Enabling Practical SDN Security Applications with OFX (The **O**pen**F**low e**X**tension Framework)

John Sonchack, Adam J. Aviv,
Eric Keller, and Jonathan M. Smith

Outline

Introduction

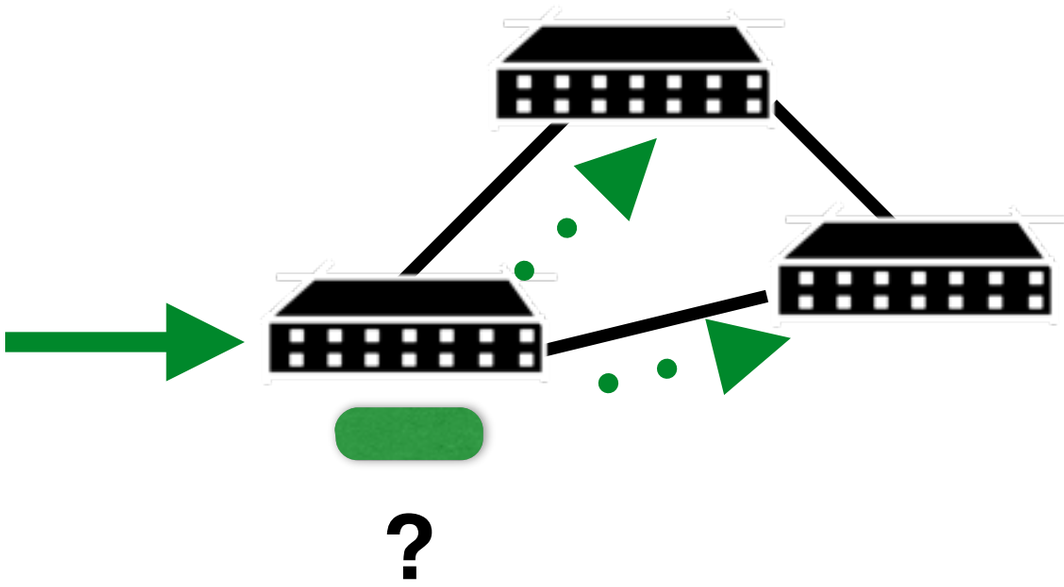
Overview of OFX

Using OFX

Benchmarks

Basic Networking: Forwarding and Routing

Packet Forwarding



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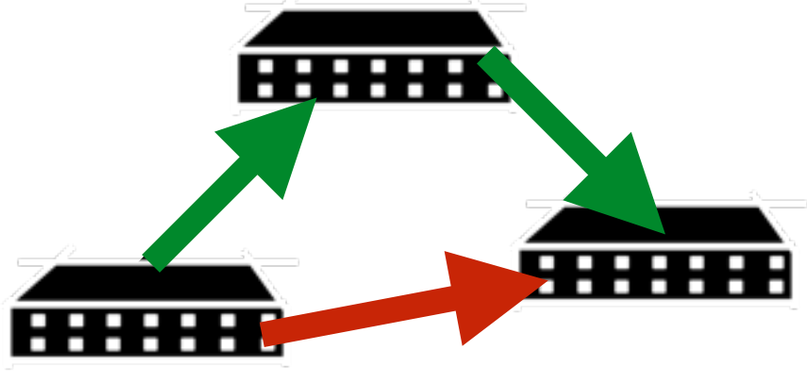
Route Computation

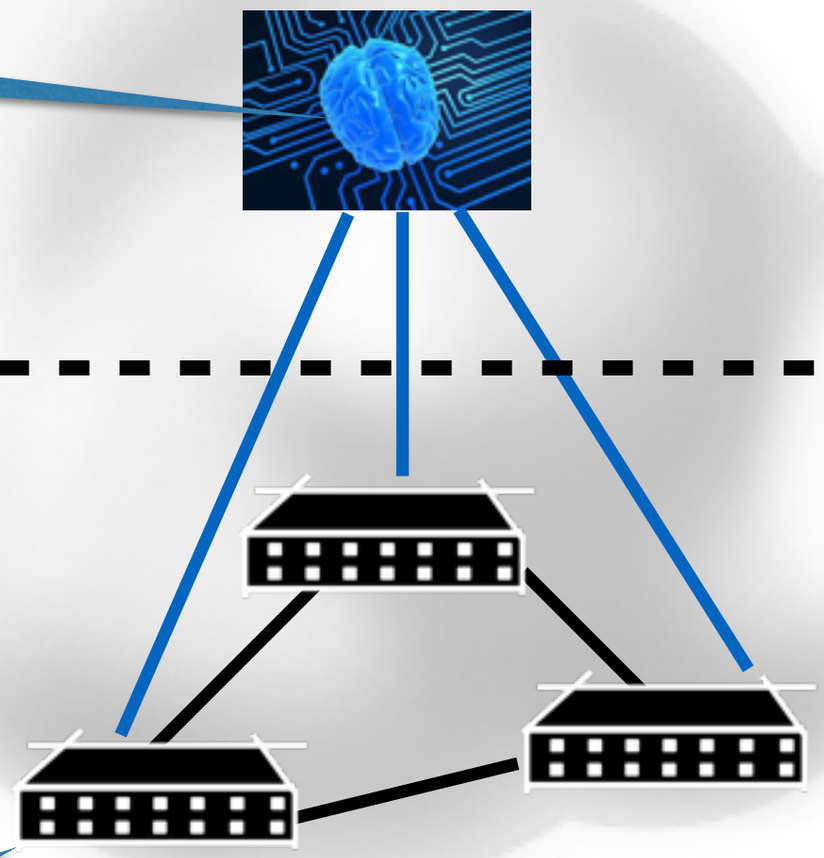


SDNs: Networking in Two Planes

Route computation

OpenFlow

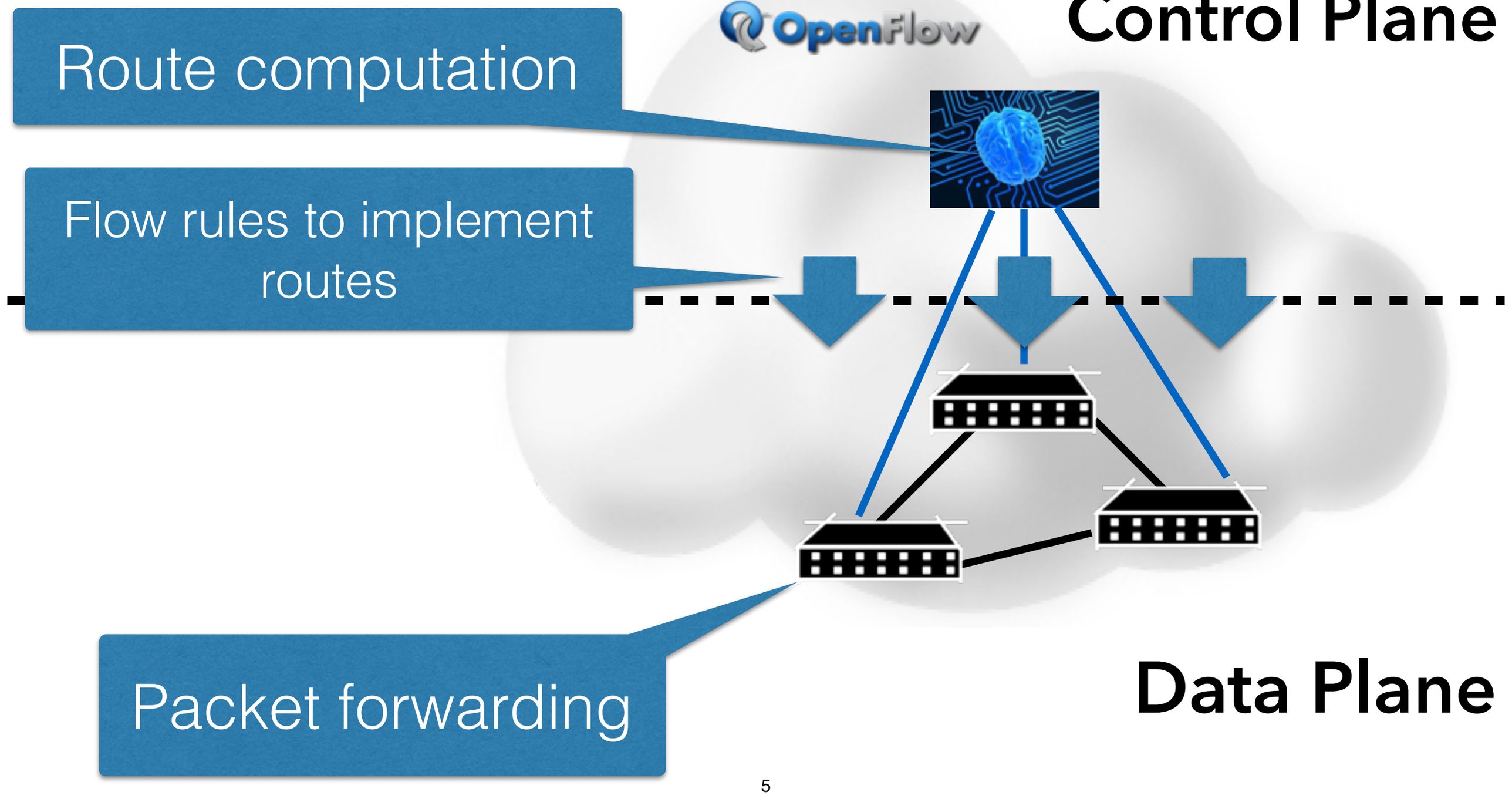
Control Plane



Packet forwarding

Data Plane

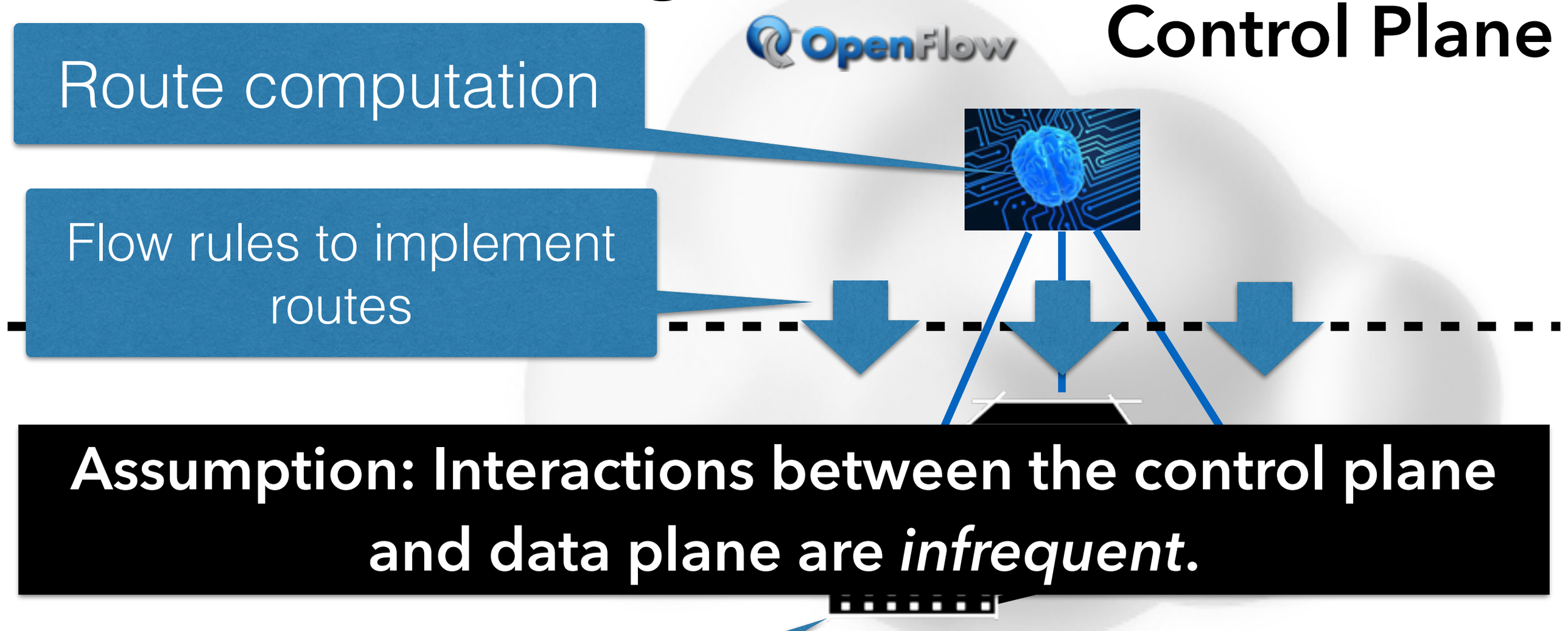
OpenFlow: A Protocol to Manage Switches



OpenFlow: A Protocol to Manage Switches

Route computation

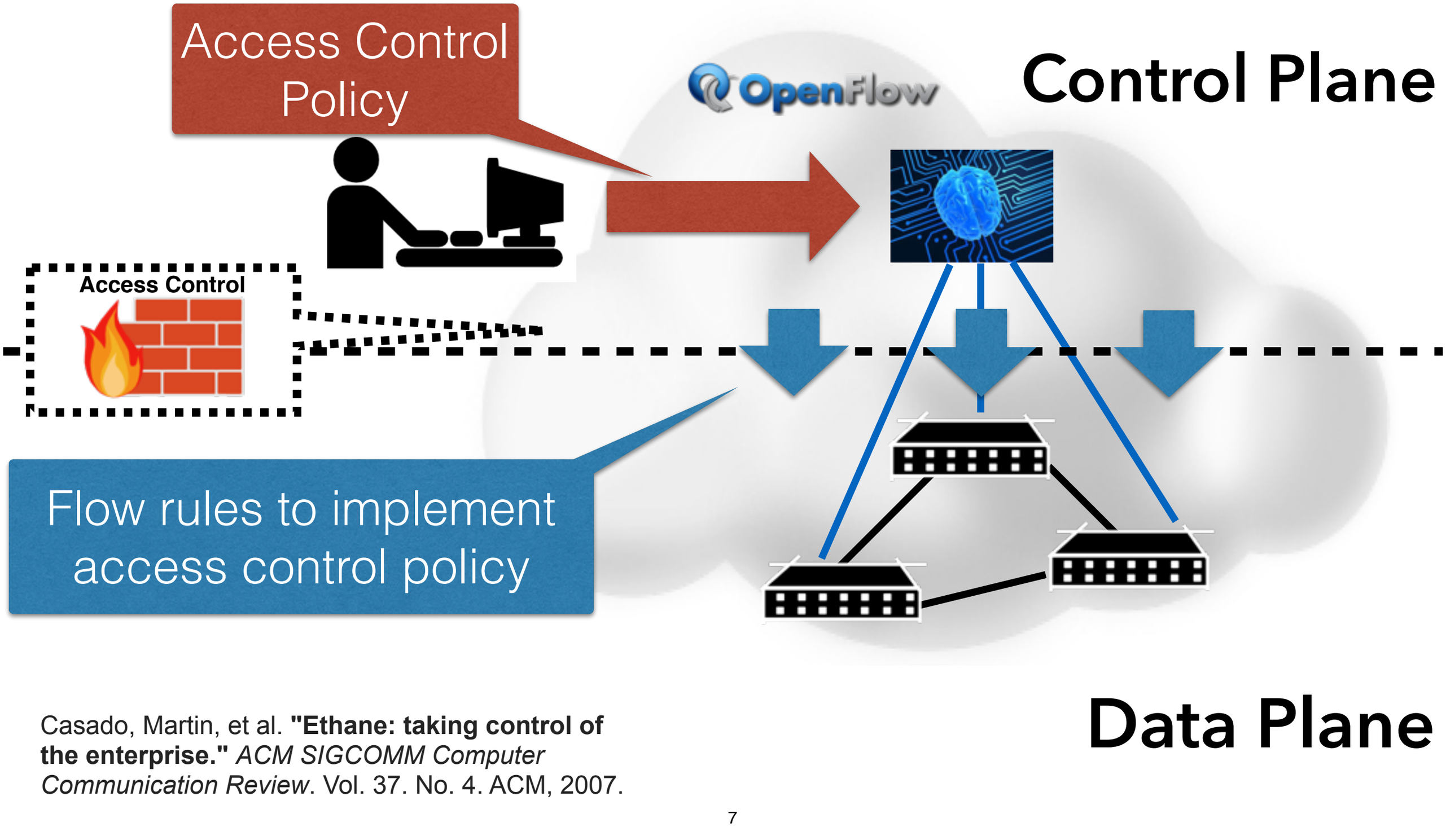
Flow rules to implement routes



Assumption: Interactions between the control plane and data plane are *infrequent*.

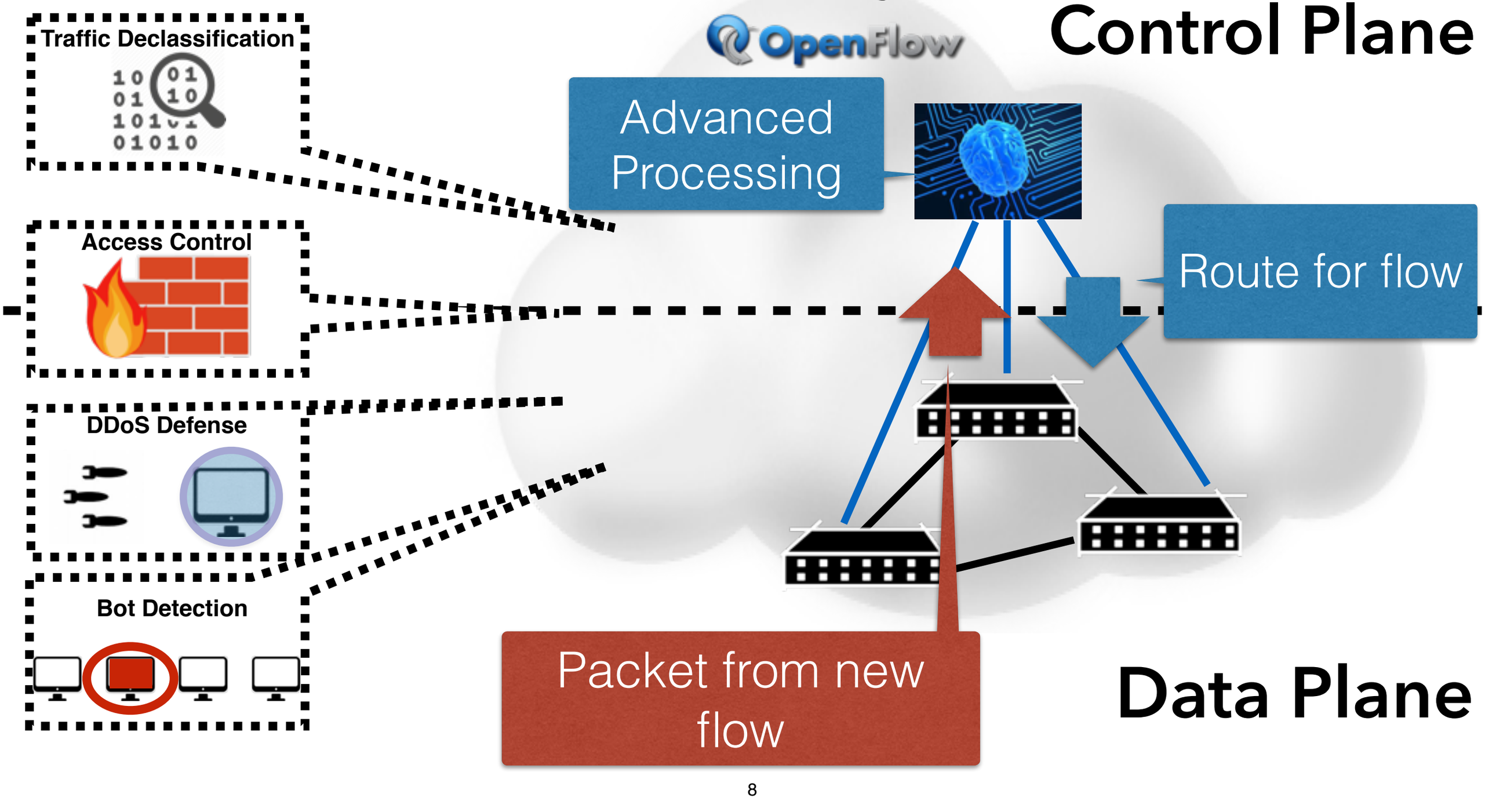
Packet forwarding

SDNs for Network Security



Casado, Martin, et al. **"Ethane: taking control of the enterprise."** *ACM SIGCOMM Computer Communication Review*. Vol. 37. No. 4. ACM, 2007.

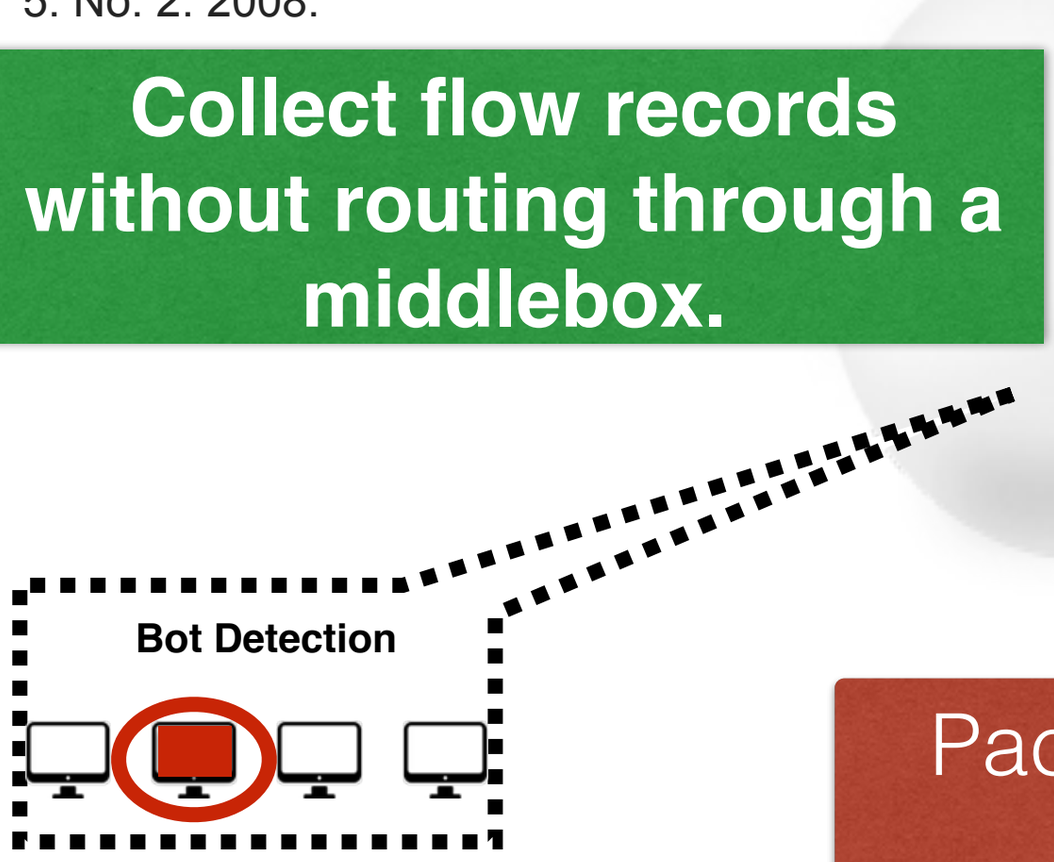
SDNs for **Dynamic** Network Security

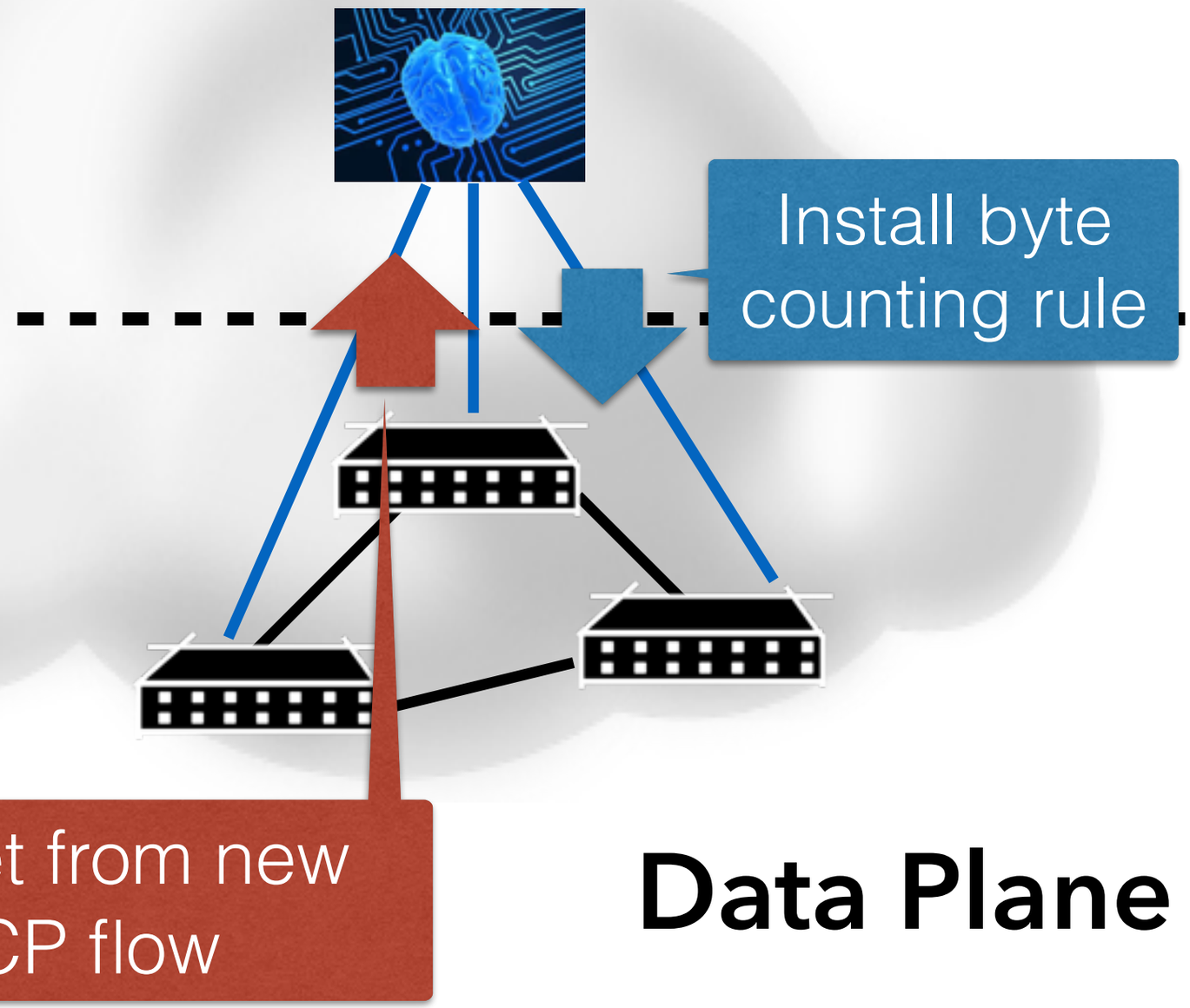


SDNs for **Dynamic** Network Security: Flow Monitoring

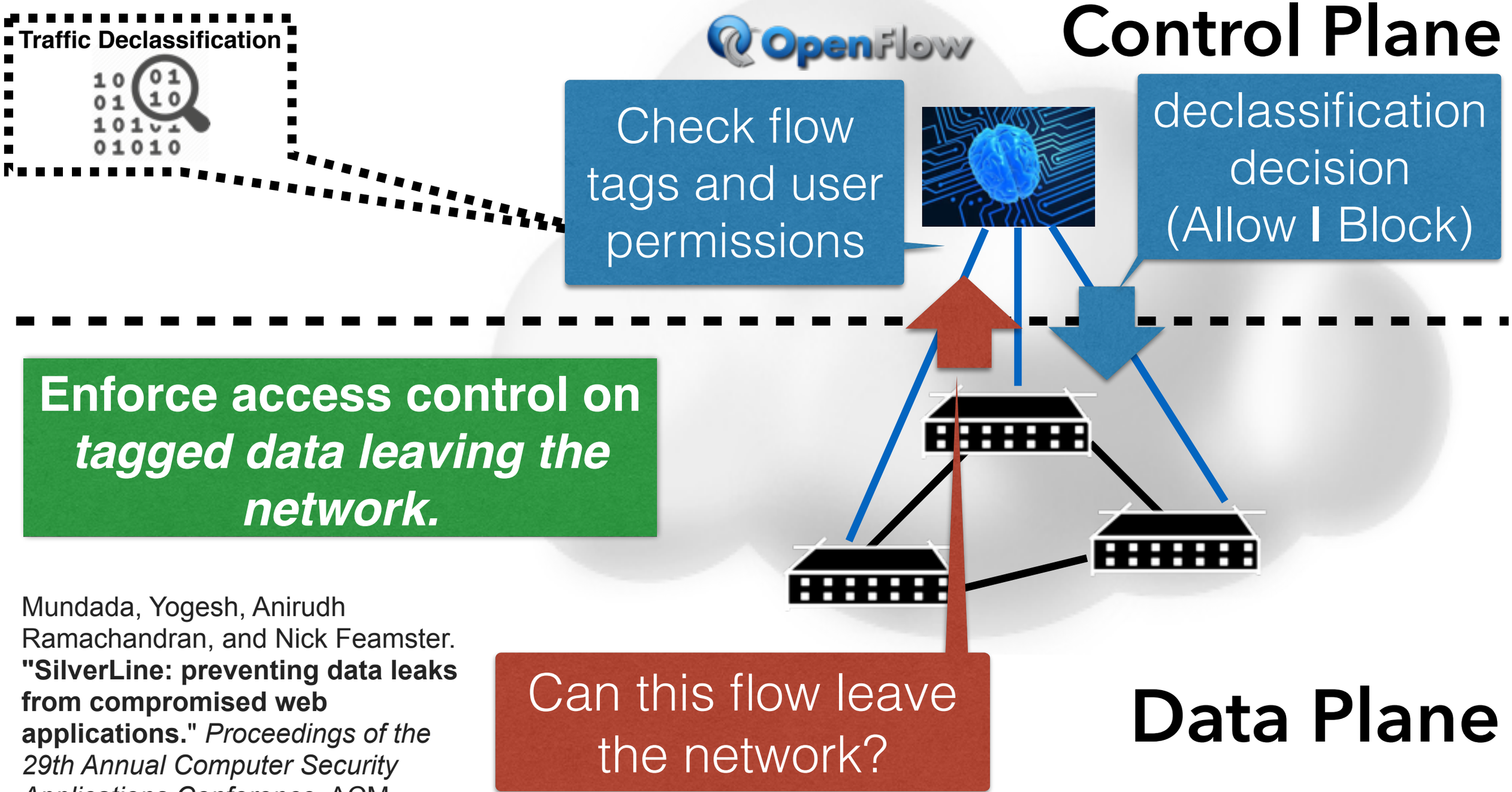
Gu, Guofei, et al. "**BotMiner: Clustering Analysis of Network Traffic for Protocol-and Structure-Independent Botnet Detection.**" *USENIX Security Symposium*. Vol. 5. No. 2. 2008.

Collect flow records without routing through a middlebox.





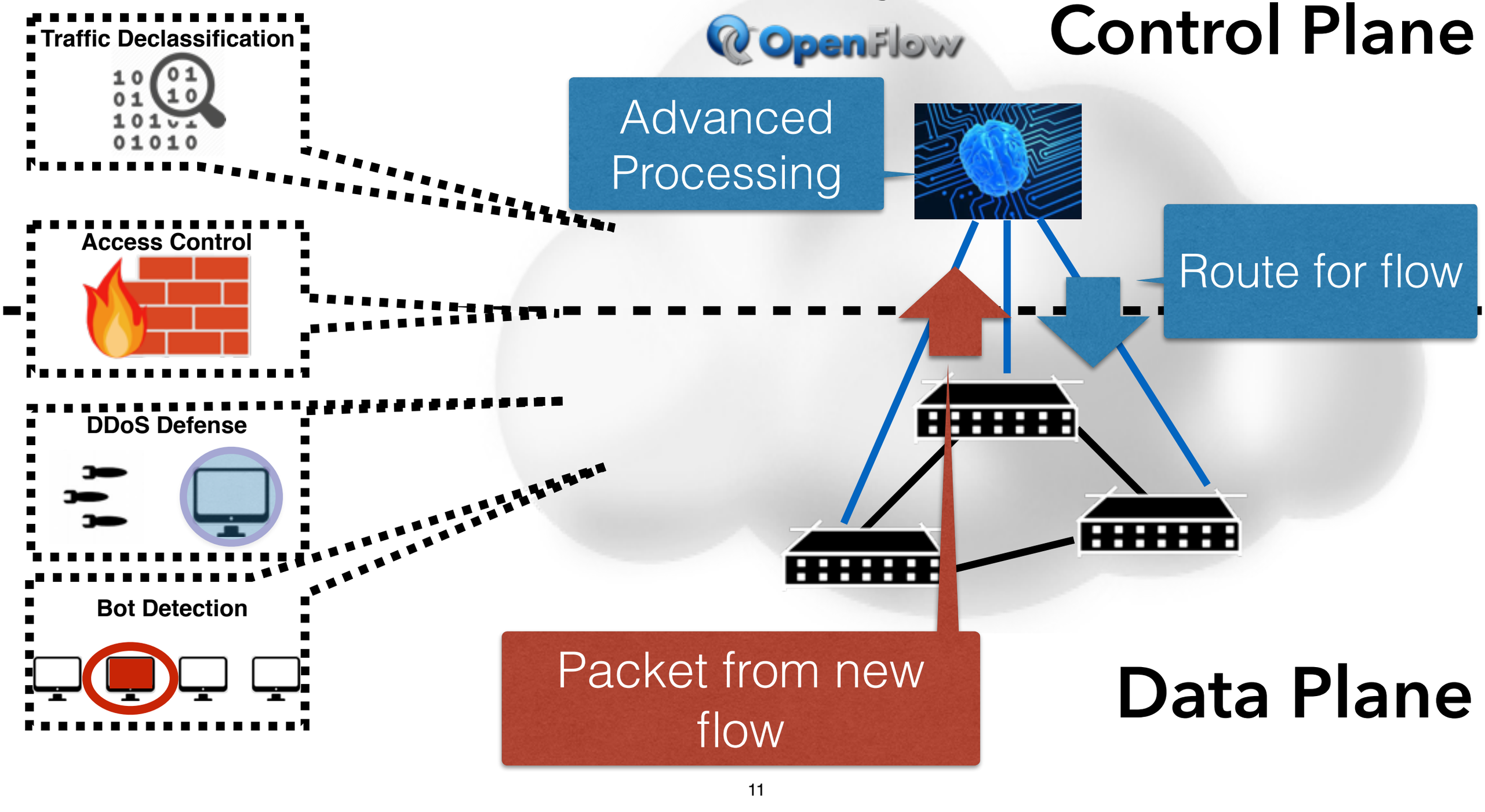
SDNs for **Dynamic** Network Security: Traffic Declassification



Enforce access control on *tagged data leaving the network.*

Mundada, Yogesh, Anirudh Ramachandran, and Nick Feamster. **"SilverLine: preventing data leaks from compromised web applications."** *Proceedings of the 29th Annual Computer Security Applications Conference*. ACM, 2013.

SDNs for **Dynamic** Network Security



SDNs for **Dynamic** Network Security

Control Plane

OpenFlow

Advanced Processing

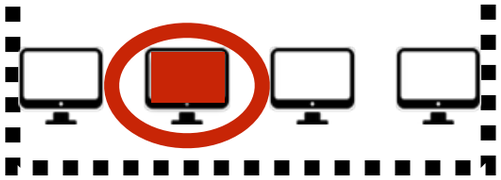
Route for flow

Traffic Declassification

Access Control

Assumption: Interactions between the control plane and data plane are *infrequent*.

Bot Detection



Packet from new flow

Data Plane

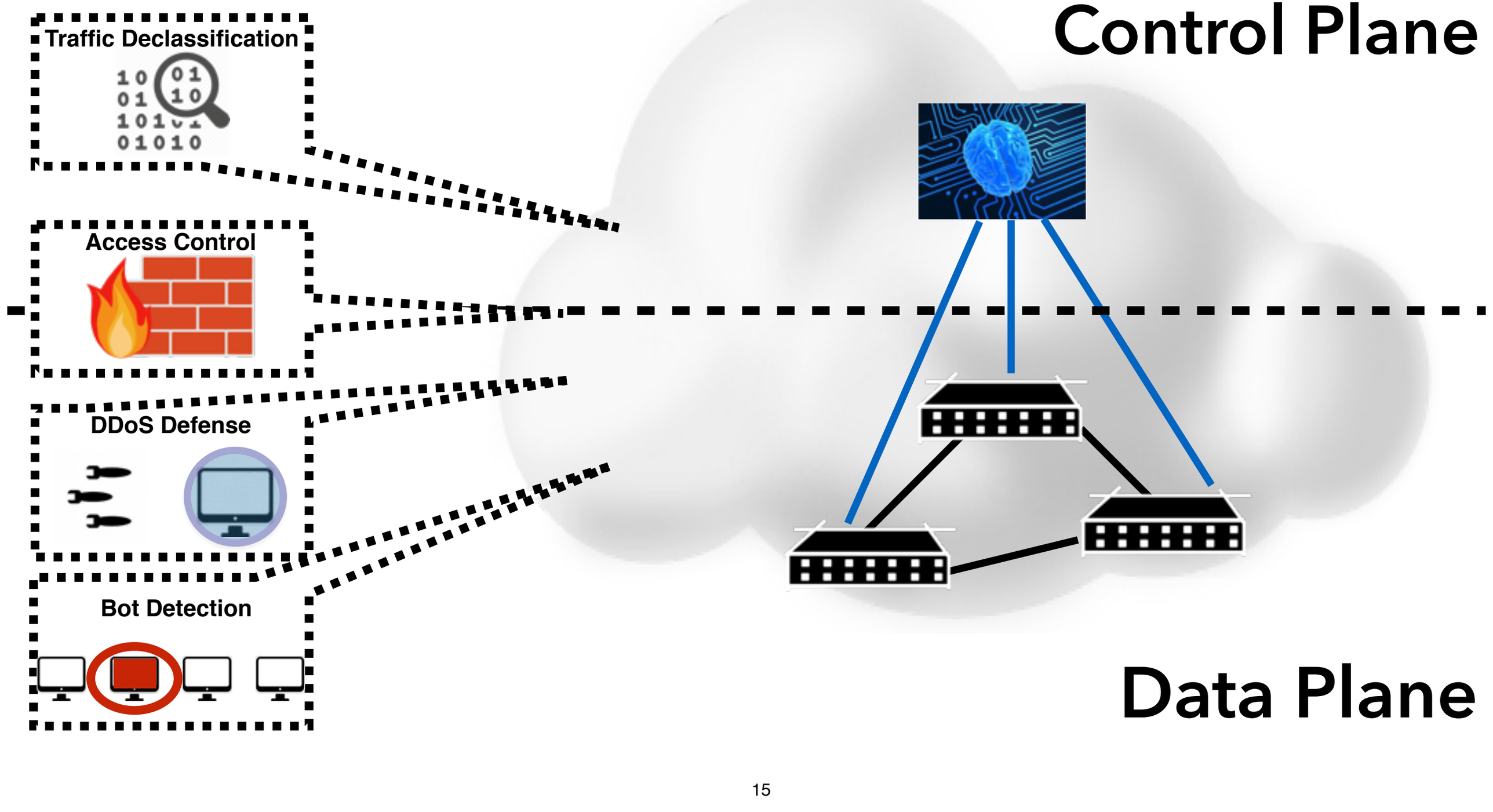
Obstacle: Low Throughput Control Path

Appelman, Michiel, and Maikel de Boer. **"Performance analysis of OpenFlow hardware."** *University of Amsterdam, Tech. Rep* (2012).

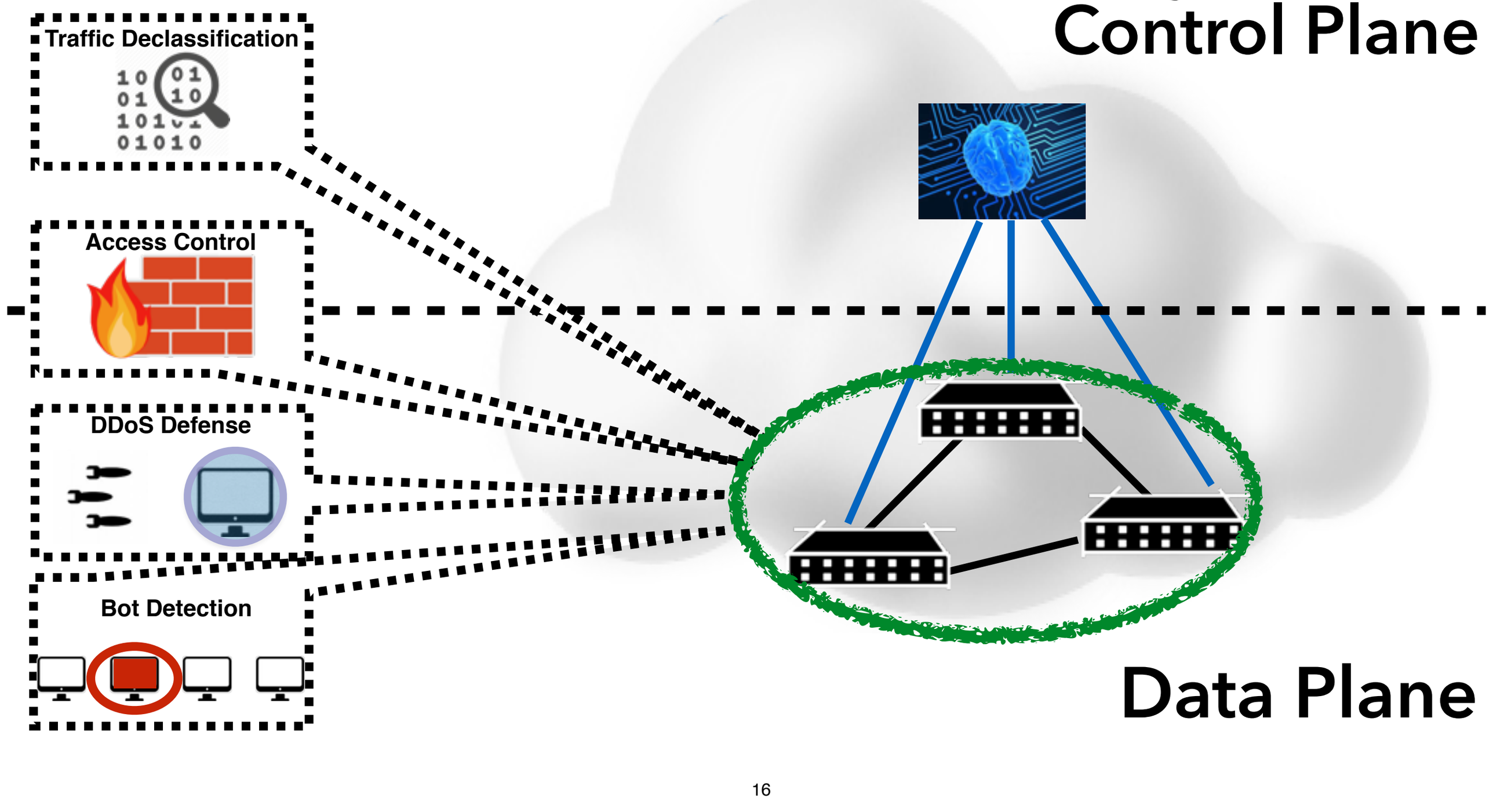
Curtis, Andrew R., et al. **"DevoFlow: scaling flow management for high-performance networks."** *ACM SIGCOMM Computer Communication Review*. Vol. 41. No. 4. ACM, 2011.

Obstacle: Centralized Control Plane

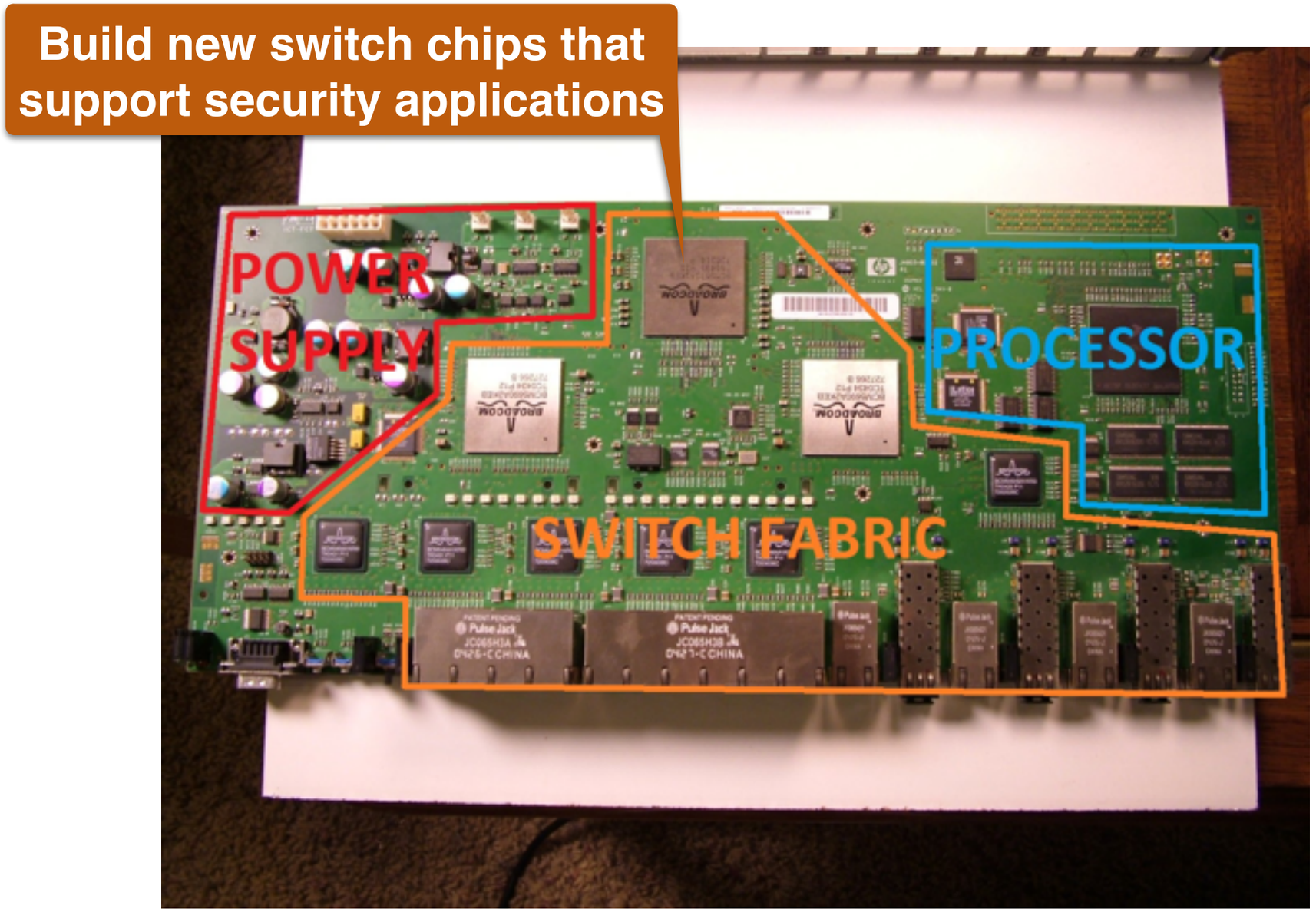
Our question: How Can We Make SDNs More Practical?



The General Approach: Switch Level Security

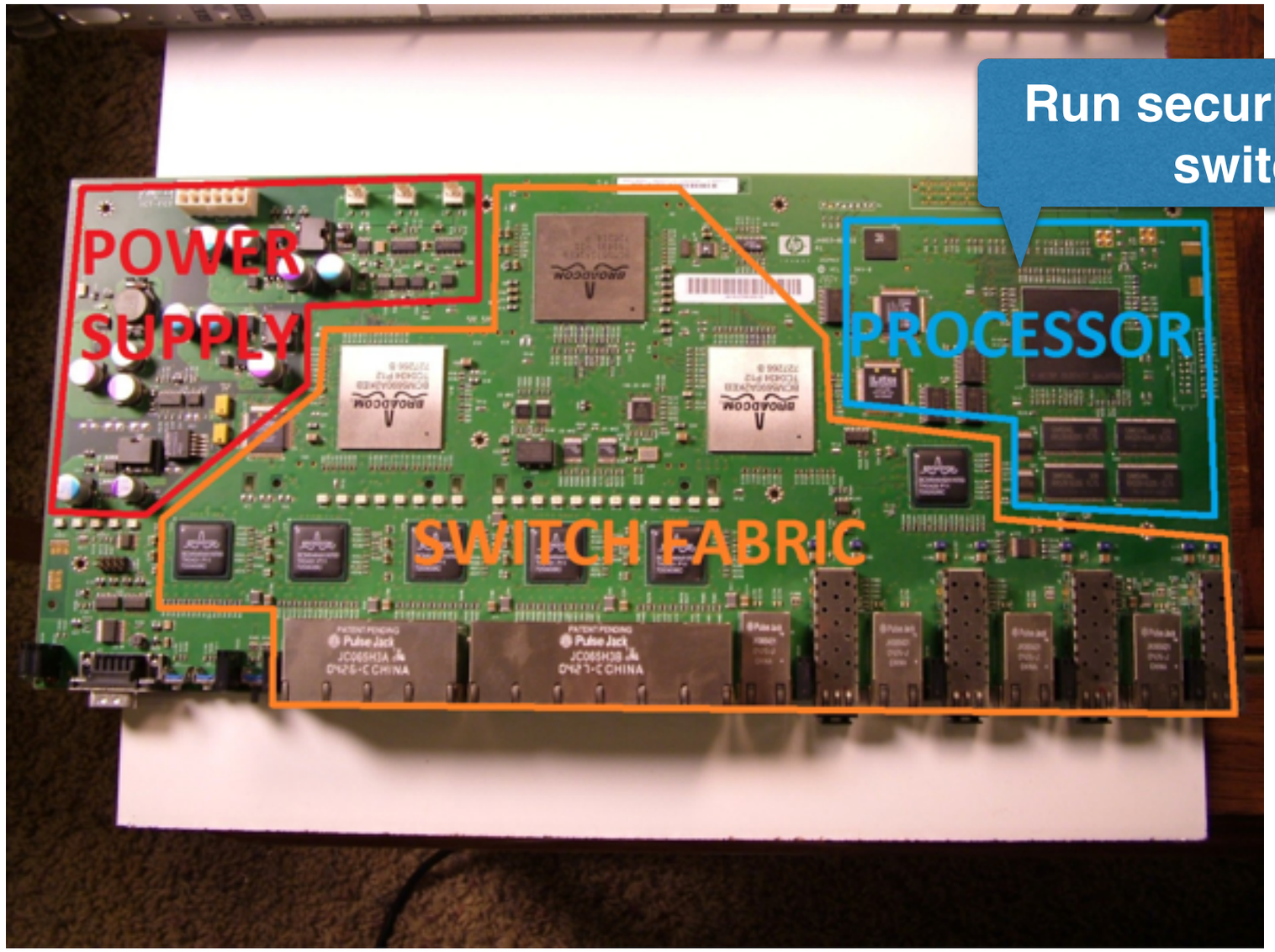


Previous Work: Security Functionality in the Forwarding Engine



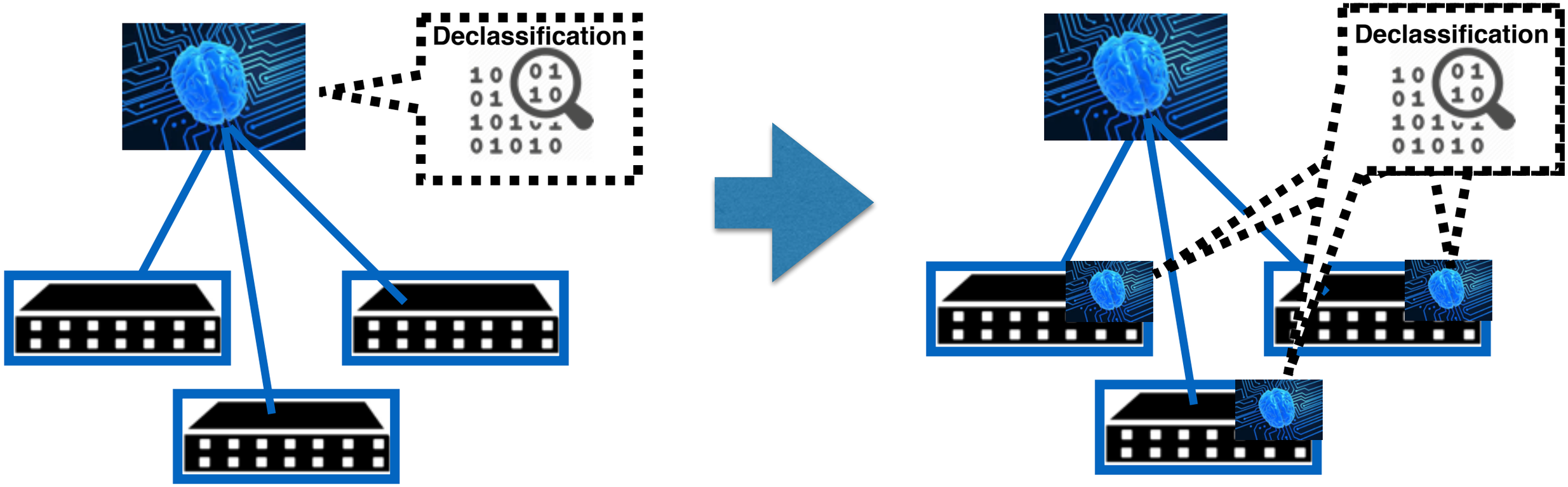
Shin, Seungwon, et al. **"Avant-guard: Scalable and vigilant switch flow management in software-defined networks."** *Proceedings of the 2013 ACM SIGSAC conference on Computer & communications security*. ACM, 2013.

Our insight: Leverage Switch CPUs



OFX: A Framework for Application-Specific Switch Extensions

Each application can load custom functionality into switches. At runtime!



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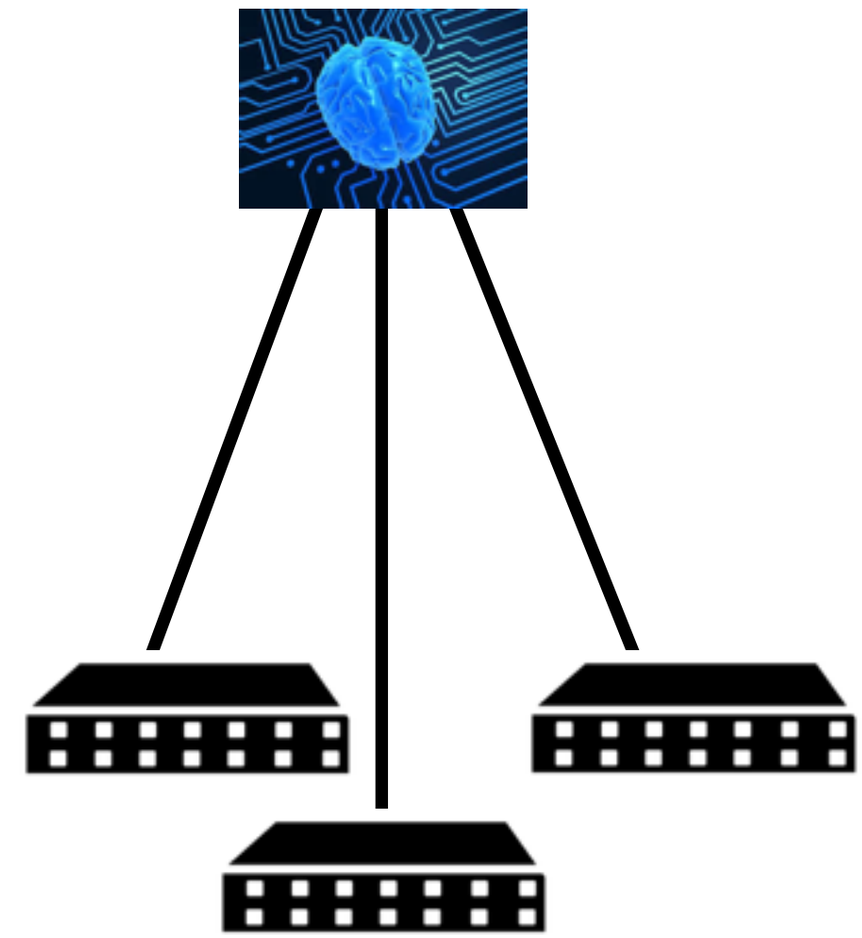
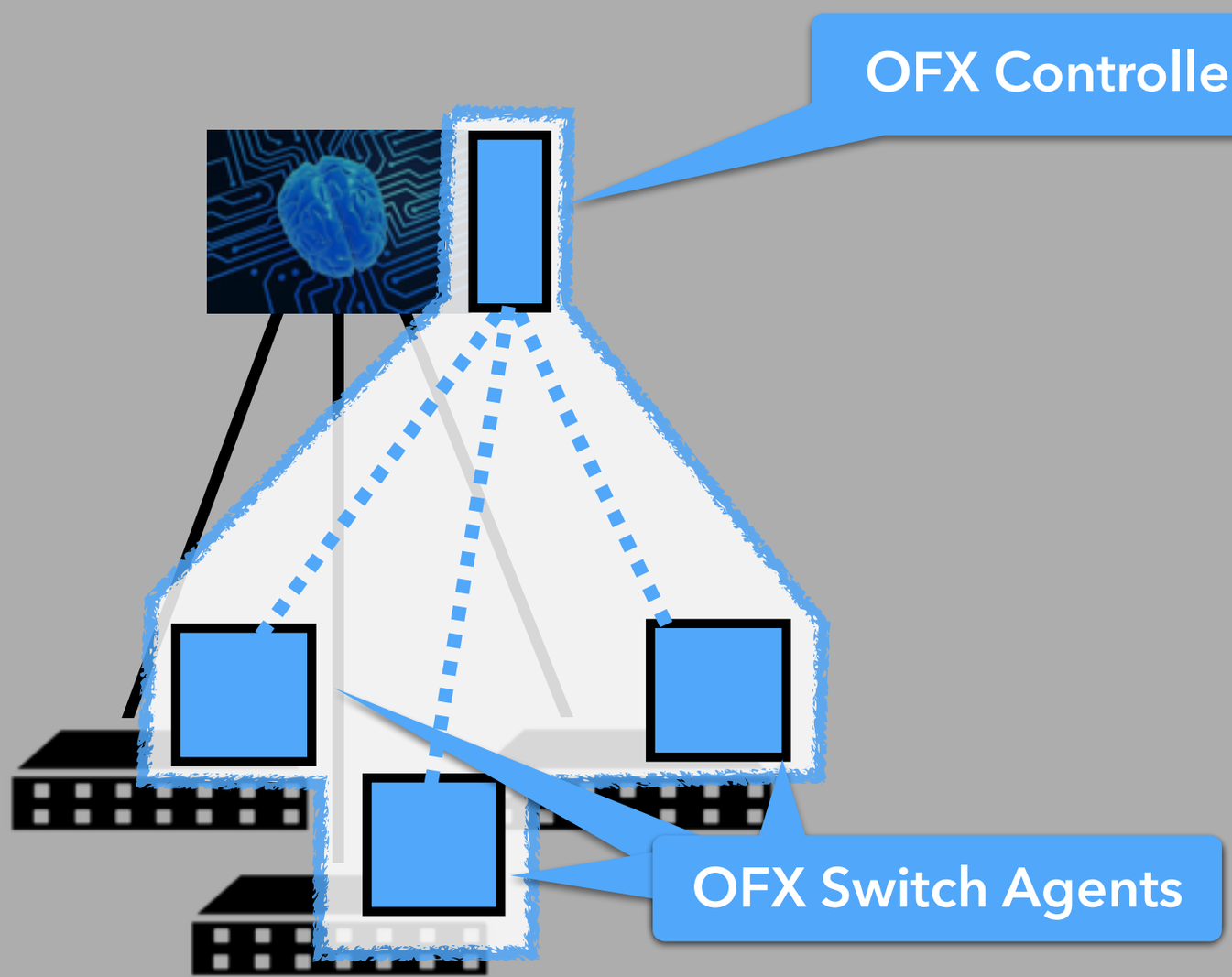
OFX at a High Level



OpenFlow stack

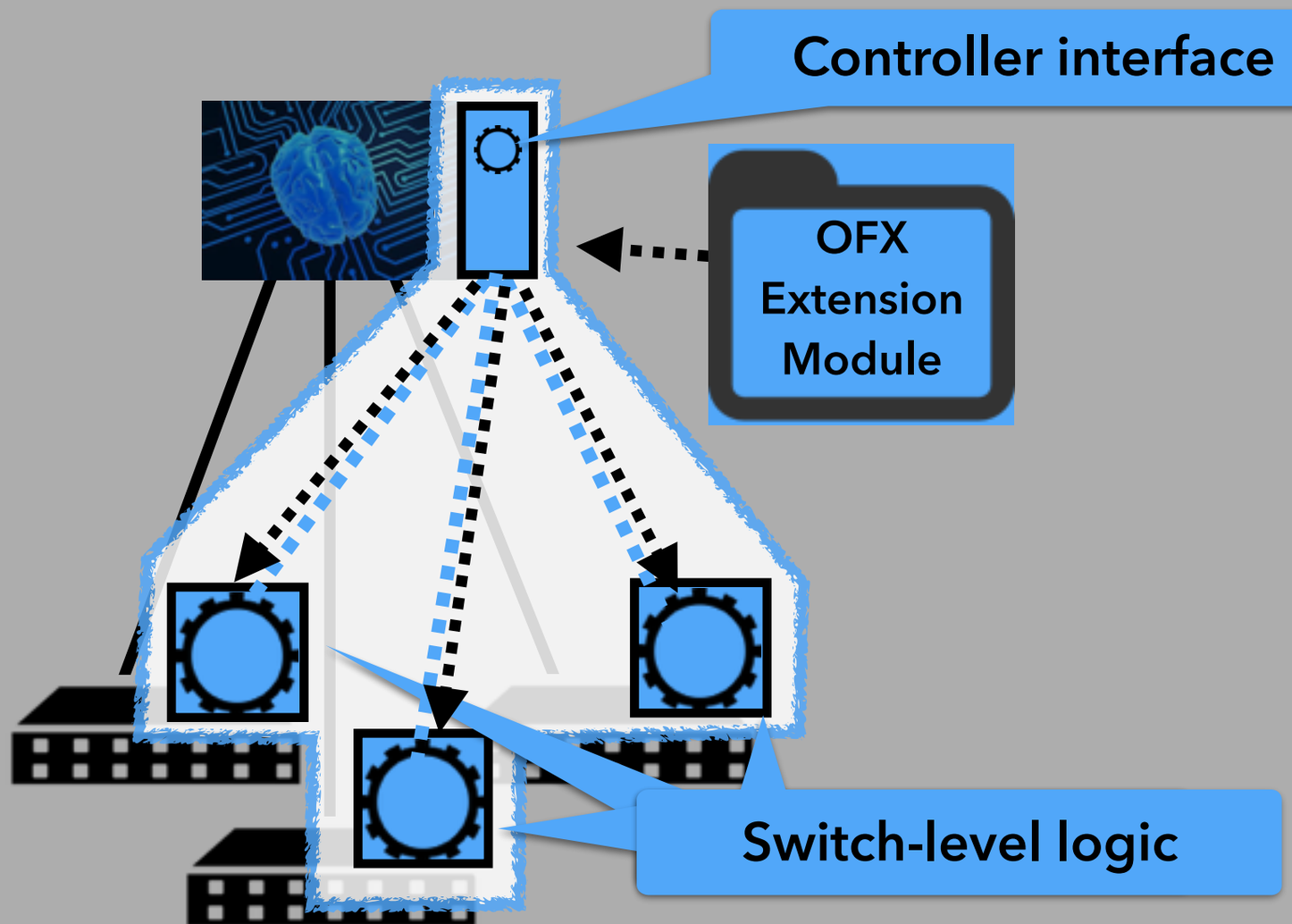
OFX at a High Level



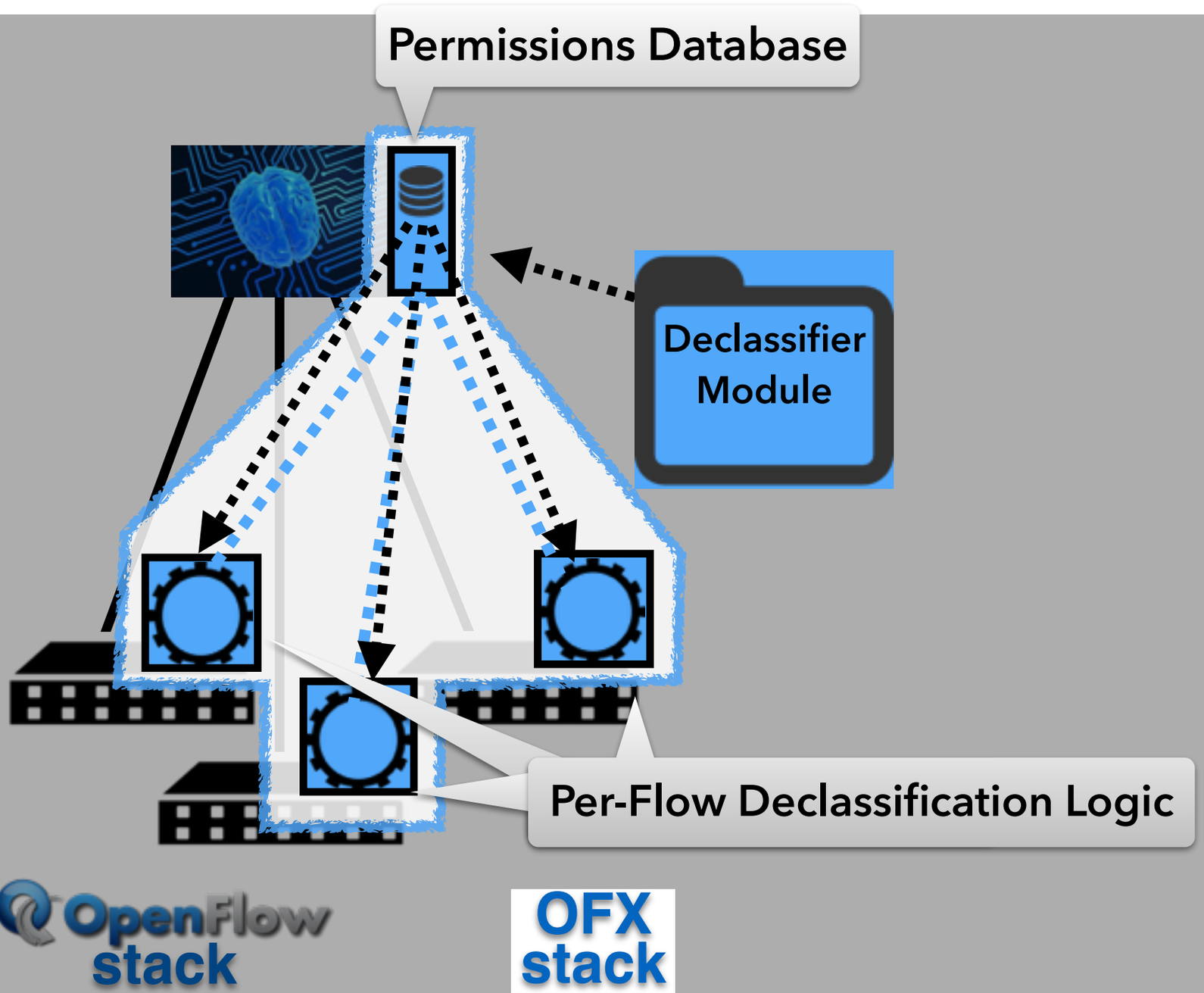
OpenFlow stack

OFX stack

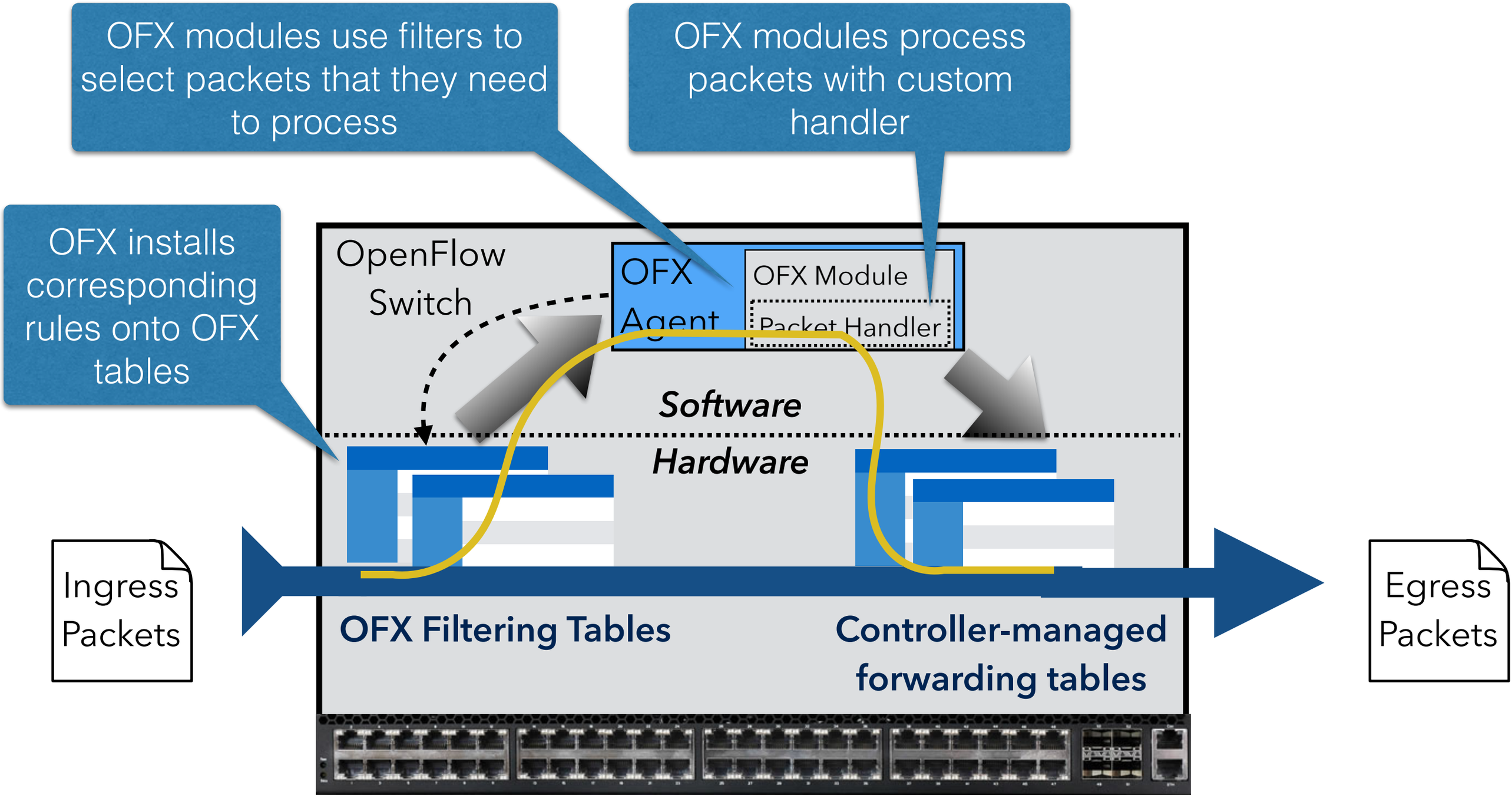
OFX at a High Level



OFX at a High Level



OFX at the Switch Level



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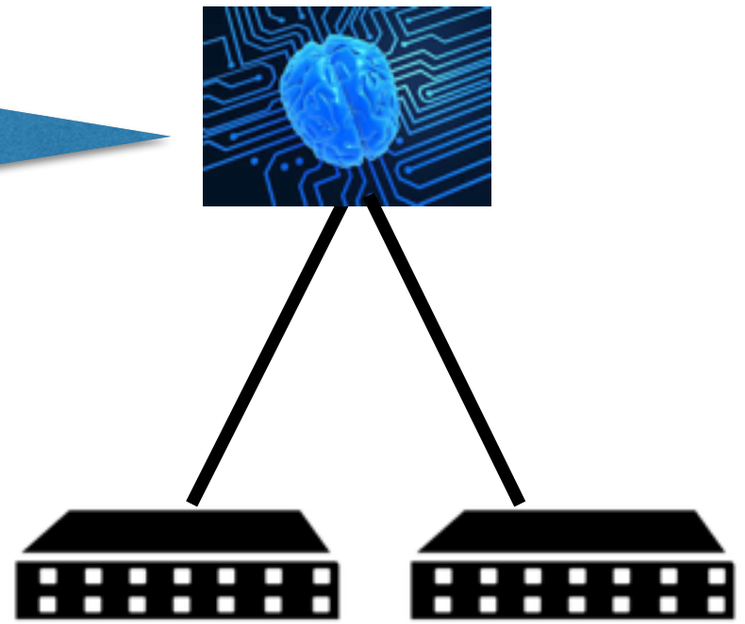
Refactoring OpenFlow Applications to use OFX

```
class DeclassifierApp(app_manager.RyuApp):

    def __init__(self, *args, **kwargs):
        super(SimpleSwitch13, self).__init__(*args, **kwargs)
        self.permissionsDb = dbServer.connect()
        self.monitoredServers = []
        self.switchIds = []

    def switch_up_handler(self, switch):
        self.switchIds.append(switch.id)
        ...

    def packet_handler(self, switch, pkt):
        action = self.compute_next_hop(pkt, switch)
        if pkt.src in self.monitoredServers:
            permission = check_permission(pkt)
            if permission:
                switch.send_packet(pkt, action)
                switch.add_flow(pkt.src, pkt.dst, action)
            else:
                resetPkt = build_reset(pkt)
                switch.send(resetPkt)
                switch.add_flow(pkt.src, pkt.dst, DROP)
        else:
            switch.send_packet(pkt, action)
            ...
```



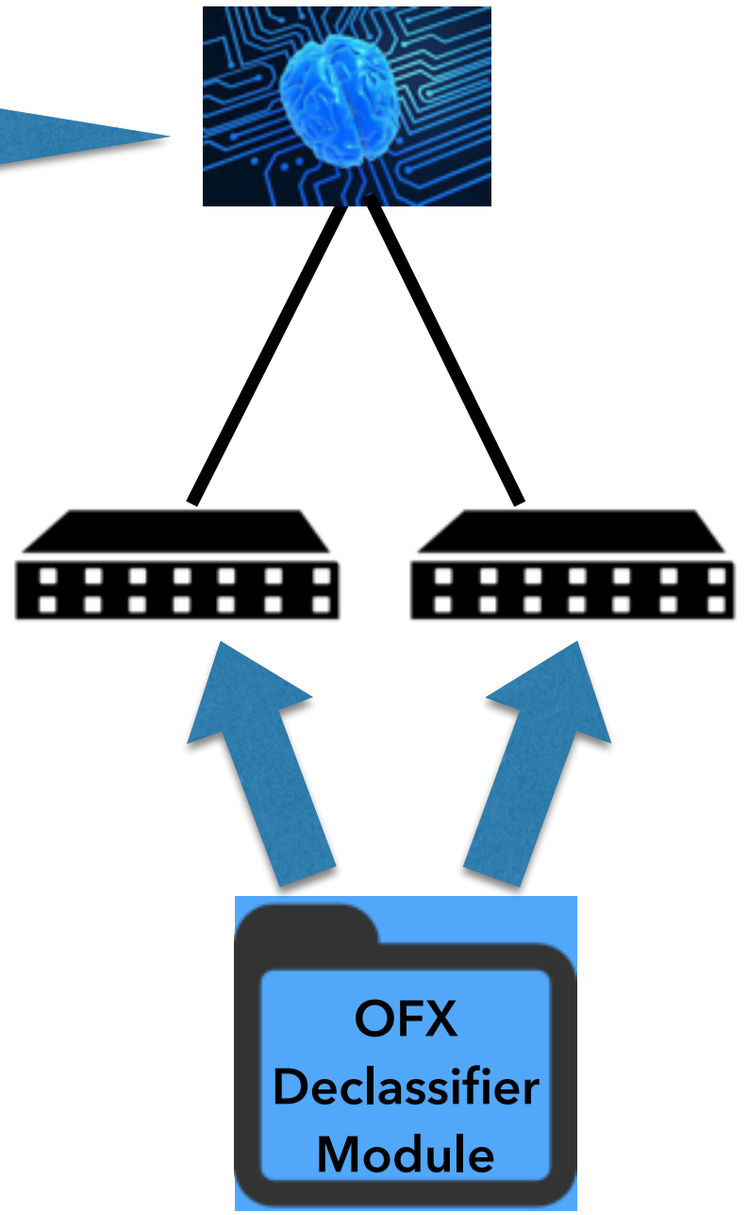
Refactoring OpenFlow Applications to use OFX

```
import OFXLib
class DeclassifierApp(app_manager.RyuApp):

    def __init__(self, *args, **kwargs):
        super(SimpleSwitch13, self).__init__(*args, **kwargs)
        self.permissionsDb = dbServer.connect()
        self.monitoredServers = []
        self.switchIds = []
        self.declassifierModule = OFXLib.load_module("dec_module")
        self.declassifierModule.permissions = self.permissionsDb

    def switch_up_handler(self, switch):
        self.switchIds.append(switch.id)
        OFXLib.install(switch, self.declassifierModule)
        ...

    def packet_handler(self, switch, pkt):
        action = self.compute_next_hop(pkt, switch)
        switch.send_packet(pkt, action)
        ...
```



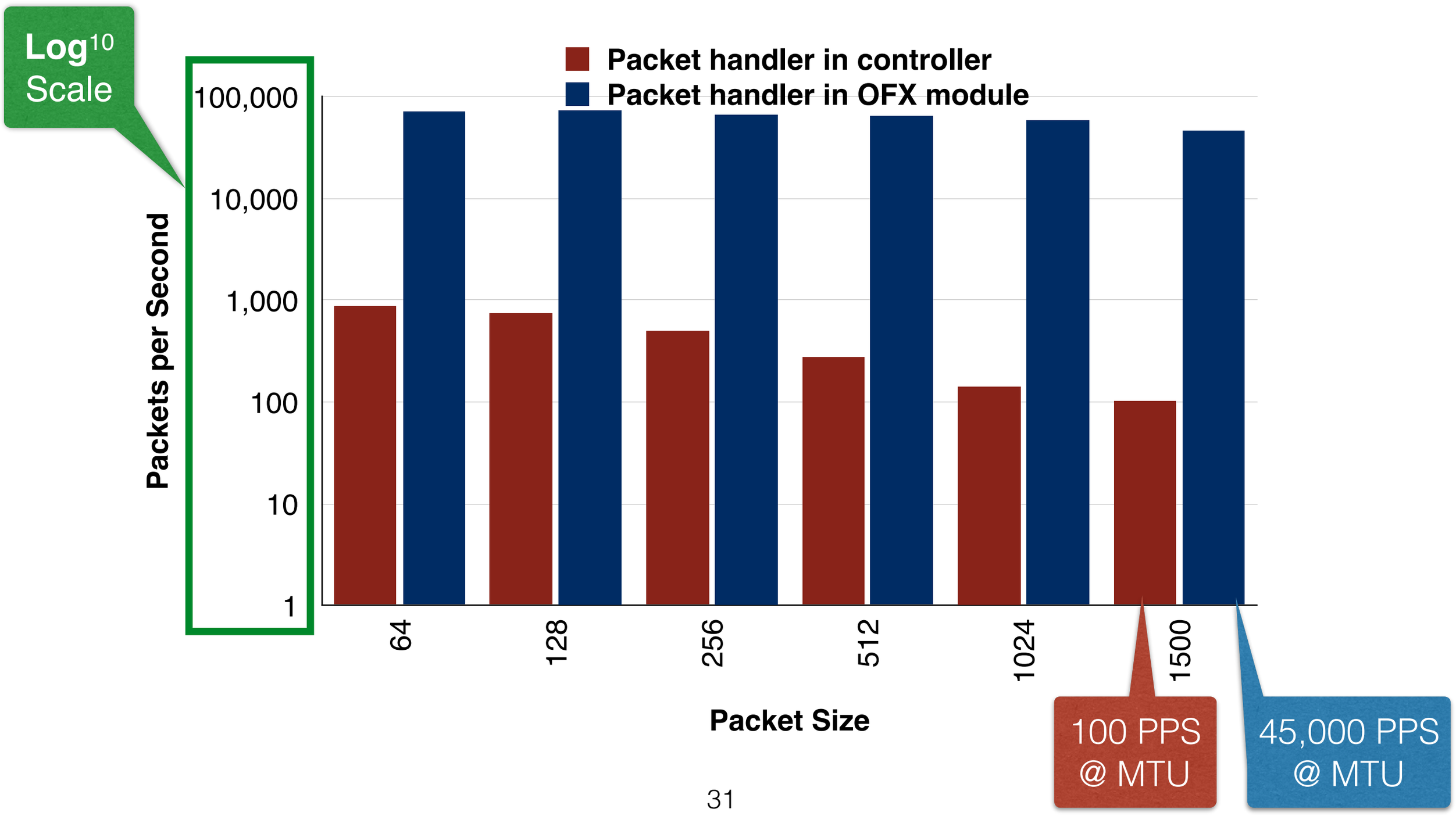
Outline

Benchmarking OFX

How much raw overhead is there for processing packets with OFX?

How do OFX based security applications perform, compared with Middlebox and OpenFlow implementations?

OFX Benchmark: Packets Per Second



Benchmarking OFX

How much raw overhead is there for processing packets with OFX?

How do OFX based security applications perform, compared with Middlebox and OpenFlow implementations?

Benchmark: Declassifier Packet Drop Rate

Implementation	Frequent arriving flows	Median	High bandwidth flows
Middlebox Proxy	0.1%	0.1%	20.4%
OpenFlow	97.5%	88.2%	0.1%
OFX	5.1%	3.2%	0.1%

OpenFlow implementation limited by flow arrival rate

Proxy implementation limited by bit rate

OFX implementation performed well in all workloads

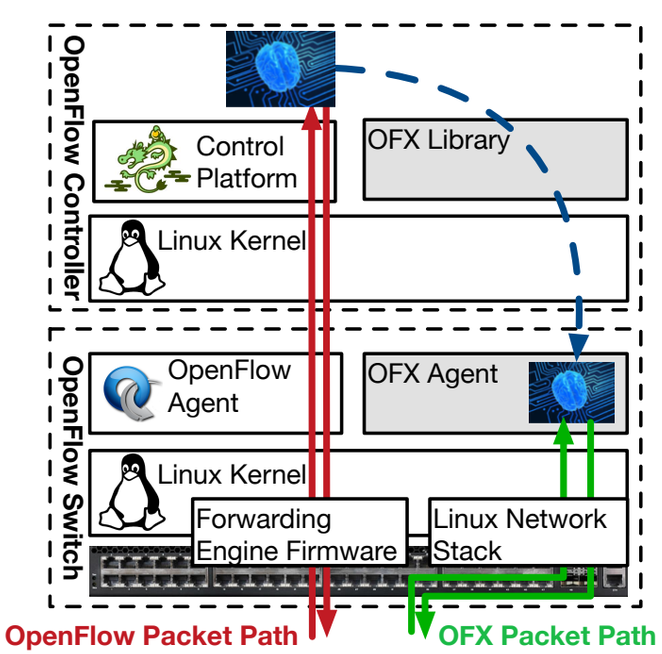
Workload Name	Frequently arriving flows	Median flows	High bandwidth flows
Flow Inter-arrival Period	0.0015 Seconds	0.015 Seconds	0.15 Seconds
Average Transmission Bandwidth	19.75 Mbps	43.57 Mbps	970.99 Mbps

. S. Kandula, S. Sengupta, A. Greenberg, P. Patel, and R. Chaiken, "**The nature of data center traffic: measurements & analysis,"** in *Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference*. ACM, 2009, pp. 202–208.

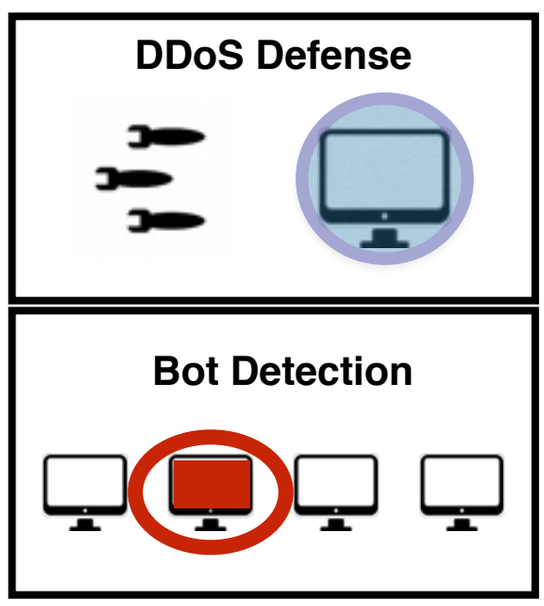
. L. Qian and B. E. Carpenter, **"A flow-based performance analysis of tcp and tcp applications,"** in *Networks (ICON), 2012 18th IEEE International Conference on*. IEEE, 2012, pp. 41–45.

In the Paper

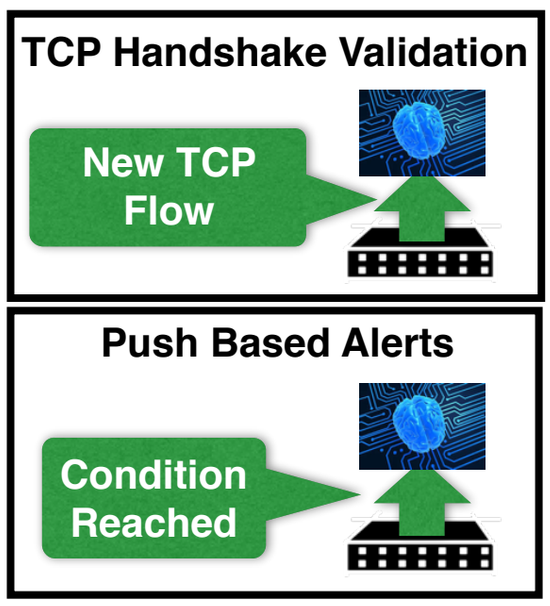
OFX API and Implementation Details



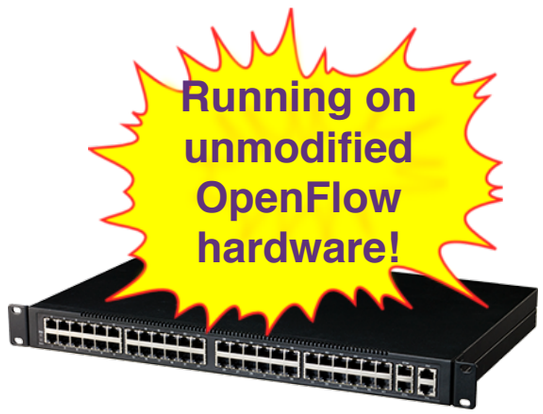
Application Specific Modules



Enhanced Switch API Modules

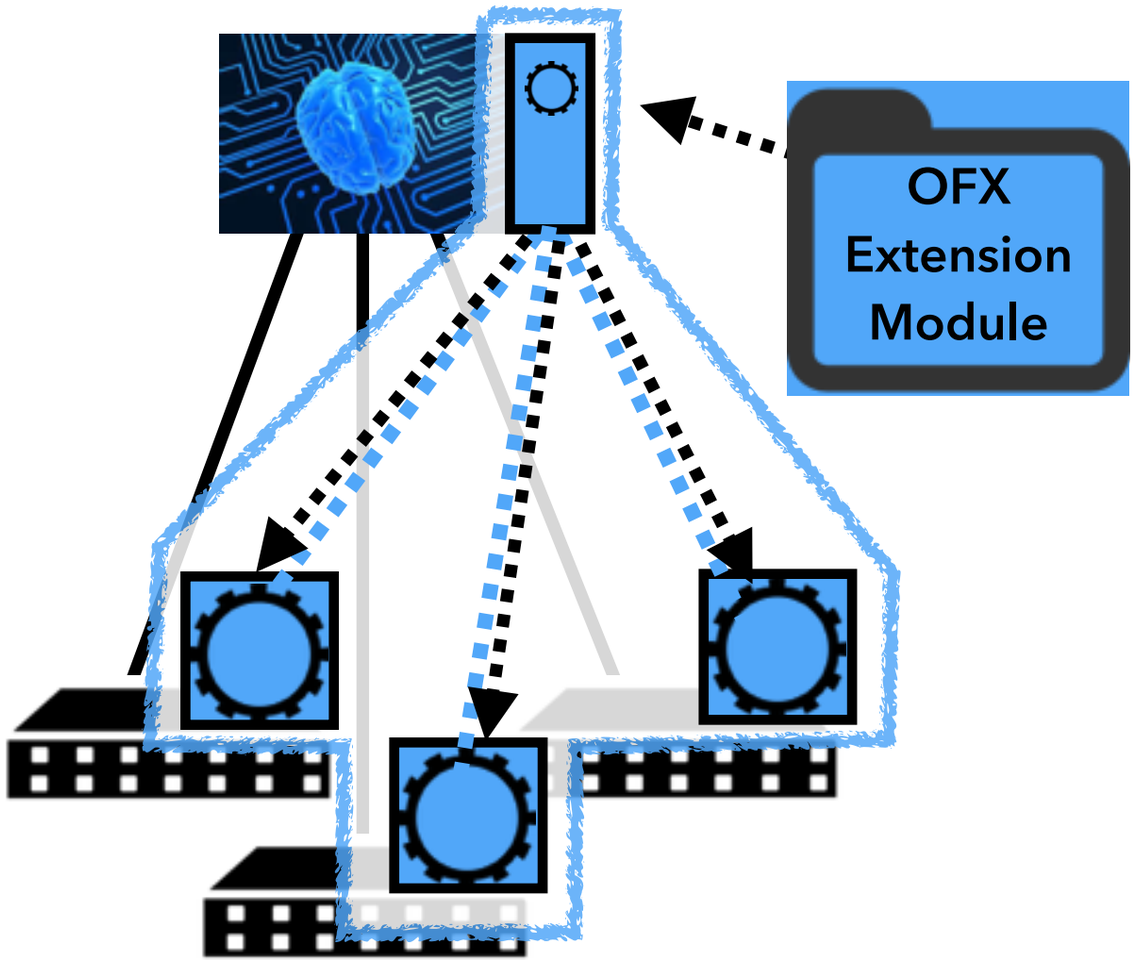


More benchmarks



Thank You

OFX: The OpenFlow Extension Framework



OFX lets OpenFlow security applications **push parts of their control plane logic down to switch CPUs**, which can greatly **improve performance and scalability on existing hardware and software.**

Penn
University of Pennsylvania

University of Colorado Boulder

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Computer Science and Information Technology
Scientia ut amicos servemus
Scientia ut hostes vincamus