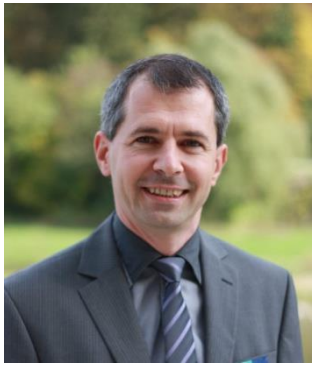
Software Defined Networking and Security

Ivan Pepelnjak (ip@ipSpace.net)

ipSpace.net AG

Who is Ivan Pepelnjak (@ioshints)



- Networking engineer since 1985
- Technical director, later Chief Technology Advisor @ NIL Data Communications
- Consultant, blogger, book and webinar author @ ipSpace.net AG
- Teaching “Scalable Web Application Design” at University of Ljubljana

Cisco Champion

CISCO CCIE EMERITUS

vmware vEXPERT

Focus:

- Large-scale data centers and network virtualization
- Networking solutions for cloud computing
- Scalable application design
- Core IP routing/MPLS, IPv6, VPN

Software Defined Networking

What is SDN?

SDN is the physical separation of the network control plane from the forwarding plane, and where a control plane controls several devices

Open Networking Foundation

Let's call whatever we can ship today SDN

Vendor X

SDN is the magic buzzword that will bring us VC funding

Startup Y

Is the ONF definition too restrictive? Shall we limit SDN to their understanding of it?

Motivations Behind SDN Movement

Very large cloud providers (ONF founders):

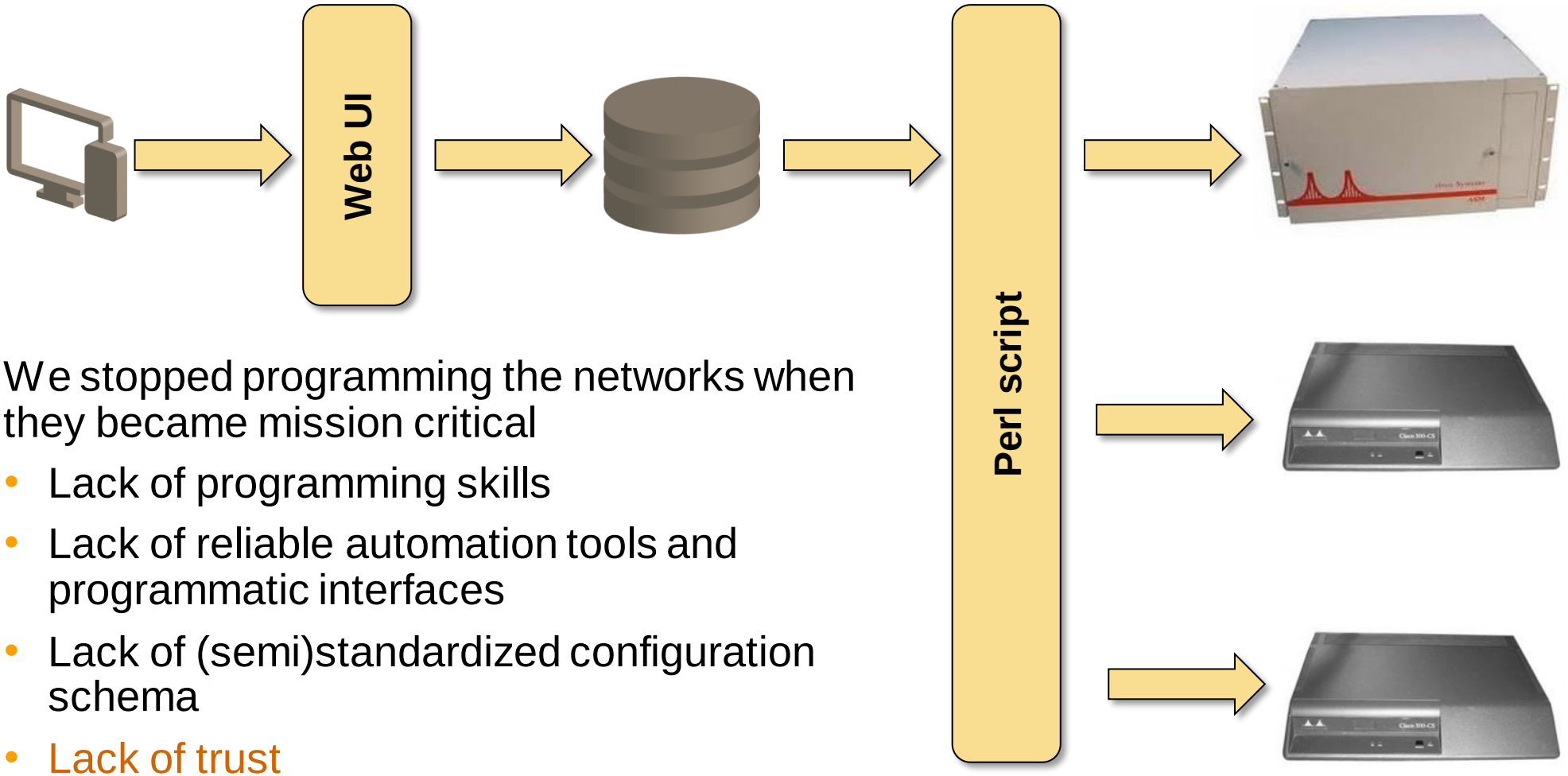
- Give me cheap hardware, I will build my software (Google)
- Implement my own features or protocols (Yahoo)
- Whitebox hardware + open-source software (Facebook)

Real-life requirements

- Faster software development
- Programmable network elements
- Faster provisioning
- Centralized intelligence, visibility and policies

The second set of requirements makes more sense for most customers

Did We Have SDN in 1992?



We stopped programming the networks when they became mission critical

- Lack of programming skills
- Lack of reliable automation tools and programmatic interfaces
- Lack of (semi)standardized configuration schema
- Lack of trust

Why have we stopped doing it? What went wrong?

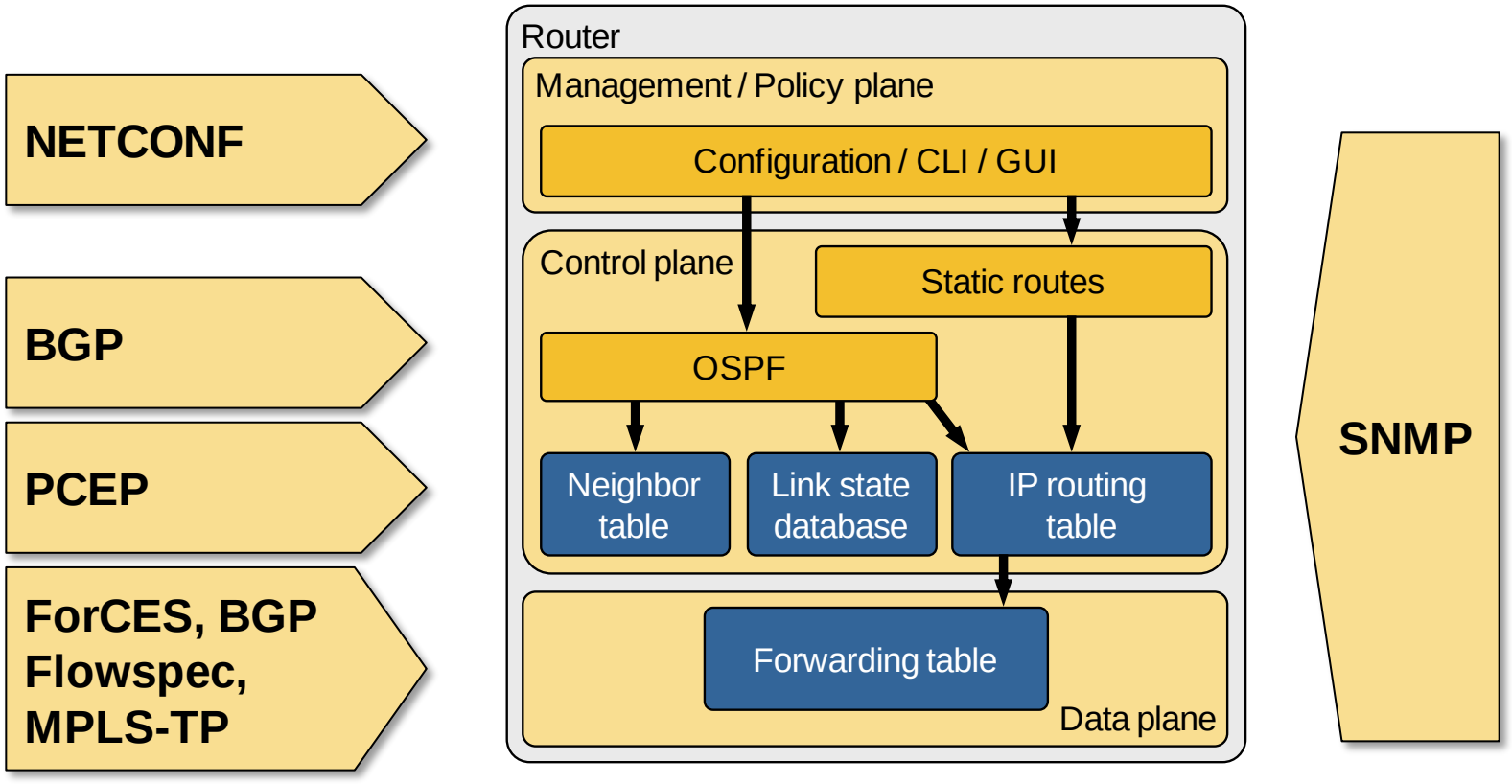
SDN Principles Revisited

- Centralized controllers
- Decisions made based on end-to-end visibility
- Automatic programming or configuration of network devices

Usual objections

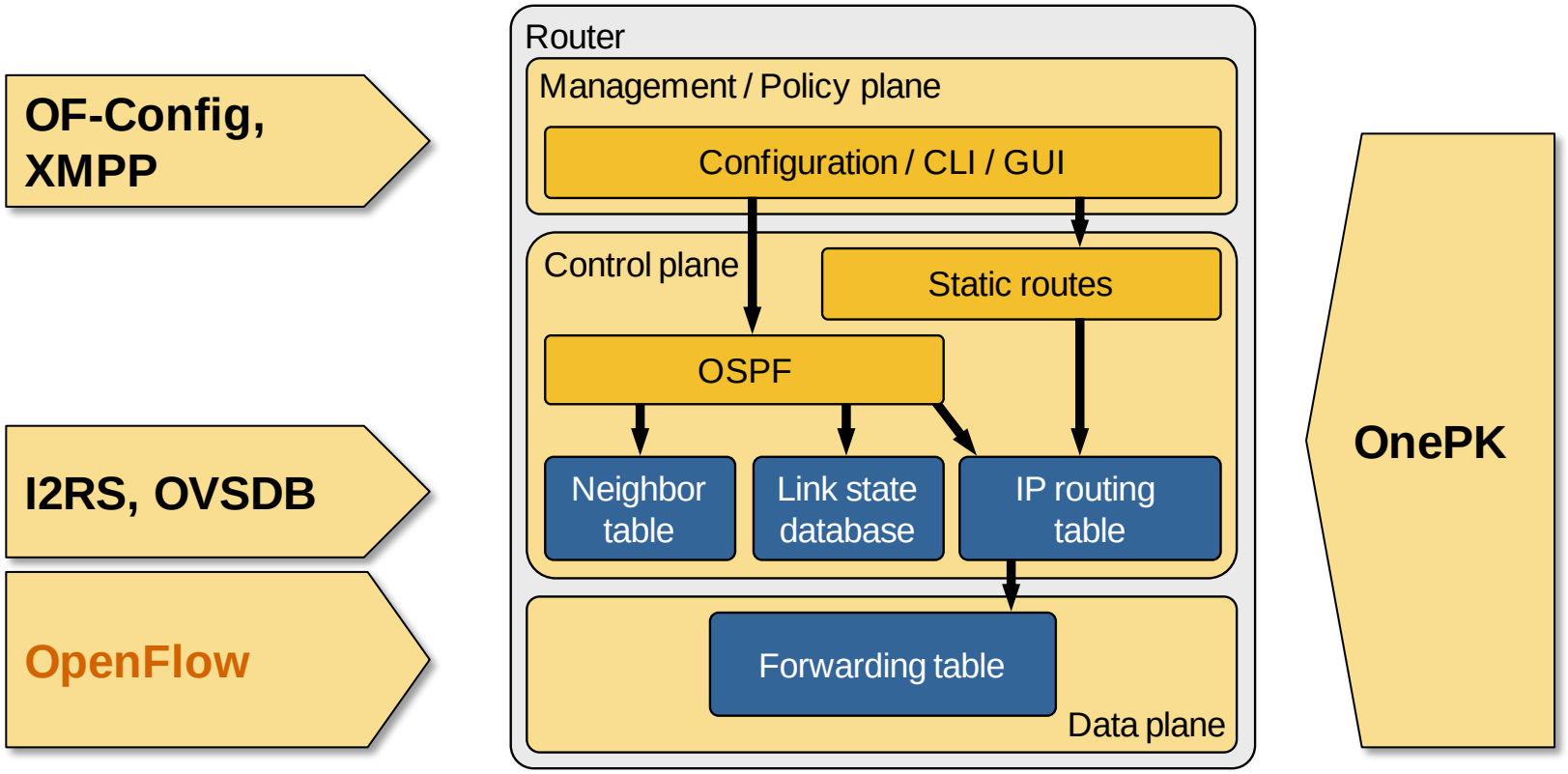
- How is this different from Single-Pane-of-Glass?
- What happens when network partitions?
- Why should it work this time?

Can We Do SDN Today?



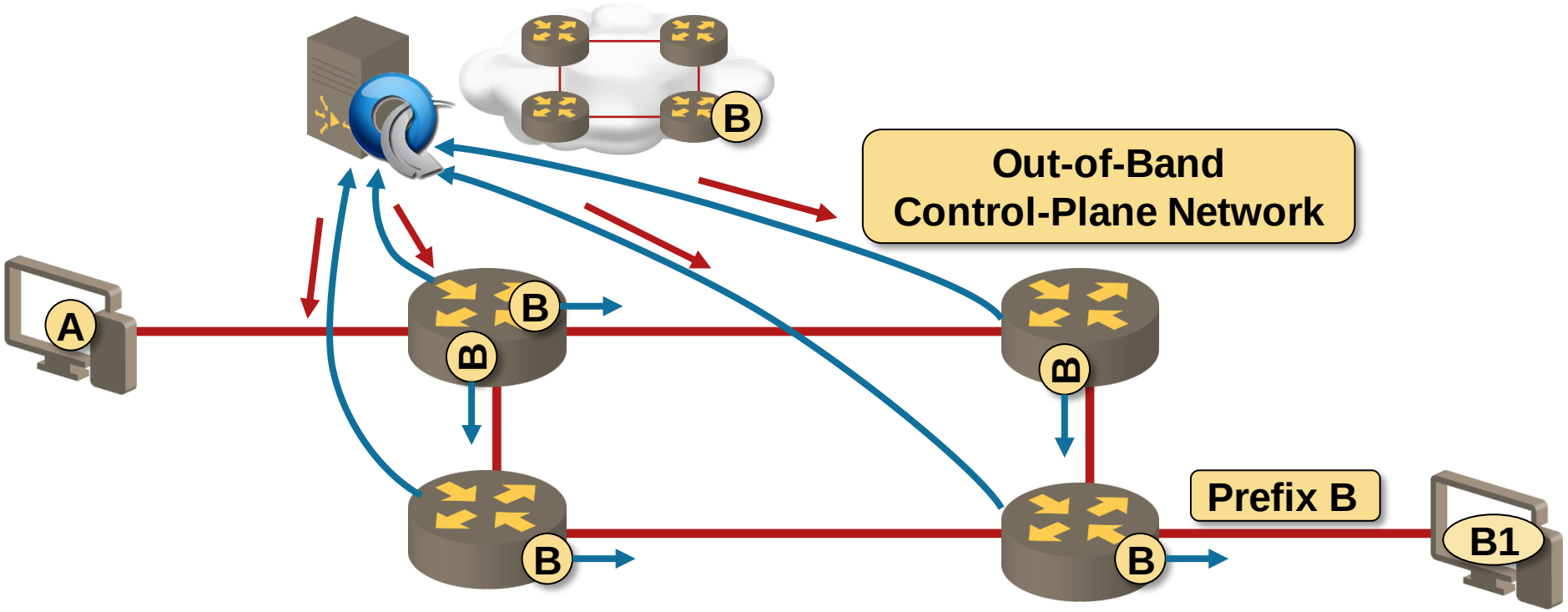
- Vendor APIs: Cisco, Juniper
- Scripting: Cisco, Juniper, Arista, Dell, F5 ...

Emerging Protocols



OpenFlow 101

OpenFlow = Control / Data Plane Separation



Basic principles:

- Control / Management plane in a dedicated *controller*
- Networking devices perform forwarding and maintenance functions
- IP / SSL connectivity between controller and OpenFlow switch
- OpenFlow = Forwarding table (TCAM) download protocol

OpenFlow Concepts Are not New (RFC 1925, sect 2.11)

Do you still remember ...

- Frame Relay and ATM networks
- SONET/SDH
- ForCES
- MPLS-TP

The problems are always the same:

- Forwarding state abstraction / scalability
- Distributed network resilience with centralized control plane
- Fast feedback loops
- Fast convergence (FRR, PIC)
- Linecard protocols (BFD, LACP, LLDP ...)

Shipping OpenFlow Products

Switches – Commercial

- Arista 7500/7150
- Brocade MLX/NetIron products
- Cisco Nexus 3000
- Dell N3000/N400
- Extreme BlackDiamond
- HP ProCurve
- IBM BNT G8264
- Juniper MX & EX9200 (not GA)
- NEC ProgrammableFlow switches
- Smaller vendors (Mikrotik, ODMs)

Switches – Open Source

- Open vSwitch (Xen, KVM)
- NetFPGA reference implementation
- OpenWRT
- Mininet (emulation)

Controllers – Commercial

- NEC ProgrammableFlow Controller
- VMware NSX
- Big Switch Networks
- Cisco eXtensible Network Controller
- HP VAN SDN Controller

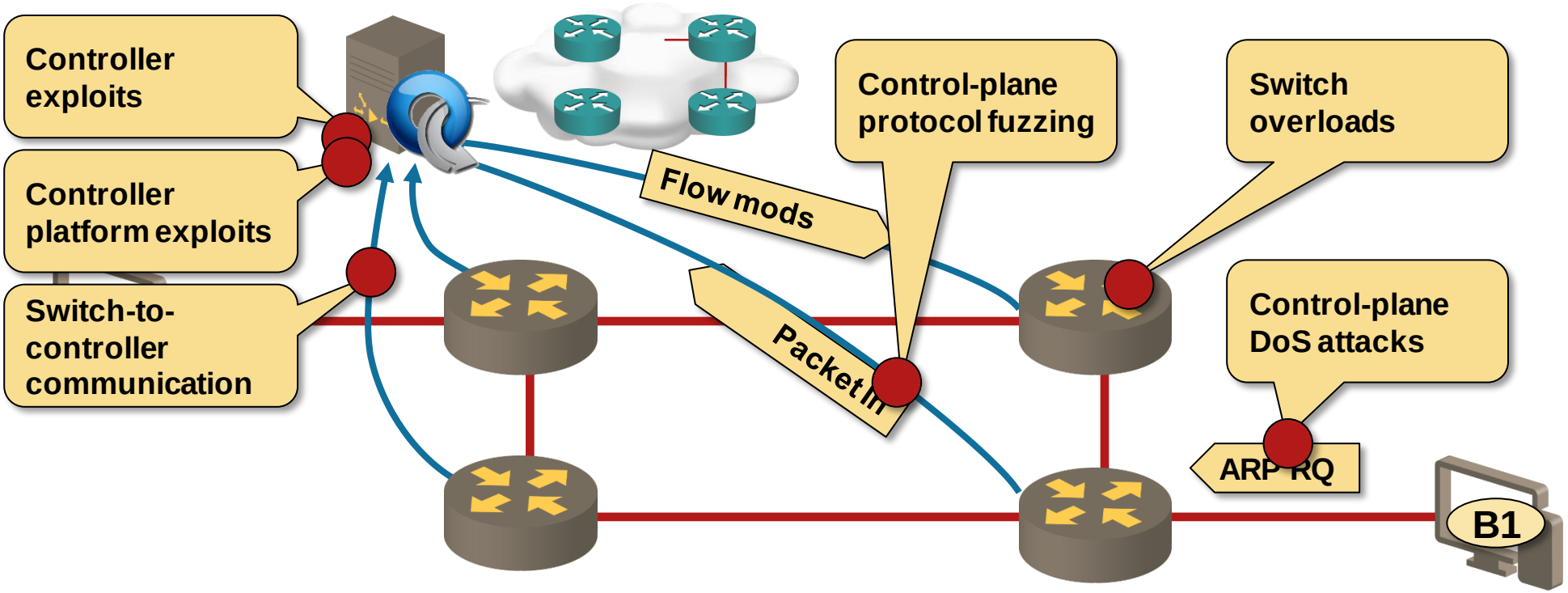
Controllers – Open Source

- Open Daylight (Java)
- NOX (C++/Python)
- Beacon (Java)
- Floodlight (Java)
- Maestro (Java)
- RouteFlow (NOX, Quagga, ...)
- NodeFlow (JavaScript)
- Trema (Ruby)

More @ http://www.sdncentral.com/shipping-sdn-products/

SDN Security Challenges

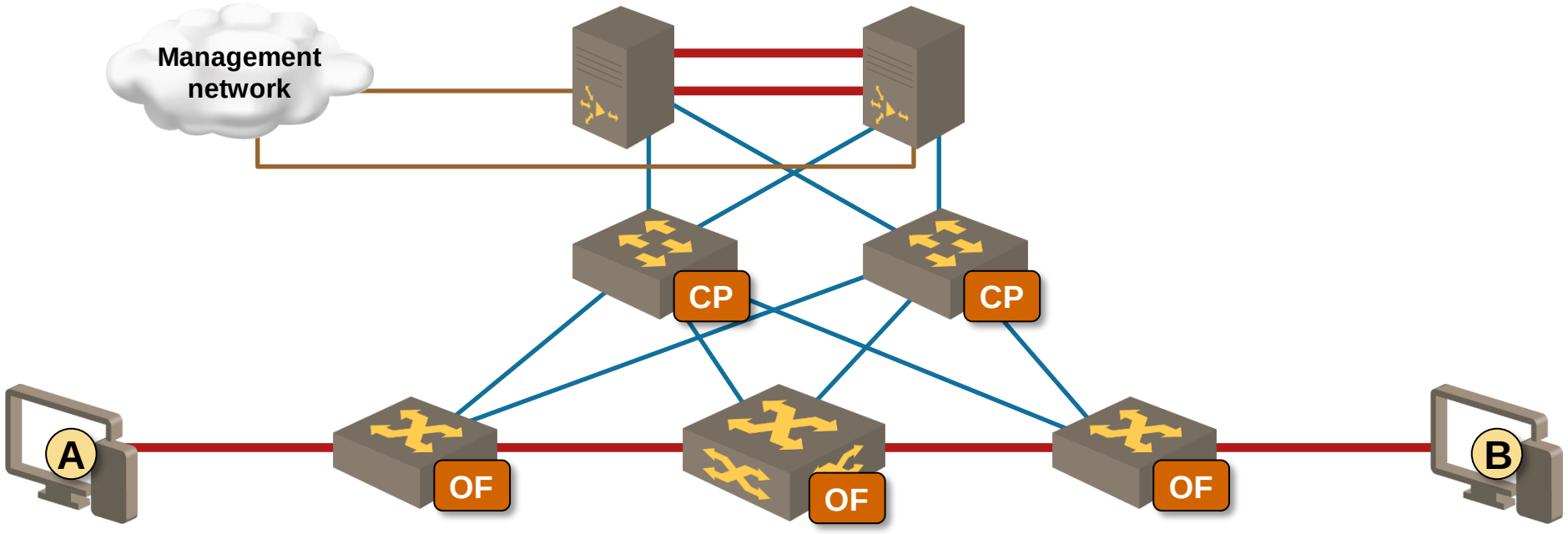
Threat Analysis



- Control-plane attacks
- Denial-of-service attack (switch and controller)
- Fuzzing attacks

SDN controller is a very lucrative target

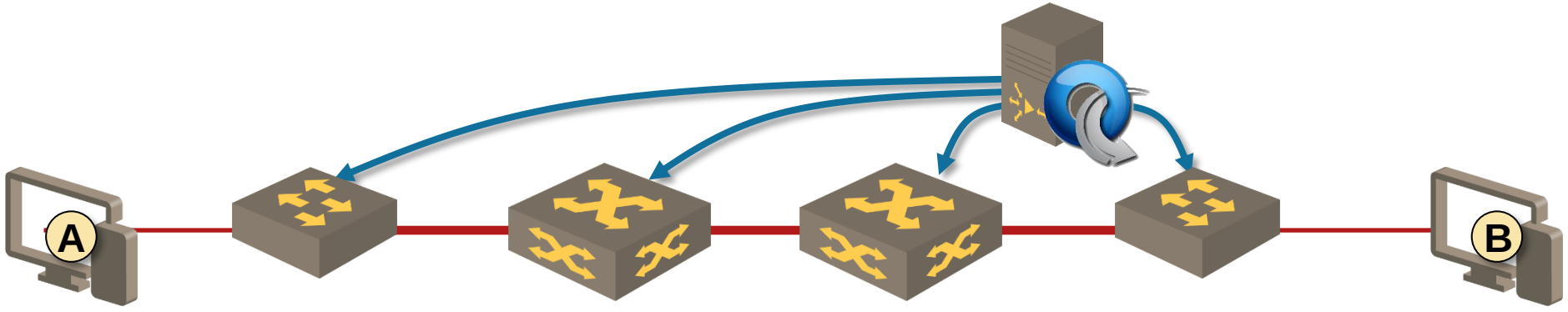
Separate Data Plane



Well-known solutions

- Encrypted switch-to-controller communications
- Separate management- or control-plane network
- Forwarding and management contexts in the switches

Proactive Flow Setups



Reactive flow setups

- Punt unknown packets to the controller
- Compute forwarding paths on demand
- Install flow entries based on actual traffic

Scalability concerns

- Flow granularity
- Packet punting rate
- Flow modification rate

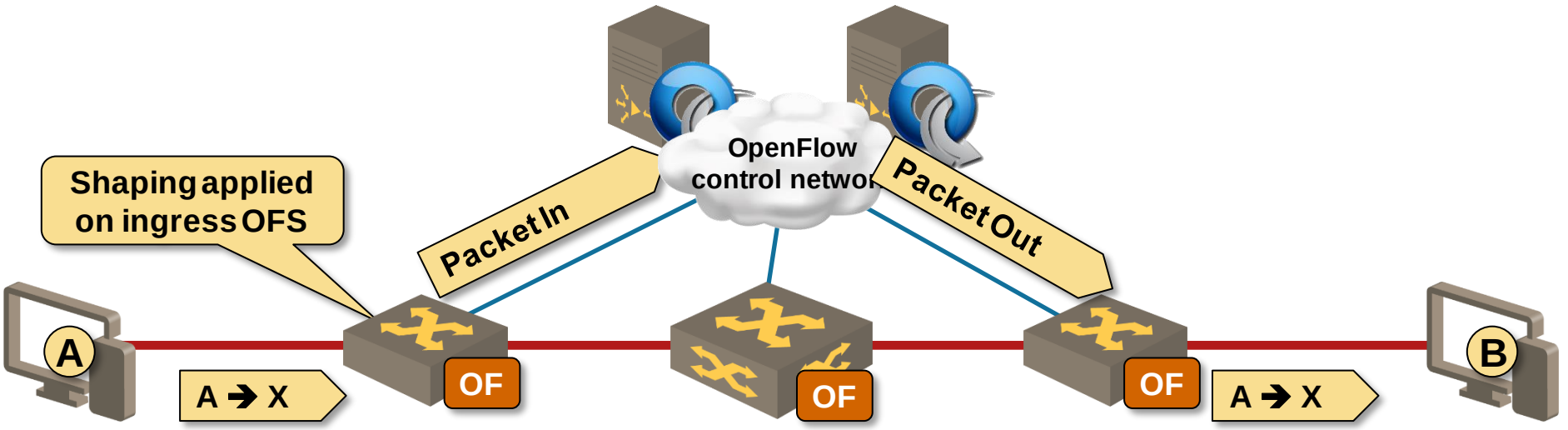
Proactive flow setups

- Discover network topology
- Discover endpoints
- Compute optimal forwarding topology
- Download flow entries

No data plane controller involvement

- Exceptions: ARP and MAC learning

Control-Plane Protection



- OpenFlow switches send all unknown packets to controller
- Unicast flooding performed through controller ➔ control plane interference
- Control-plane protection needed in ingress OpenFlow switches

Hardening an SDN Solution

Common design guidelines

- Out-of-band Control Plane
- Minimize the control-plane involvement
- Use OpenFlow solutions with coarse-grained proactive forwarding model
- Prefer solutions with distributed intelligence

Switch hardening

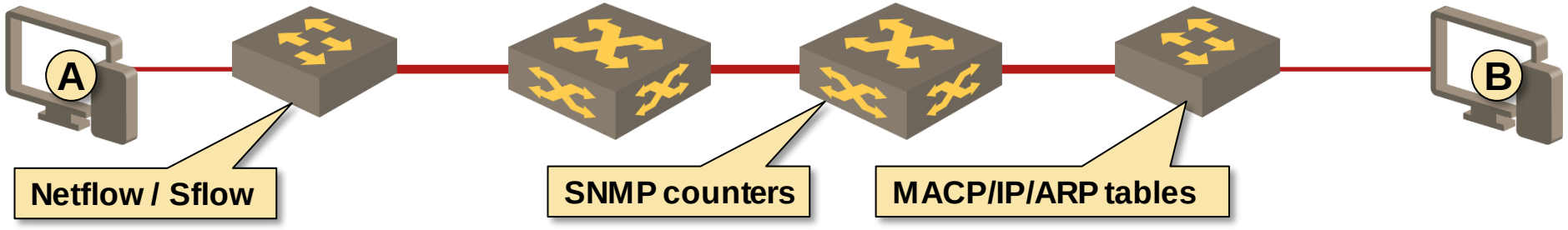
- Strict control/data plane separation
- Control-plane policing in OpenFlow networks

Controller hardening

- Most controllers run on Linux ➔ you know what to do

Use Case: Network Monitoring and Tapping

Network Monitoring in Traditional Networks



Traffic statistics

- Too coarse (interface counters), detailed (Netflow / IPFIX) or sampled (Sflow)
- Limited visibility in multi-tenant environments

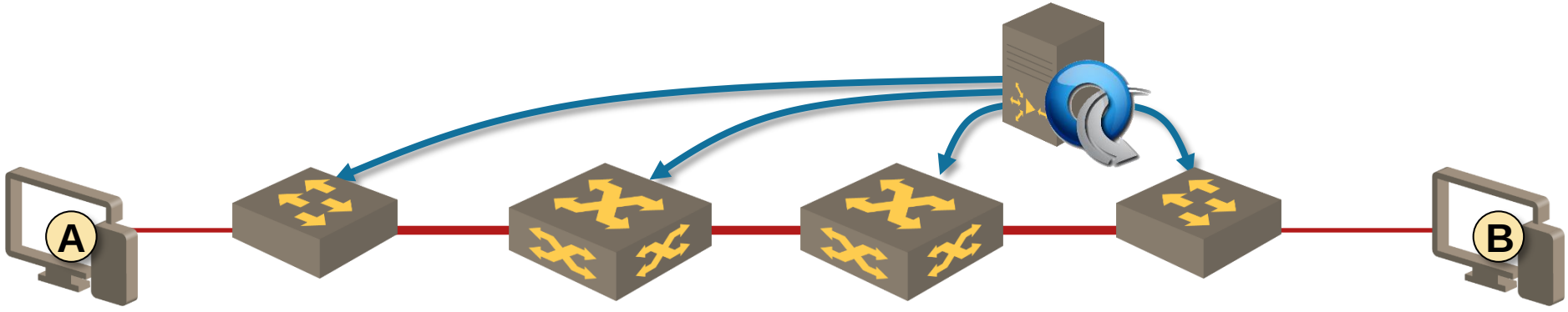
Endpoint visibility

- Available on edge network devices
- Hard to summarize into a searchable format

Forwarding information

- Information distributed across numerous devices (MAC tables, ARP tables, IP forwarding tables)
- Hard to reconstruct expected traffic path

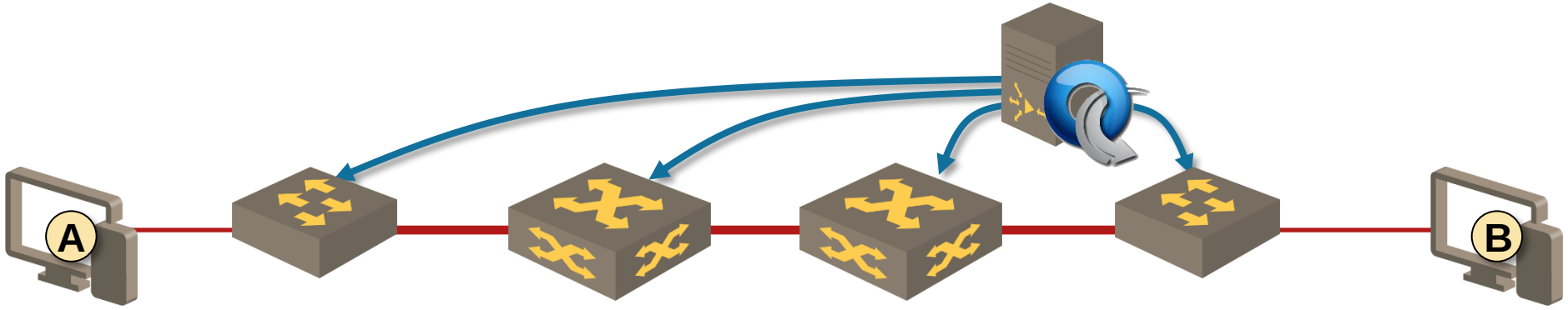
Network Monitoring in Controller-Based Networks



Controller is the authoritative source of information on

- Network configuration
- Network topology
- Forwarding paths
- Endpoints (IP prefixes or IP/MAC addresses)

Network Monitoring in OpenFlow-Based Networks



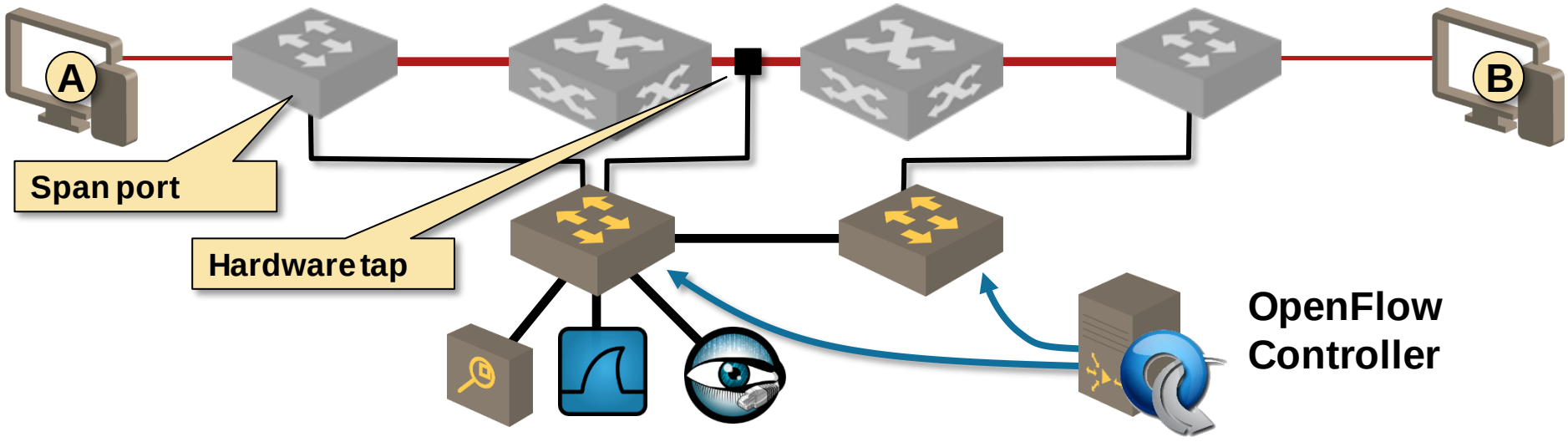
OpenFlow statistics

- Byte- and packet counters associated with every OpenFlow entry
- Controller can read flow statistics (similar to SNMP interface counters)
- Flow counters reported to OpenFlow controller every time a switch removes a flow due to idle timeout

Traffic statistics in OpenFlow controller

- Controller can collect traffic statistics at any granularity ➔ configured with flow entries downloaded to the switches
- Constraint: switch hardware or software limits

OpenFlow/SDN in Tap Aggregation Network



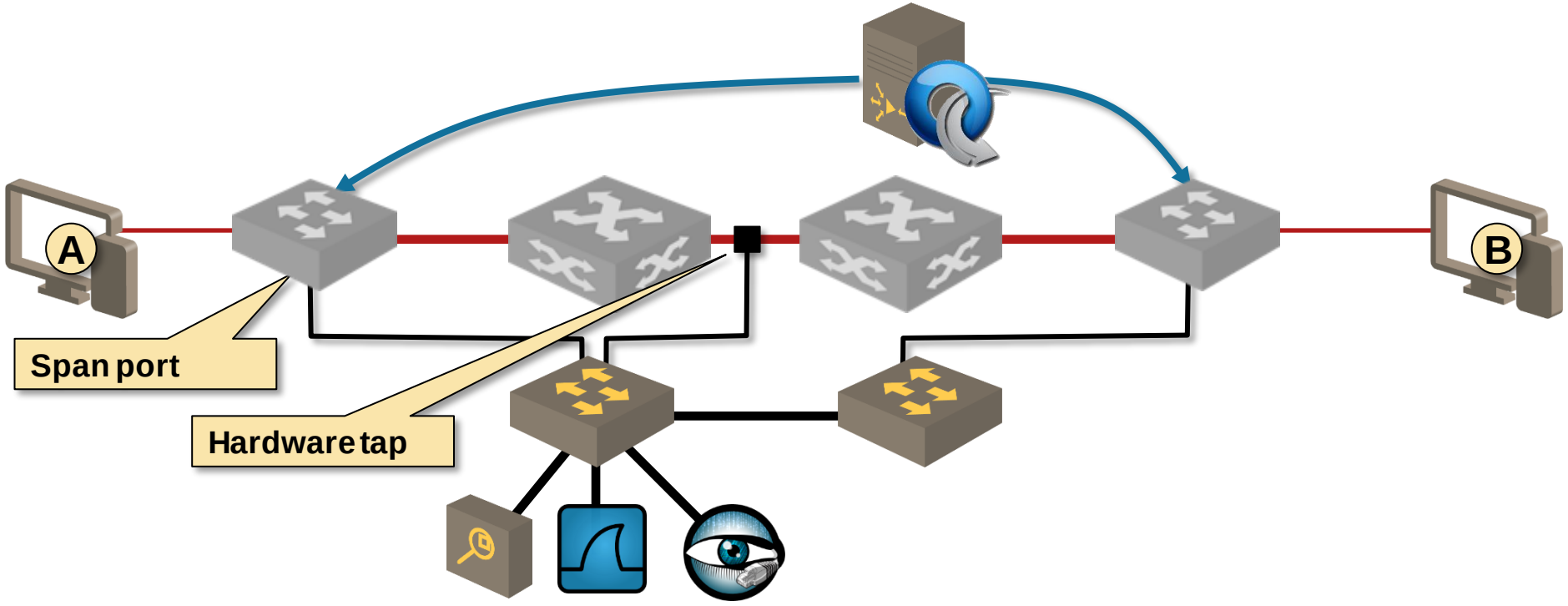
Solution Overview

- Replace dedicated tap aggregation equipment with standard OpenFlow-capable switches
- Program filtering and forwarding rules with OpenFlow

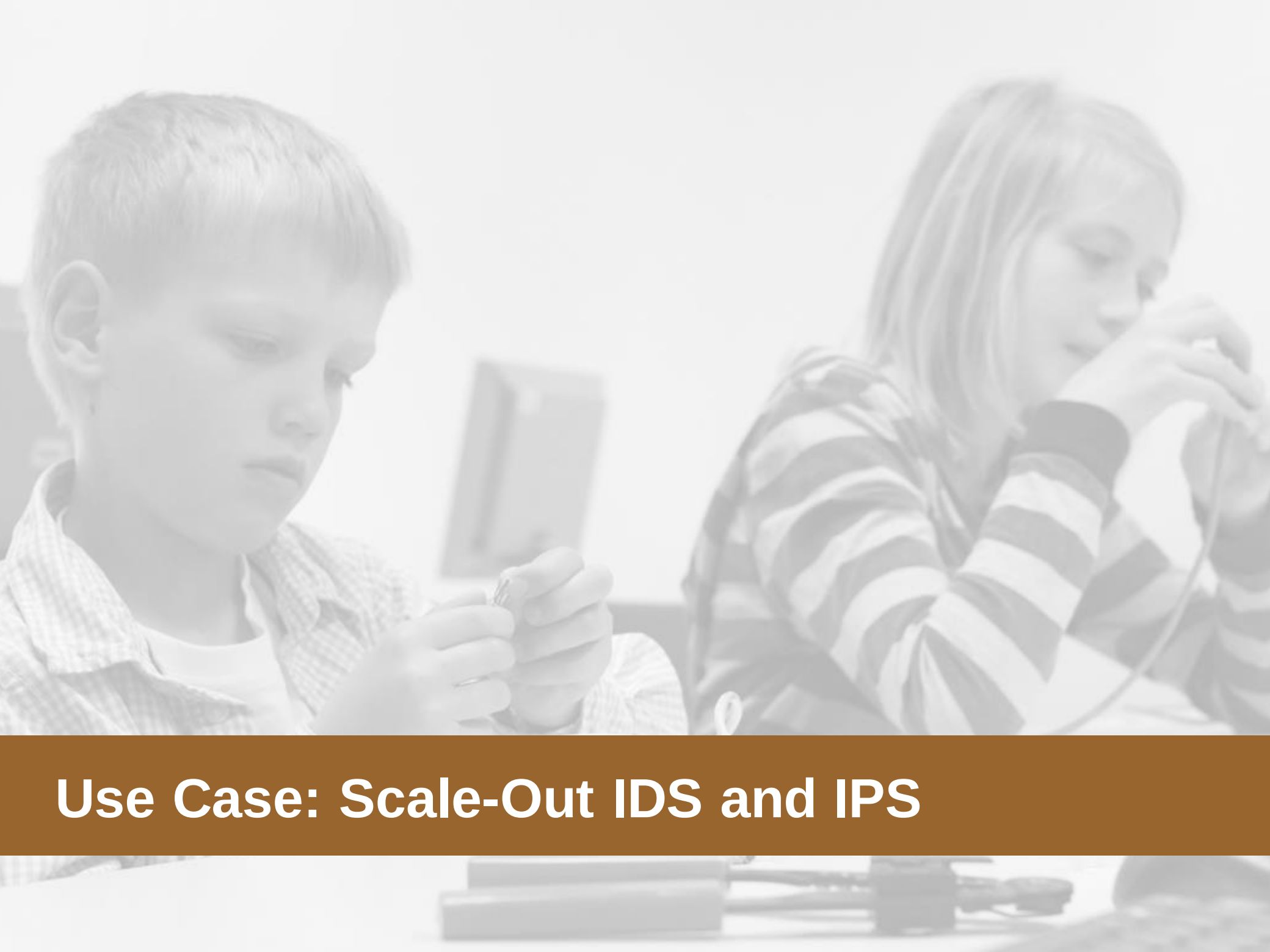
Benefits of OpenFlow

- Based on commodity switches
- Filter early in the forwarding path ➔ use capturing devices more efficiently
- N-tuple filtering
- Flow-based metering
- Simple tap- and filter changes

Traffic Tapping with OpenFlow Switches

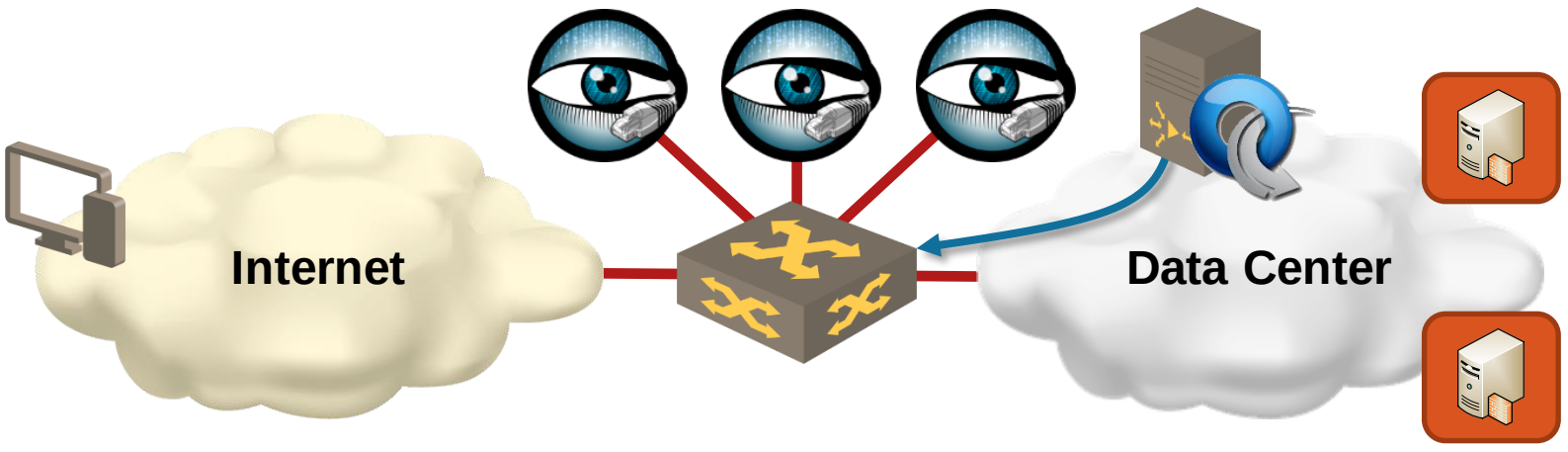


- Use OpenFlow flows to mirror traffic to SPAN ports
- Higher traffic redirection granularity ➔ lower number of SPAN ports required
- Any OpenFlow controller capable of inserting individual flows could be used



Use Case: Scale-Out IDS and IPS

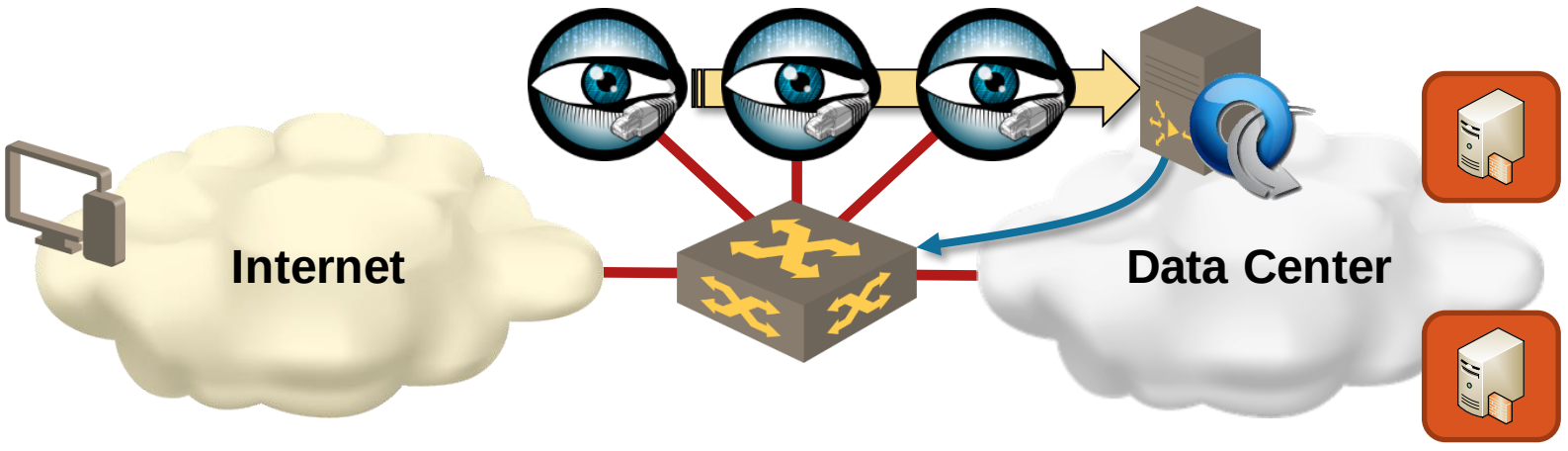
Scale Out IDS with OpenFlow Controller



OpenFlow used to distribute the load to multiple IDS appliances

- Coarse-grained flows deployed on the OpenFlow switch
- Flow granularity adjusted in real time to respond to changes in traffic
- Each appliance receives all traffic from a set of endpoints (complete session and endpoint behavior visibility)

Scale Out IPS with OpenFlow Flows



DoS detection system reports offending X-tuples

- Source IP addresses
- Targeted servers
- Applications (port numbers)

OpenFlow controller installs *drop* flows

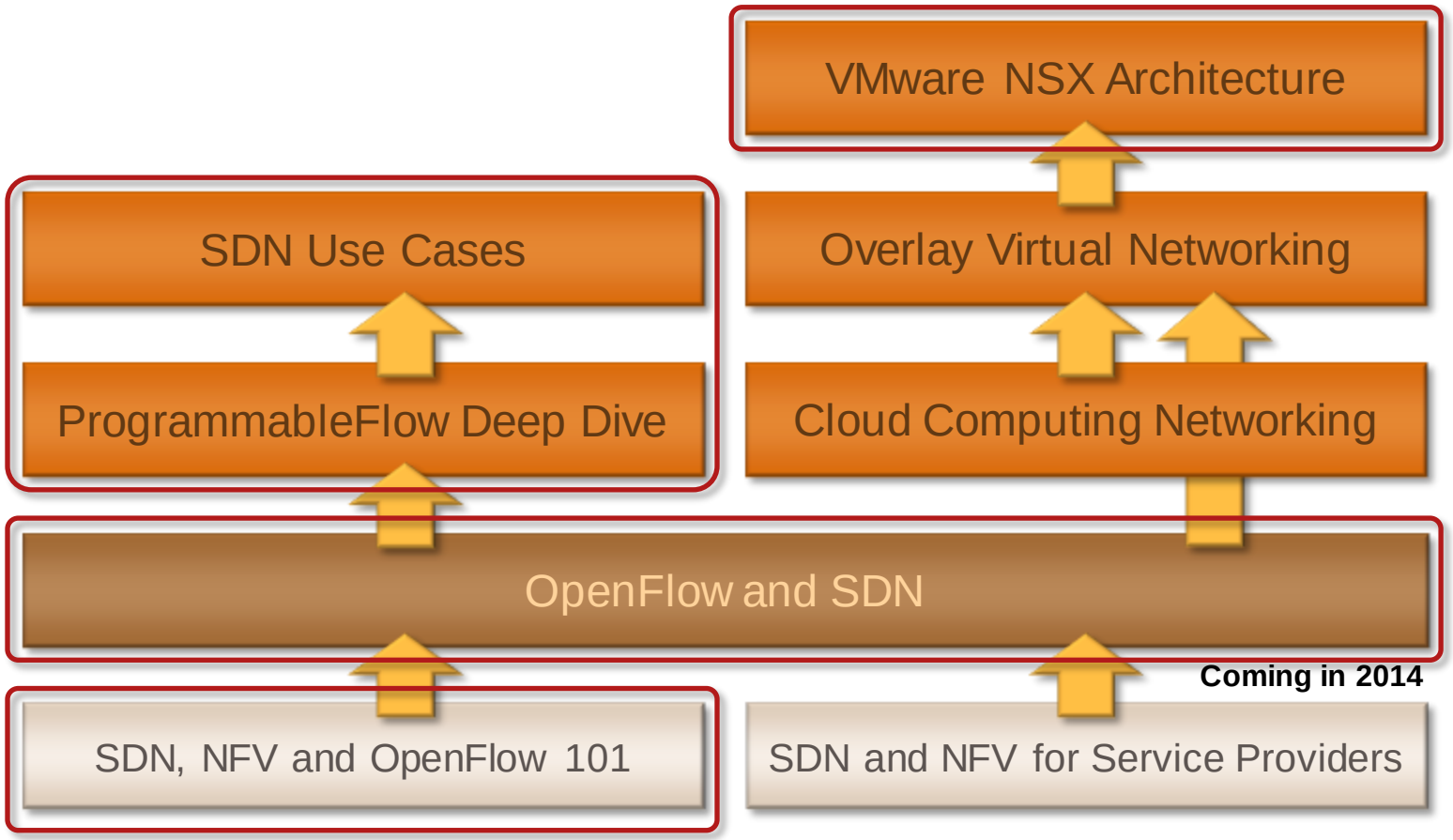
Module for Bro IDS already available

Should I Care?

Conclusions

- SDN and OpenFlow are interesting concepts
- They will significantly impact the way we do networking
- Centralized computation and management plane makes more sense than centralized control plane
- OpenFlow is just a low-level tool
- Initial SDN use cases: large data centers @ portals or cloud providers (cost cutting or virtualized networking)
- Still a very immature technology, standards are rapidly changing
- Northbound controller API is missing (but badly needed) ➔ Creating controller vendor lock-in
- Already crossed the academic ➔ commercial gap

OpenFlow and SDN Webinars on ipSpace.net



Trainings

- Live sessions
- On-Site workshops
- Recordings and subscriptions

Other resources

- Consulting
- Books and case studies

More information @ http://www.ipSpace.net/SDN

Questions?

Send them to ip@ipSpace.net or @ioshints