SDN Fundamentals

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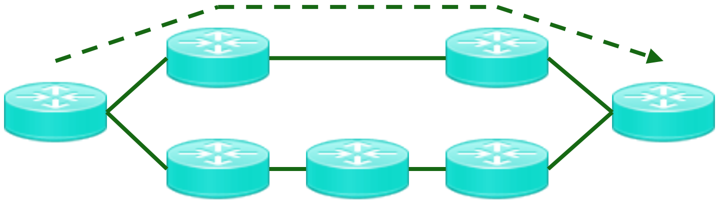
Overview

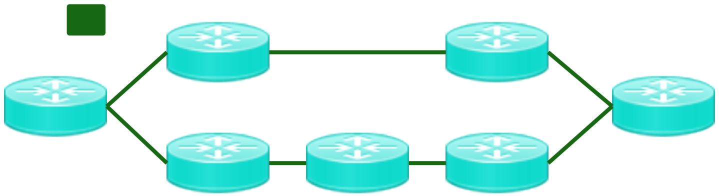
- Evolution of routers
- The Clean Slate project
- OpenFlow
- Emergence and evolution of SDN
- SDN architecture today
- Use cases
- Standards development
- Comparing and contrasting with NFV

Routers

- Two key roles:

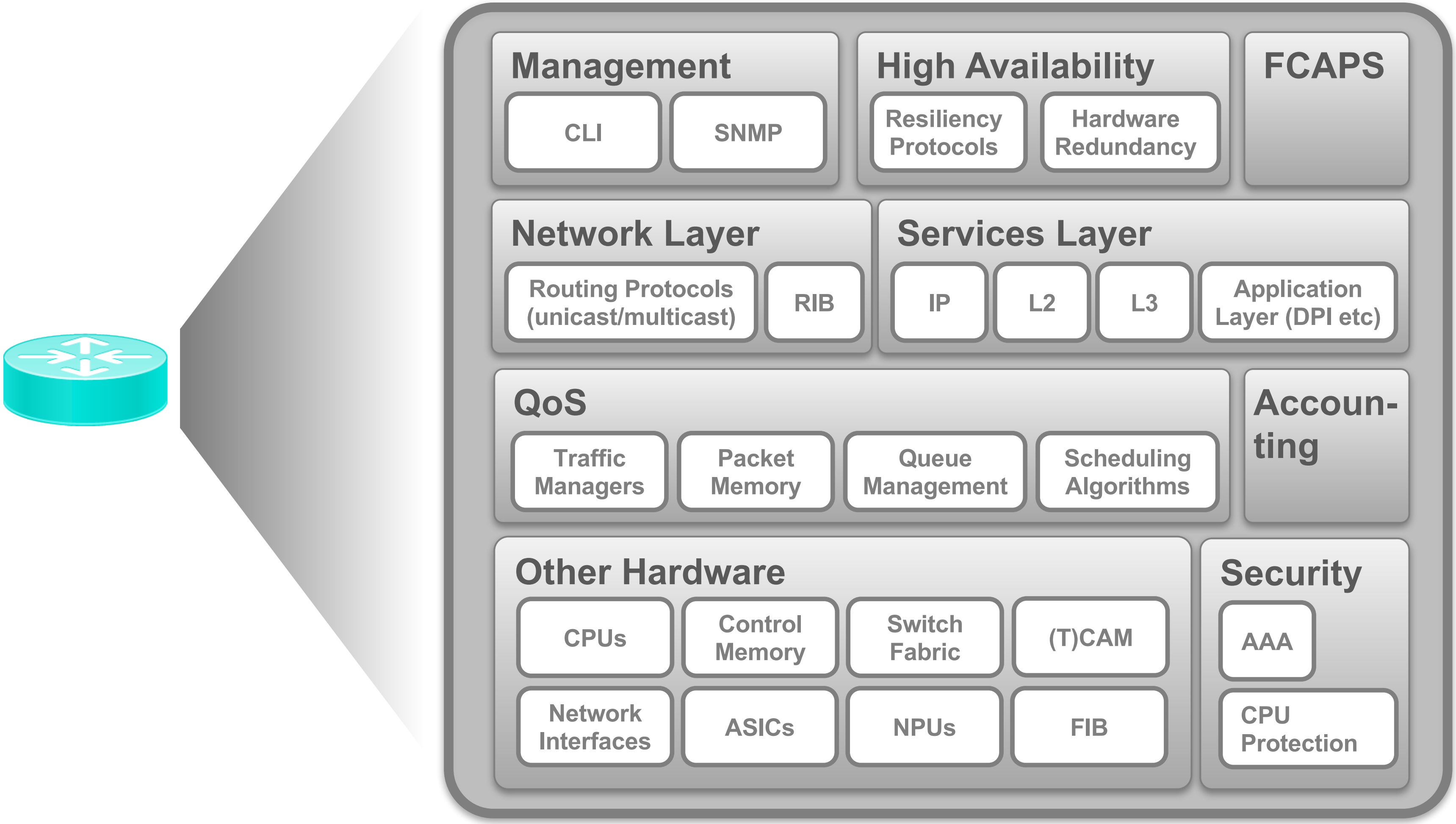


Determining network paths



Packet forwarding

Today’s router



Management
CLI
SNMP

High Availability
Resiliency Protocols
Hardware Redundancy

FCAPS

Network Layer
Routing Protocols (unicast/multicast)
RIB

Services Layer
IP
L2
L3
Application Layer (DPI etc)

QoS
Traffic Managers
Packet Memory
Queue Management
Scheduling Algorithms

Accoun-ting

Other Hardware
CPUs
Control Memory
Switch Fabric
(T)CAM
Network Interfaces
ASICs
NPUs
FIB

Security
AAA
CPU Protection

How did we get here ?

Distribution of complexity

- ‘End-to-end principle’
- Better scaling
- Survivability; spreading of risk

Backwards compatibility

- “Flag days” not realistic
- Short-term, incremental evolution of technology; no major overhaul in last 20 years

Unanticipated applications

- Networking is a victim of its own success
- New applications have been delivered on top of existing capabilities

Need for higher performance

- Tight coupling between different planes seen as critical for delivering higher performance

Stanford University
CLEAN SLATE
An Interdisciplinary Research Program

Clean Slate Project (1)

Two research questions:

With what we know today, if we were to start again with a clean slate, how would we design a global communications infrastructure

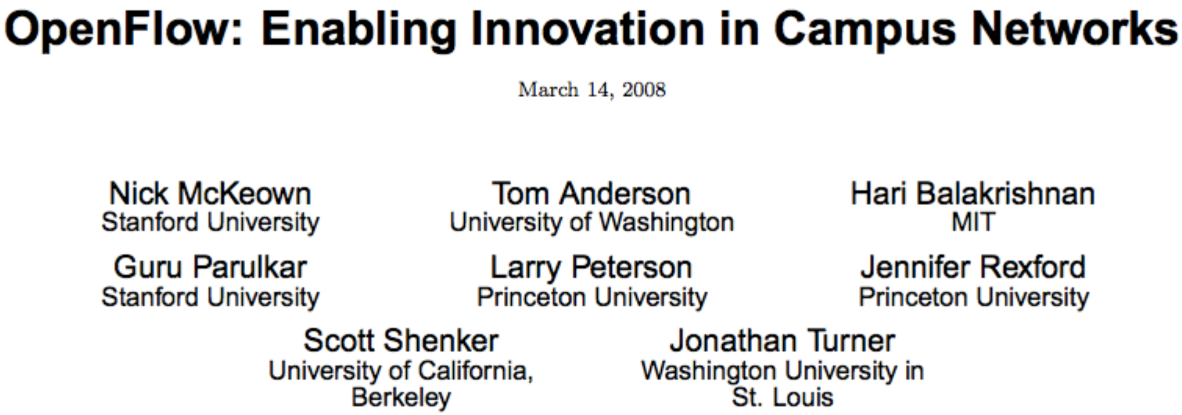
How should the Internet look in 15 years?

Mission: Re-invent the Internet

Stanford University
CLEAN SLATE
An Interdisciplinary Research Program

Clean Slate Project (2)

- One of the flagship projects was ‘Internet Infrastructure: OpenFlow and Software Defined Networking’
- Seminal paper on OpenFlow…



OpenFlow: Enabling Innovation in Campus Networks

March 14, 2008

Nick McKeown
Stanford University

Tom Anderson
University of Washington

Hari Balakrishnan
MIT

Guru Parulkar
Stanford University

Larry Peterson
Princeton University

Jennifer Rexford
Princeton University

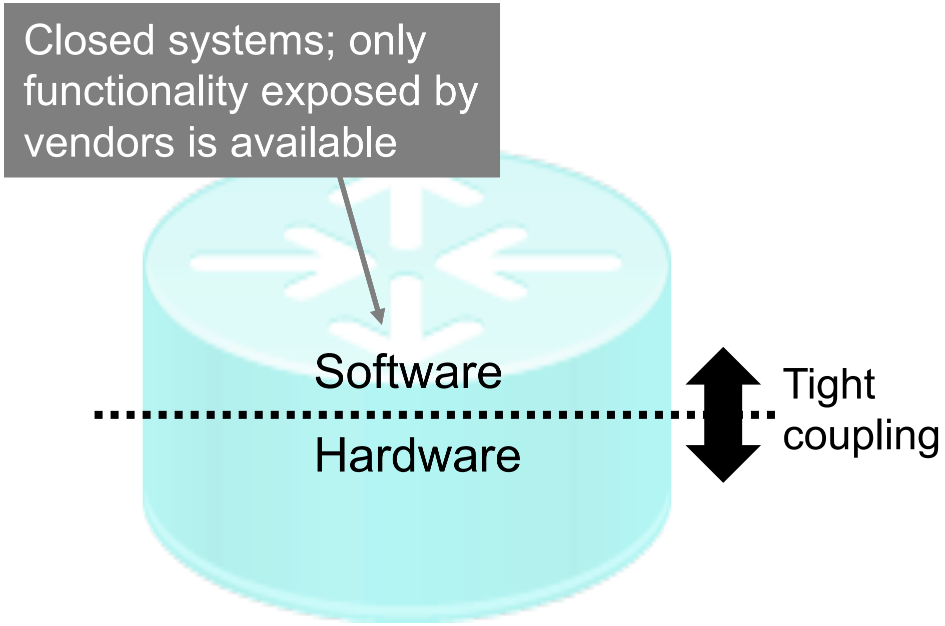
Scott Shenker
University of California, Berkeley

Jonathan Turner
Washington University in St. Louis

...kicked off the SDN movement and the data communications world would never be the same again

OpenFlow: The Problem

- Initial Problem:
  - A mechanism was required for researchers to run experimental network protocols.
  - Open software platforms did not provide the required performance and commercial solutions were too closed and inflexible.



Closed systems; only functionality exposed by vendors is available

Software

Hardware

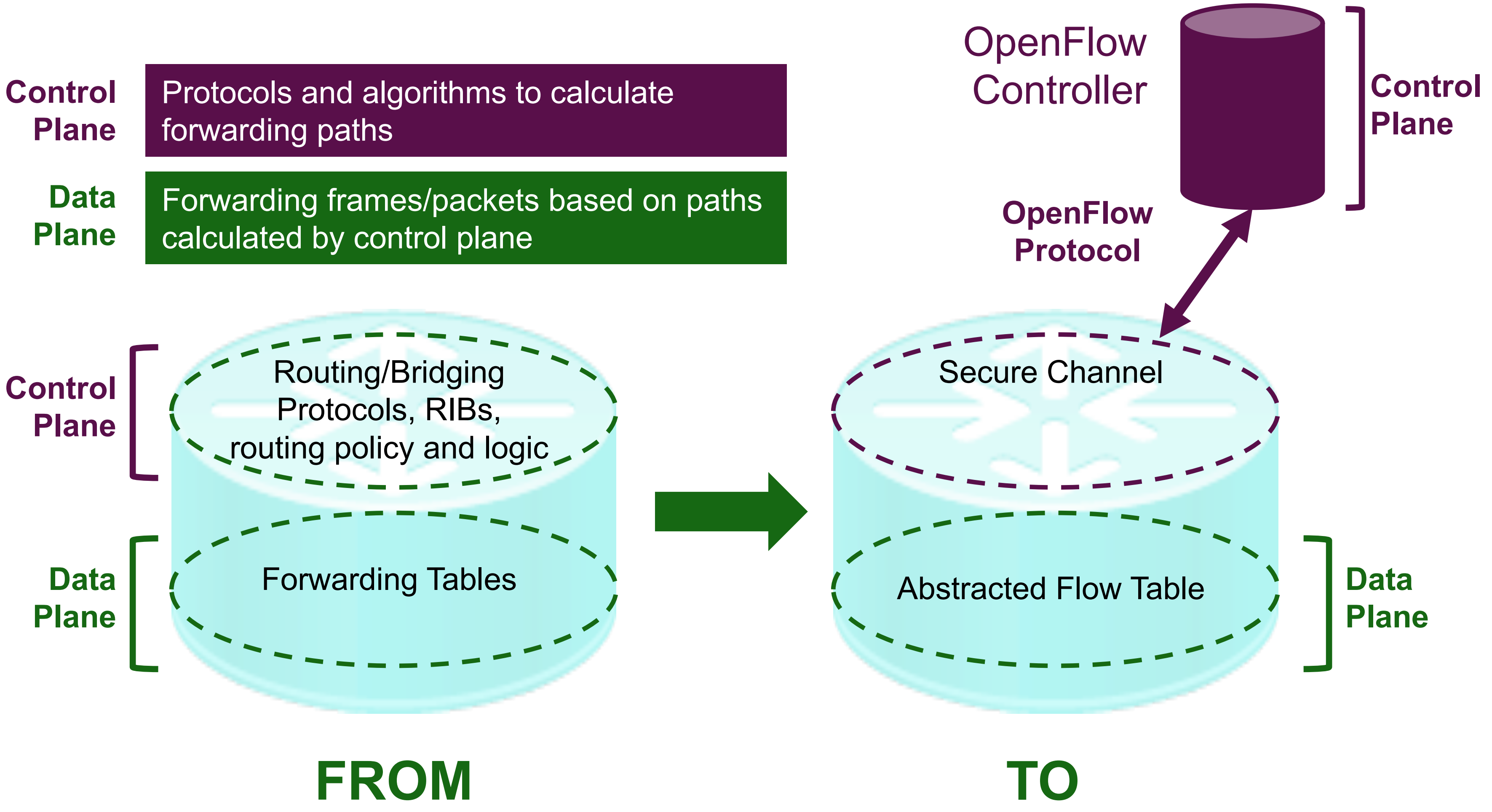
Tight coupling

Challenge: how do we influence packet switching/forwarding behaviour ?

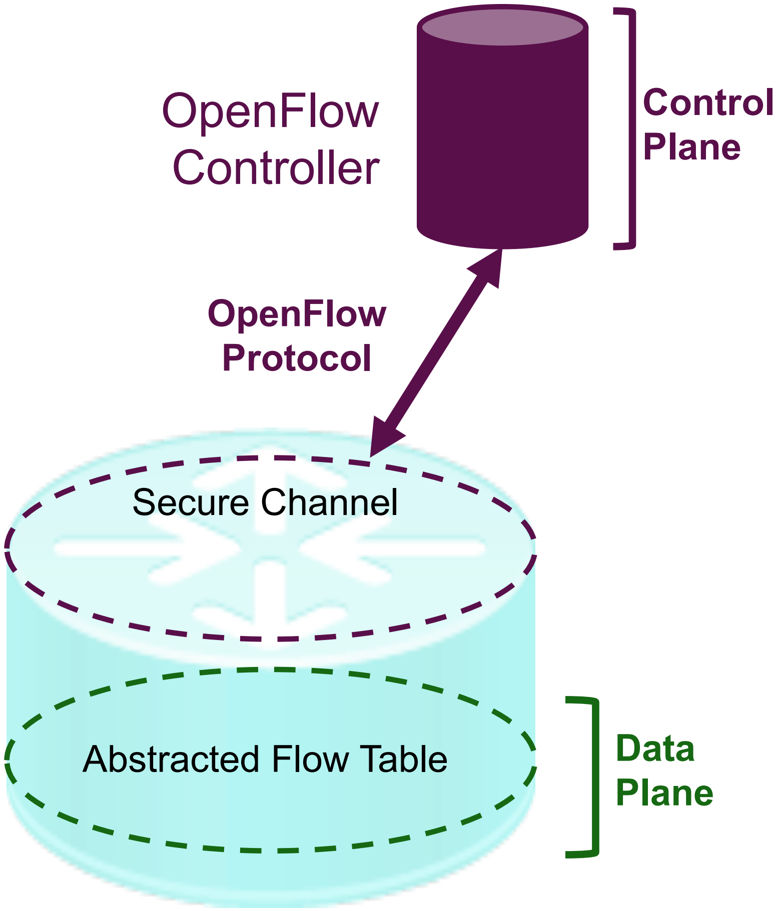
OpenFlow: The Solution (1)

Control Plane Protocols and algorithms to calculate forwarding paths

Data Plane Forwarding frames/packets based on paths calculated by control plane



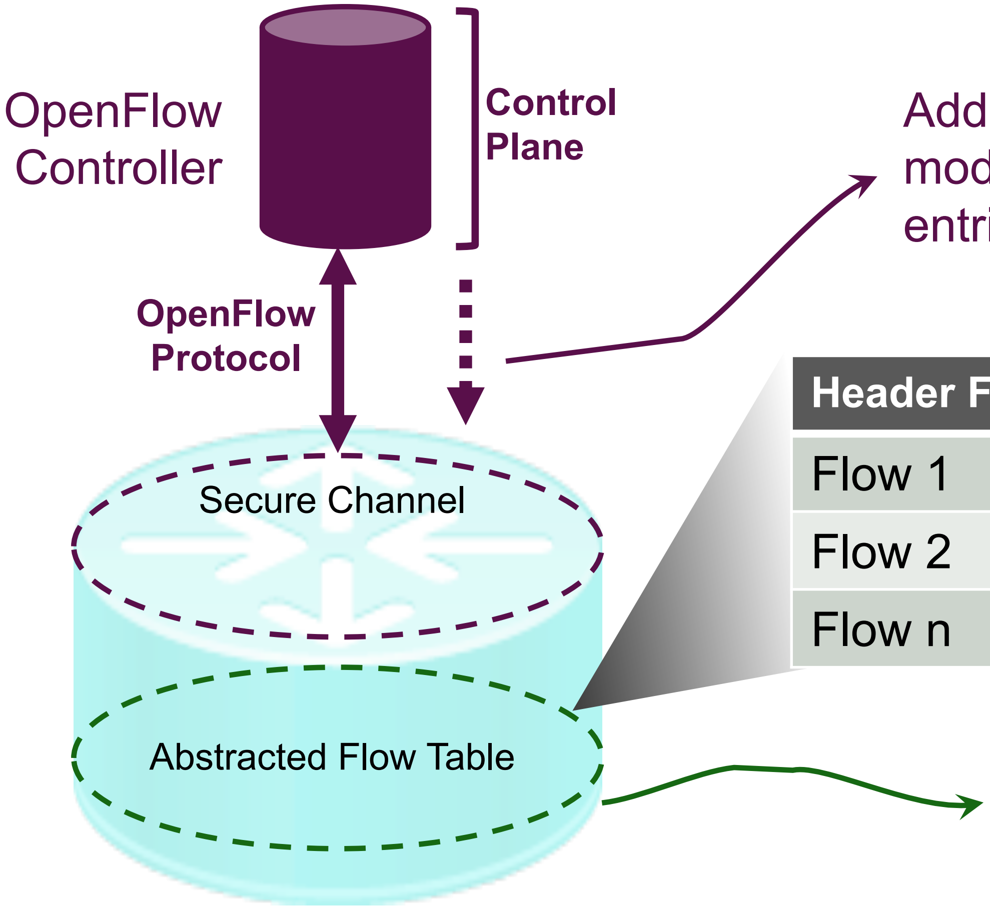
OpenFlow: The Solution (2)



The Solution:

- OpenFlow provided a compromise that provided a means of influencing switching/routing decisions without opening up network software.
- The control software would run on a controller; the outcomes of the calculations would be pushed down to the data plane running on the network element

OpenFlow: How it works (1)



Adds, deletes and modifies flow table entries

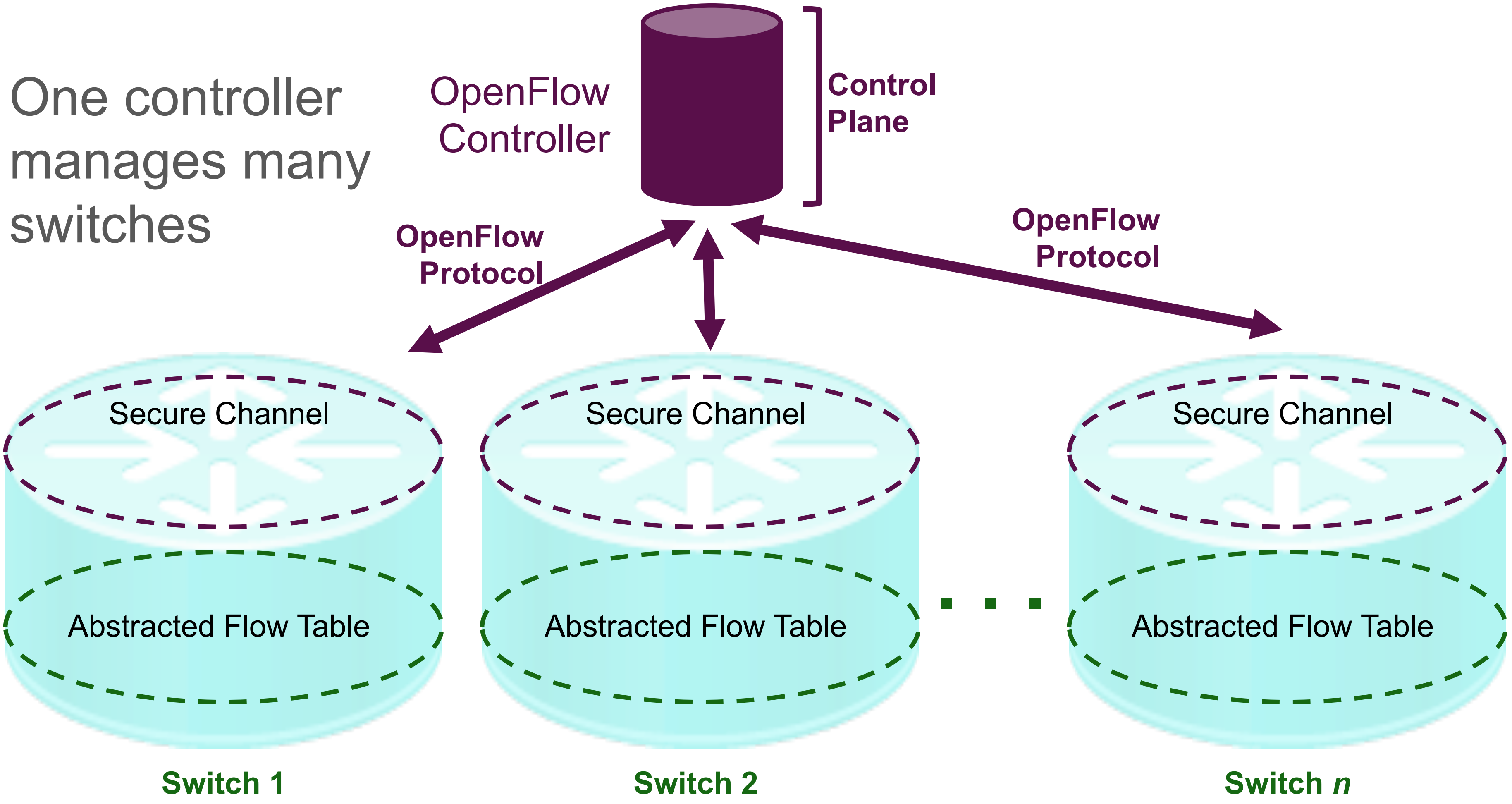
Header Fields*	Actions	Counters
Flow 1	Forward to port 1/1	
Flow 2	Drop	
Flow n	Send to controller	

Switch forwards traffic by matching against header fields and taking corresponding actions

* Ingress Port, Ethernet SA, Ethernet DA, VLAN ID, VLAN PCP, IP SA, IP DA, IP Proto, IP ToS, Source L4 Port, Dest L2 Port etc….

OpenFlow: How it works (2)

One controller manages many switches



OpenFlow: Today

- Initially synonymous with SDN
- Today, OpenFlow is relegated to being just a part of the greater SDN architecture, with other protocols competing in the same space
- It is, however, responsible for the most radical paradigm shift in IP in recent times.

OpenFlow: Implications

- Two primary implications:

The control plane (processes to determine how traffic is handled) is physically **decoupled** from the data plane (forwards traffic according to decisions passed down by the control plane).

The control plane is **consolidated and centralised**: a single software control plane controls multiple data planes (previously a 1:1 correspondence).

The Birth of SDN

The separation of control and data plane was **not** an objective in itself but was a consequence of the compromise approach taken by OpenFlow

It heralded a new era of **programmability** that has been vastly enhanced with new architectures and capabilities

The term '**SDN**' itself was coined in an article about the OpenFlow project at Stanford

(http://www2.technologyreview.com/news/412194/tr10-software-defined-networking/)

Emergence and evolution of SDN

- OpenFlow was a starting point…
  – Ushered in an era of programmability
  – But a complete decoupling of the control plane and data plane was not practical:
    - We would have had to solve all the problems the industry had spent decades solving and refining: resiliency, scalability, convergence, redundancy etc

- SDN architecture today
  – Hybrid approach where some elements of the control plane remain distributed while others are centralised.
  – Many different architectural models
  – All of them aspire to achieve the goals of agility and network programmability

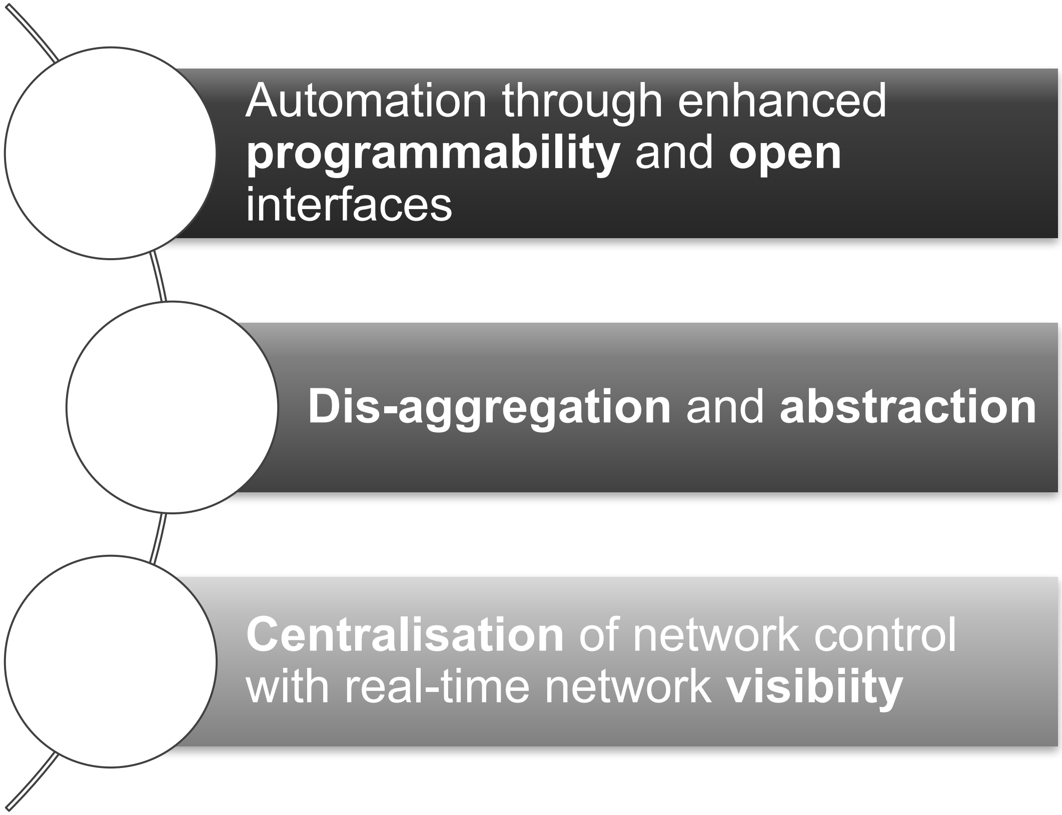
Defining SDN

ONF: The physical separation of the network control plane from the forwarding plane, and where a control plane controls several devices.

This definition is too narrow…

SDN is …

A new approach to networking that provides greater **network agility** and **flexibility** by:



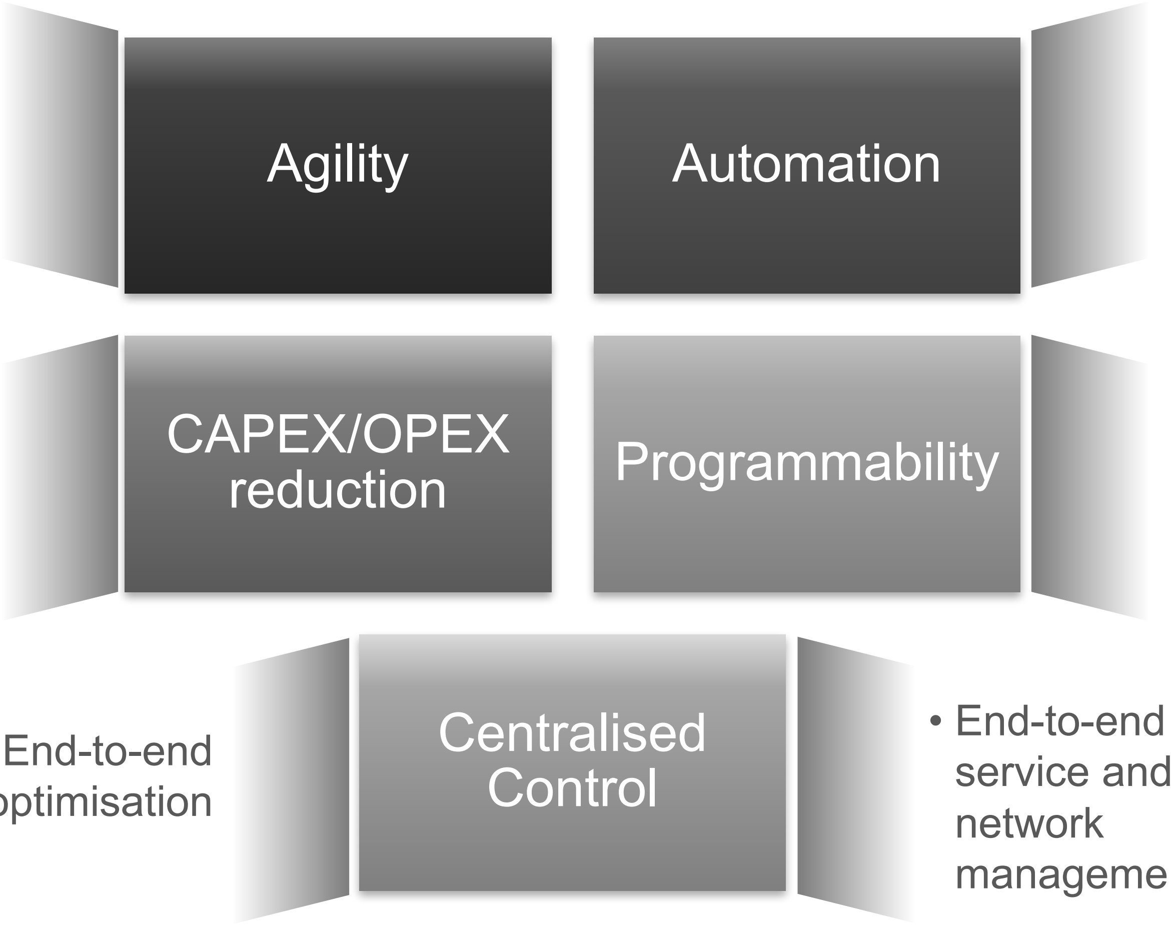
Automation through enhanced **programmability** and **open** interfaces

Dis-aggregation and **abstraction**

Centralisation of network control with real-time network **visibiity**

As much a marketing term as a technical one

Objectives and benefits of SDN



Agility

- Quicker introduction of new services for faster time to revenue

Automation

- Service provisioning
- Network provisioning
- Service automation

CAPEX/OPEX reduction

- Reduction in hardware and network operations costs

Programmability

- Abstraction via simplified, open interfaces

Centralised Control

- End-to-end optimisation
- End-to-end service and network management

SDN SDOs

IETF®

ONF
OPEN NETWORKING FOUNDATION

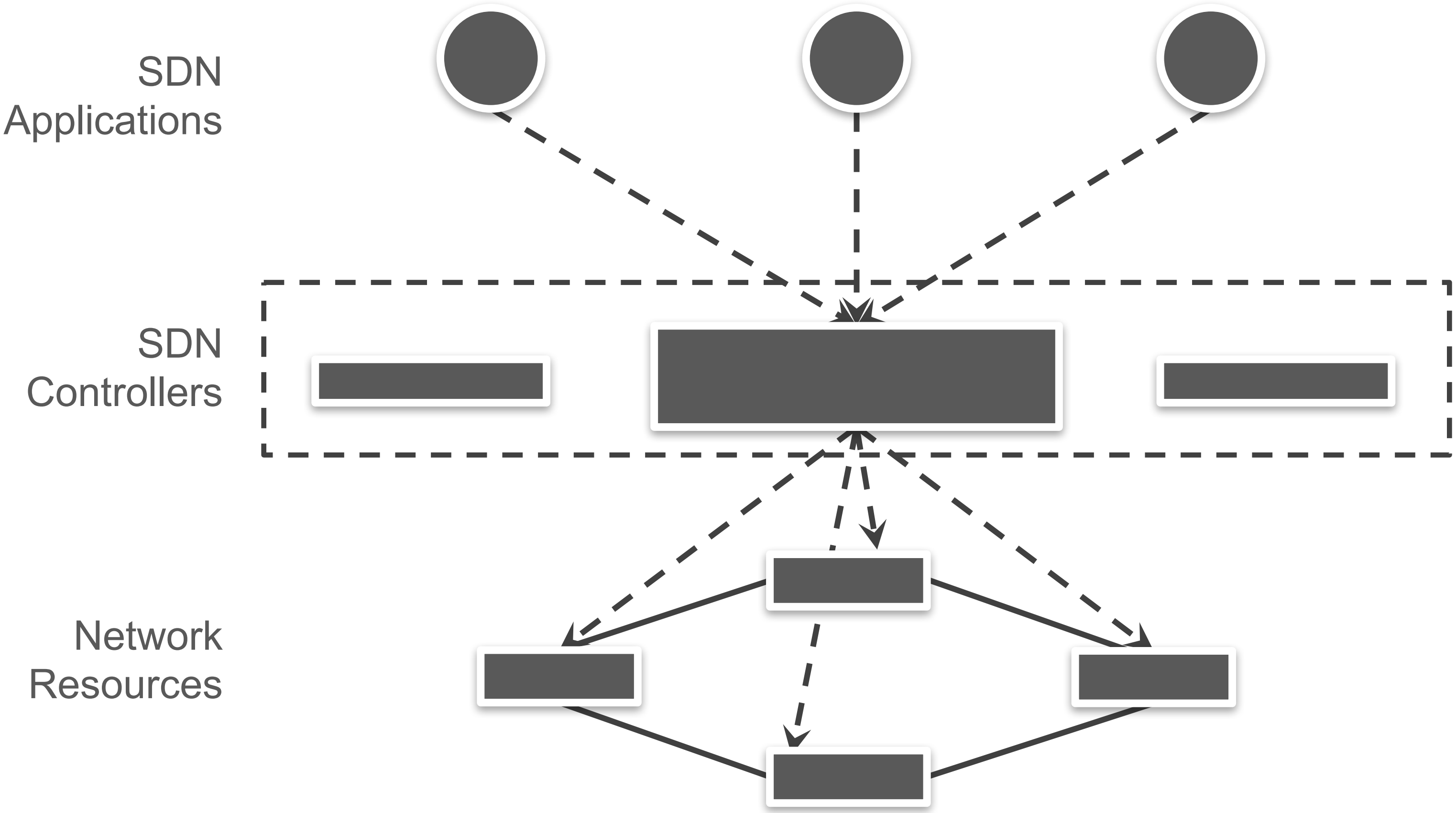
MEF
METRO ETHERNET FORUM

ITU

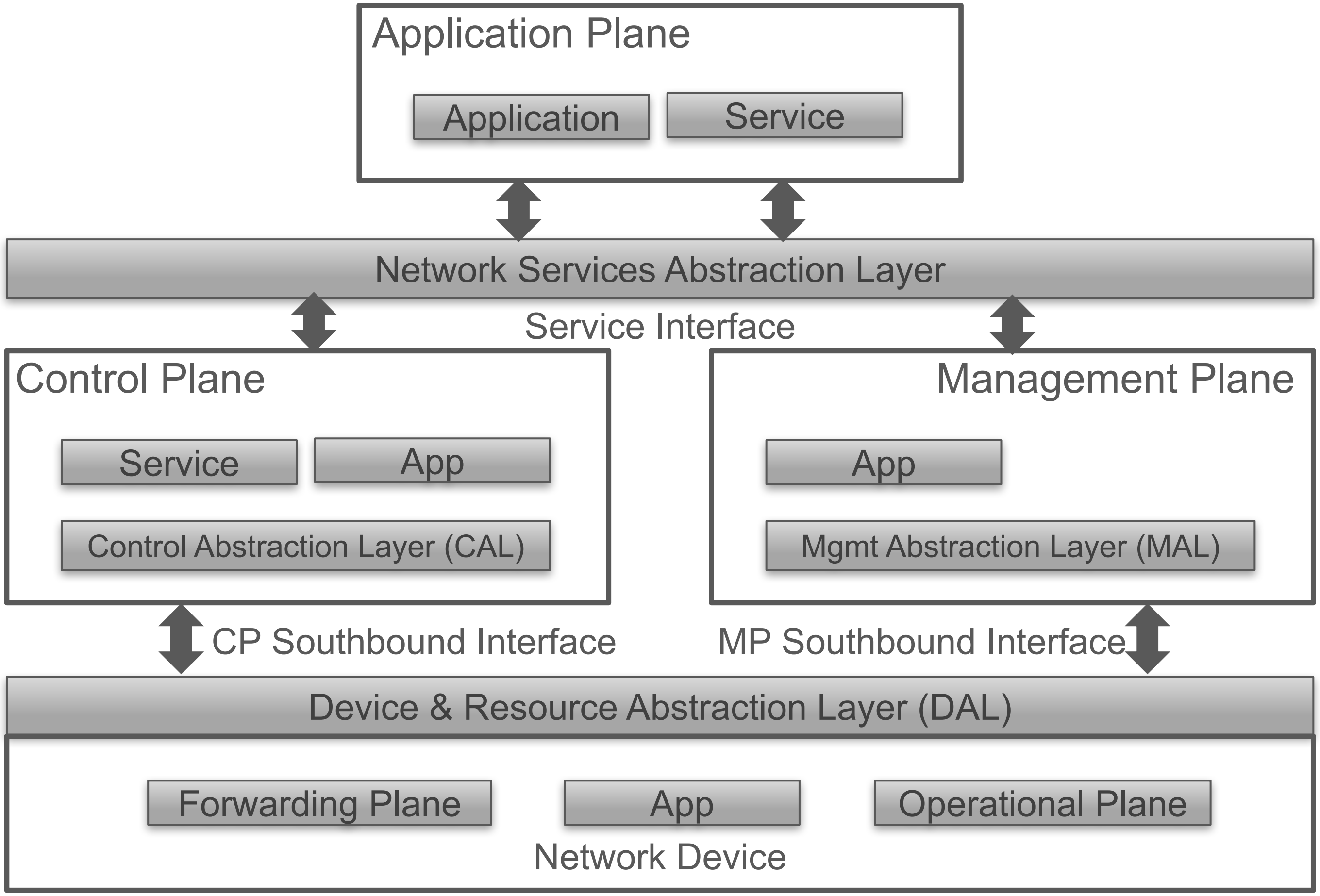
broadband forum

SDN architectural framework (1)

ITU-T Y.3300

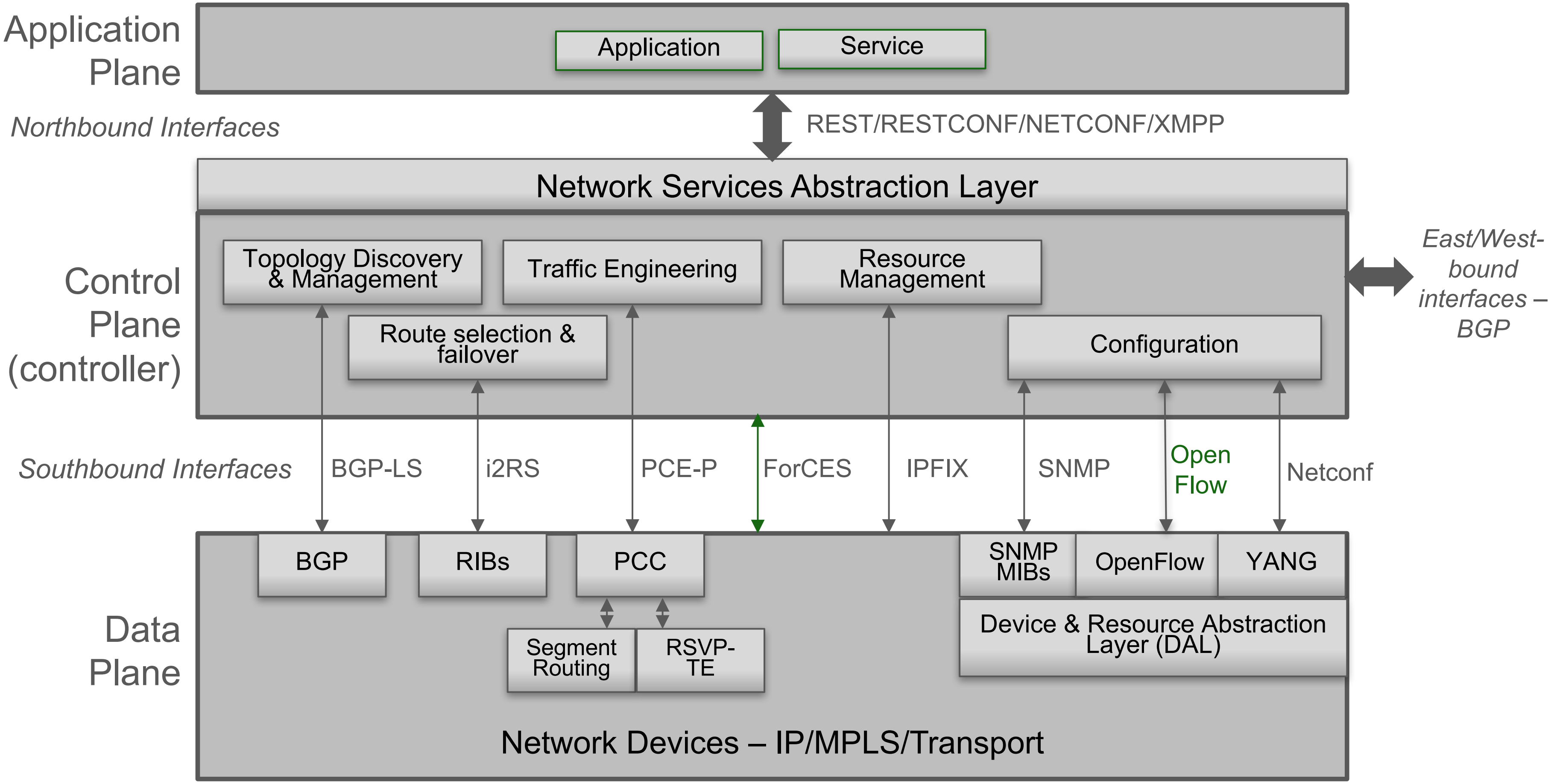


SDN architectural framework (2)



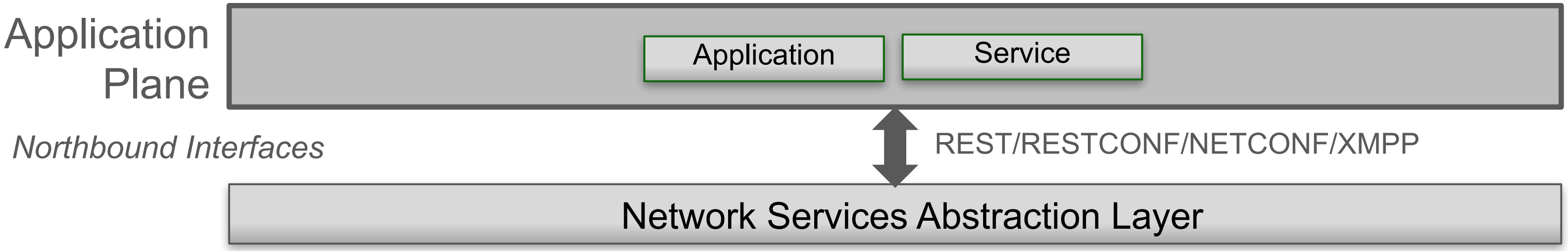
RFC 7426

SDN architectural framework (3)


Application Plane
Application
Service
Northbound Interfaces
REST/RESTCONF/NETCONF/XMPP
Network Services Abstraction Layer
Control Plane (controller)
Topology Discovery & Management
Traffic Engineering
Resource Management
Route selection & failover
Configuration
East/West-bound interfaces – BGP
Southbound Interfaces
BGP-LS
i2RS
PCE-P
ForCES
IPFIX
SNMP
Open Flow
Netconf
Data Plane
BGP
RIBs
PCC
SNMP MIBs
OpenFlow
YANG
Segment Routing
RSVP-TE
Device & Resource Abstraction Layer (DAL)
Network Devices – IP/MPLS/Transport

Note: designations of north-bound and south-bound are relative to the control plane ("controller")

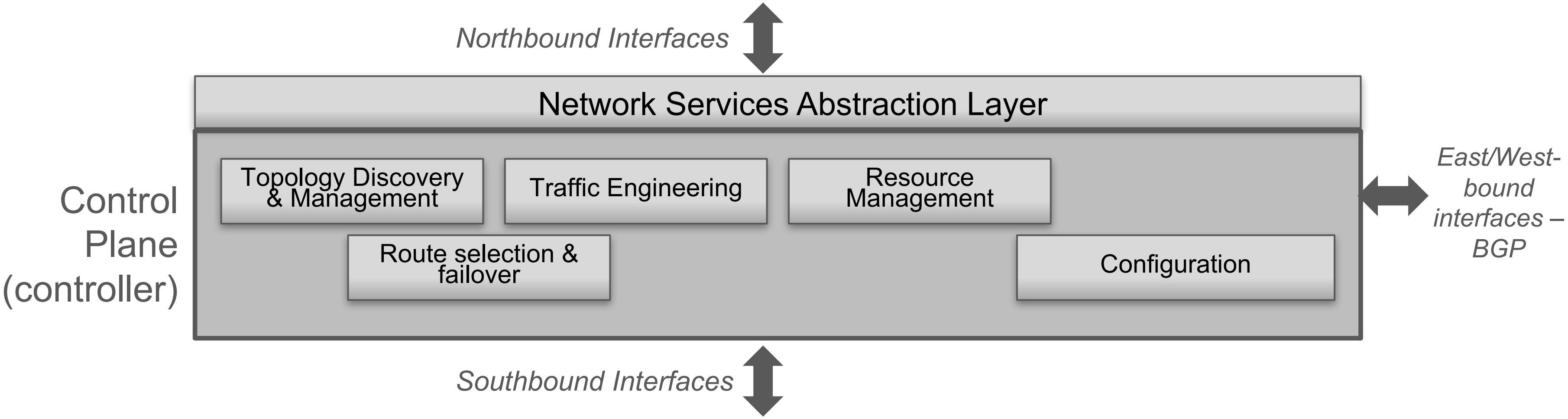
Elements of SDN architecture (1)


Application Plane
Application
Service
Northbound Interfaces
REST/RESTCONF/NETCONF/XMPP
Network Services Abstraction Layer

- Application Plane
  - "Consumers" of the network
  - Traffic optimisation applications
  - OSS systems
  - End-customer self-service portals
  - Etc.

- Northbound interfaces
  - Abstraction of network services towards applications and services
- Network Services Abstraction Layer:
  - Normalises network and service constructs via an open API or interfaces - YANG models, NETCONF, RESTCONF

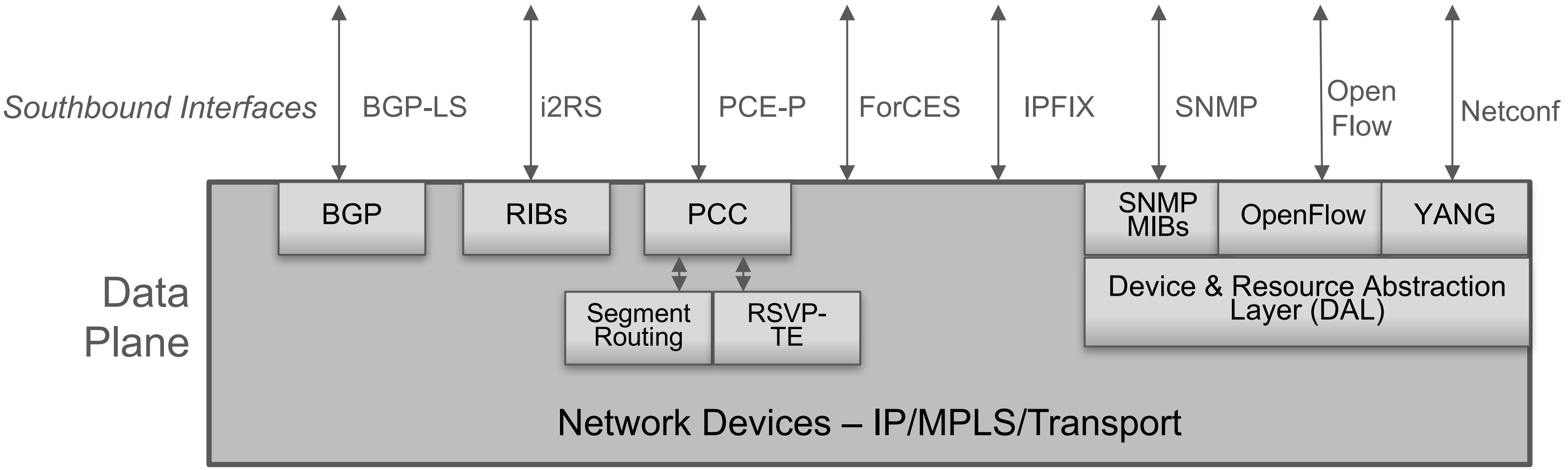
Elements of SDN architecture (2)


Northbound Interfaces
Network Services Abstraction Layer
Control Plane (controller)
Topology Discovery & Management
Traffic Engineering
Resource Management
Route selection & failover
Configuration
East/West-bound interfaces – BGP
Southbound Interfaces

- Control Plane layer
  - “The Controller”; the brains of the operation
  - Translates high-level instructions from north-bound interfaces and converts them to instructions for the resource layer

  - Collection of key functions:
    - Topology discovery
    - Traffic engineering
    - Resource management
    - Route selection and failover
    - Service configuration
    - Mediation
  - Southbound interfaces

Elements of SDN architecture (3)



- Southbound interfaces
  - Myriad interfaces, plug-ins, and protocols, including OpenFlow
  - Device-specific details abstracted from higher layers of the controller

- Data Plane
  - Traditional and newer generation dataplanes, physical and virtual
  - Augmented by SDN-friendly protocols such as Segment Routing

Key SDN use cases

Data Centre network automation

- Most widely-deployed and mature solution
- Automation of network connectivity via overlay networks
- Multi-tenancy

SD-WAN

- Extension of DC automation concepts
- Site connectivity via overlay networking

Service Automation & provisioning

- Direct customer access via portals
- Bandwidth on demand
- Bandwidth calendaring

Network optimisation

- Link and path optimisation based on real-time network state
- Running networks "hotter"

Open source projects

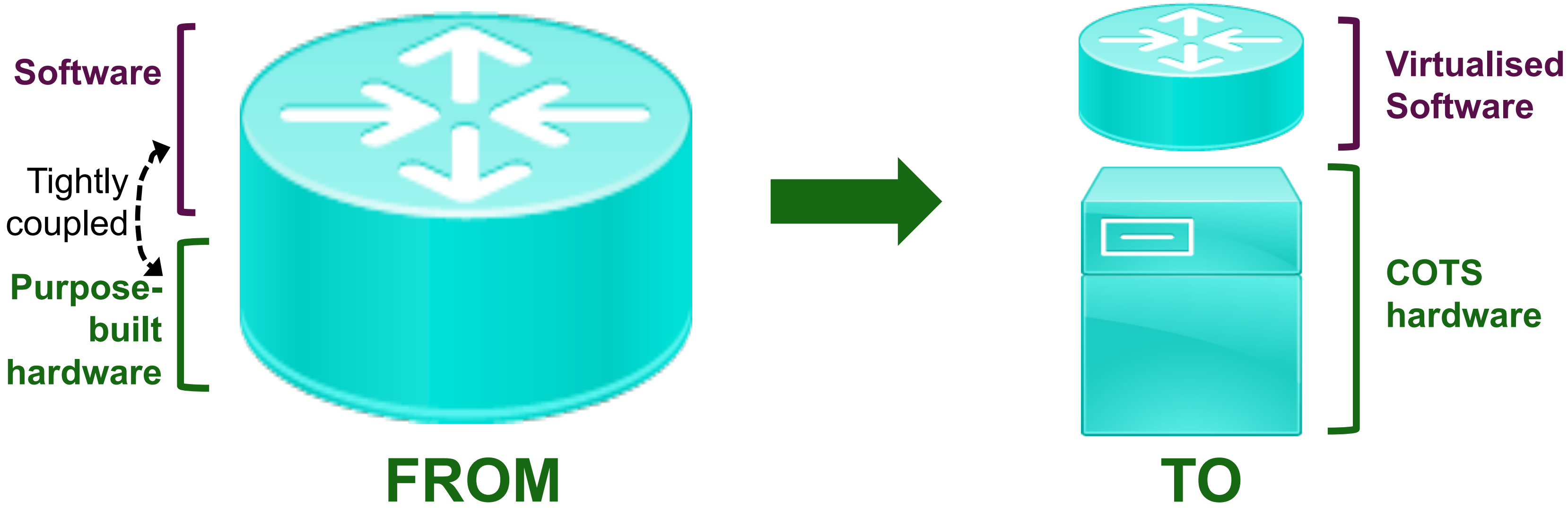
OPENDAYLIGHT

onos
Open Network Operating System

Comparing and contrasting with NFV

SDN: decouples control plane and data plane

NFV: decouples network software from closed, proprietary hardware systems



OpenFlow Demo

- HP VAN SDN Controller
- Mininet &
- OpenDayLite Controller

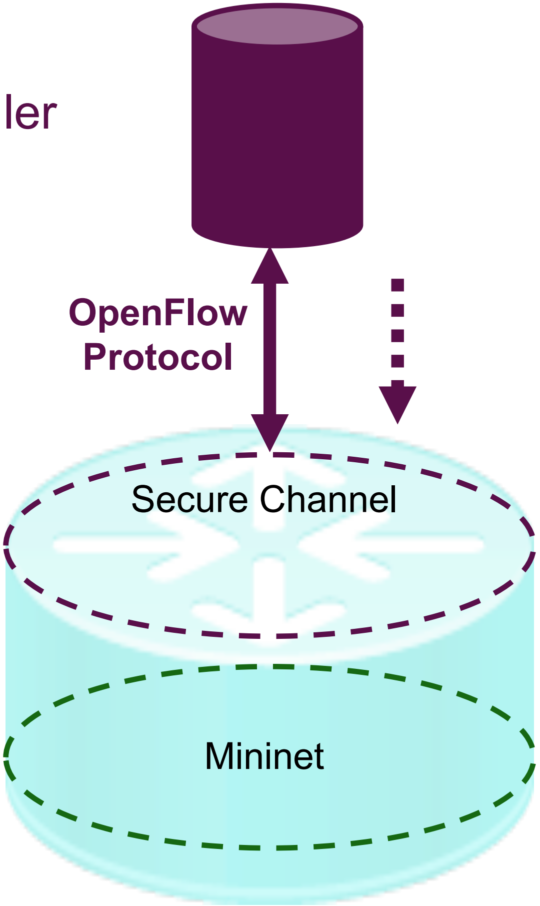
Demo Topology

HPE VAN Controller

192.168.58.10

Mininet

192.168.58.15



OpenFlow Protocol

Secure Channel

Mininet

Thank You !

Issue Date:

Revision: