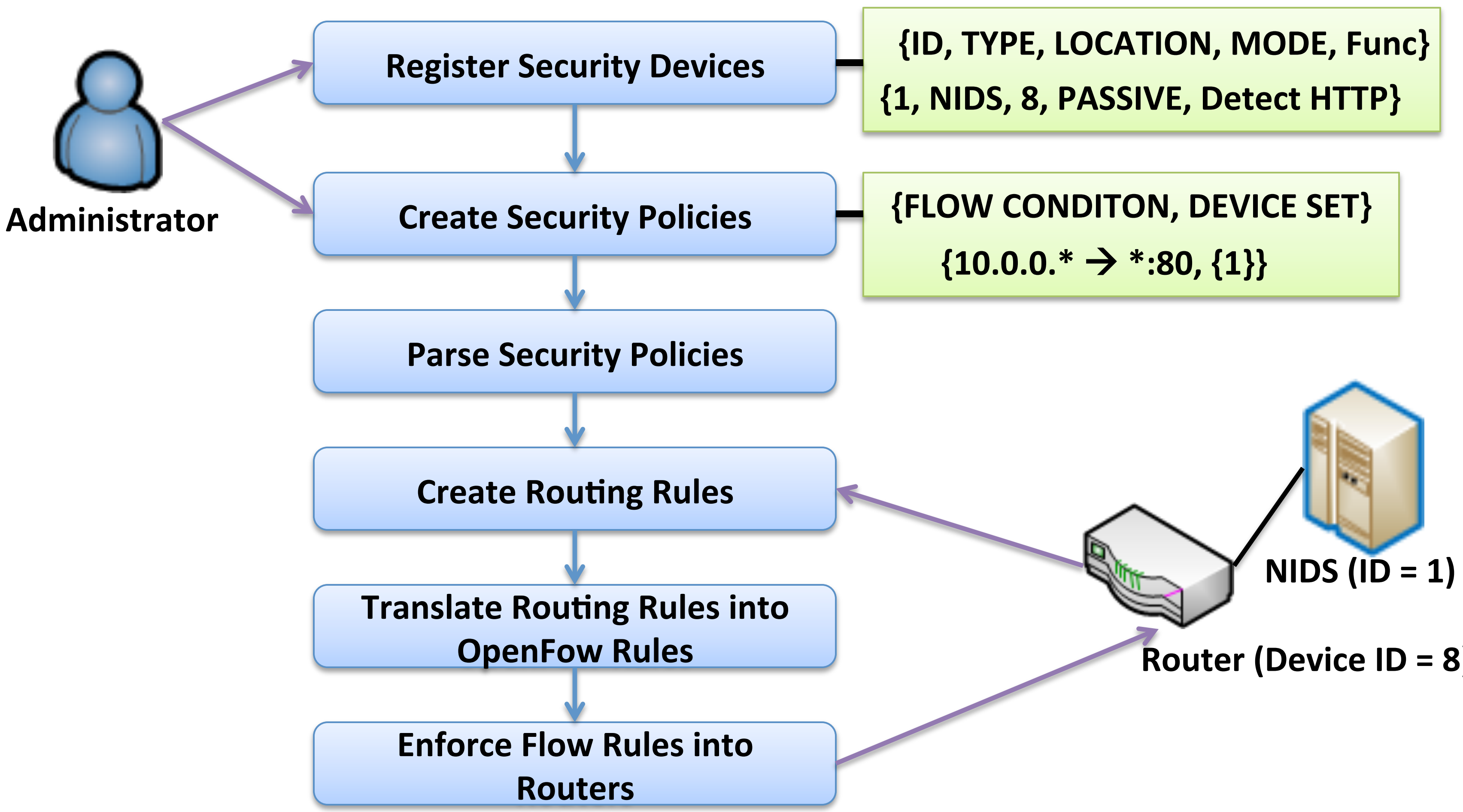
Goal

- Provide **Security Monitoring as a Service** for a cloud network
- How to Provide
  - Routing algorithms
    - The algorithms guarantee that specified (static) network security devices can monitor (dynamic) specific network flows
  - A script language
    - Register security devices easily
    - Create security policies easily

CloudWatcher

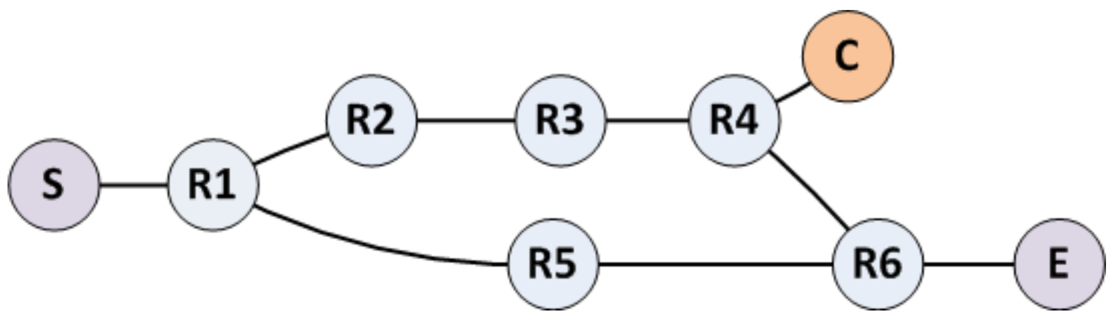
- A new framework
  - Provide **security monitoring services** for large and dynamic cloud networks
  - Detour network packets to be inspected by pre-installed network security devices automatically
    - **OpenFlow**
  - Provide a script to operate this framework

Operating Scenario



How to Control Flows

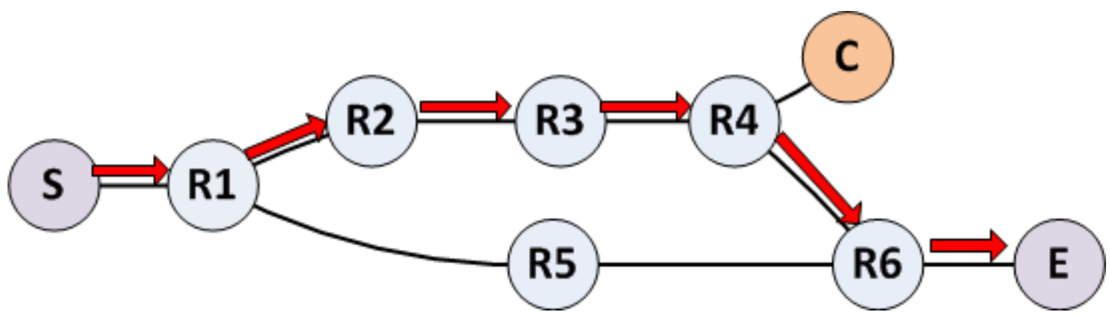
- 4 approaches
  - Multipath naïve
  - Shortest through
  - Multipath shortest
  - Shortest inline



- Sample network -
S: start node, E: end node
R: router, C: security device

Selected Controlling Algorithm Example: Shortest Through

- Find the shortest path passing through R4
  - Shortest path between S and R4
  - Shortest path between R4 and E
  - Path: S → R1 → R2 → R4 → R4 → R6 → E



- It considers the security device without producing redundant paths
- However, it may take more time to deliver packets

Summary of CloudWatcher

- CloudWatcher provides a new framework to monitor cloud networks
  - With the help of the SDN technology
- A cloud administrator can select algorithms based on network status
- A cloud administrator can monitor his network by writing simple scripts

- Work in progress; a position paper in NPSec'12

Summary of This Talk

- SDN is a new technology, and security can be a new killer app
  - SDN is impactful to drive a variety of innovations in network security
- We investigate the possibilities of security as an app and security as a service
- We propose key technologies to enable SaaA and SaaS
  - FRESCO
  - FortNOX
  - CloudWatcher
- Let's contribute together to SDN and Security!

Questions & Answers

Http://faculty.cse.tamu.edu/guofei