CSC7970 – NEXT-GENERATION NETWORKING

SOFTWARE DEFINED NETWOKRING

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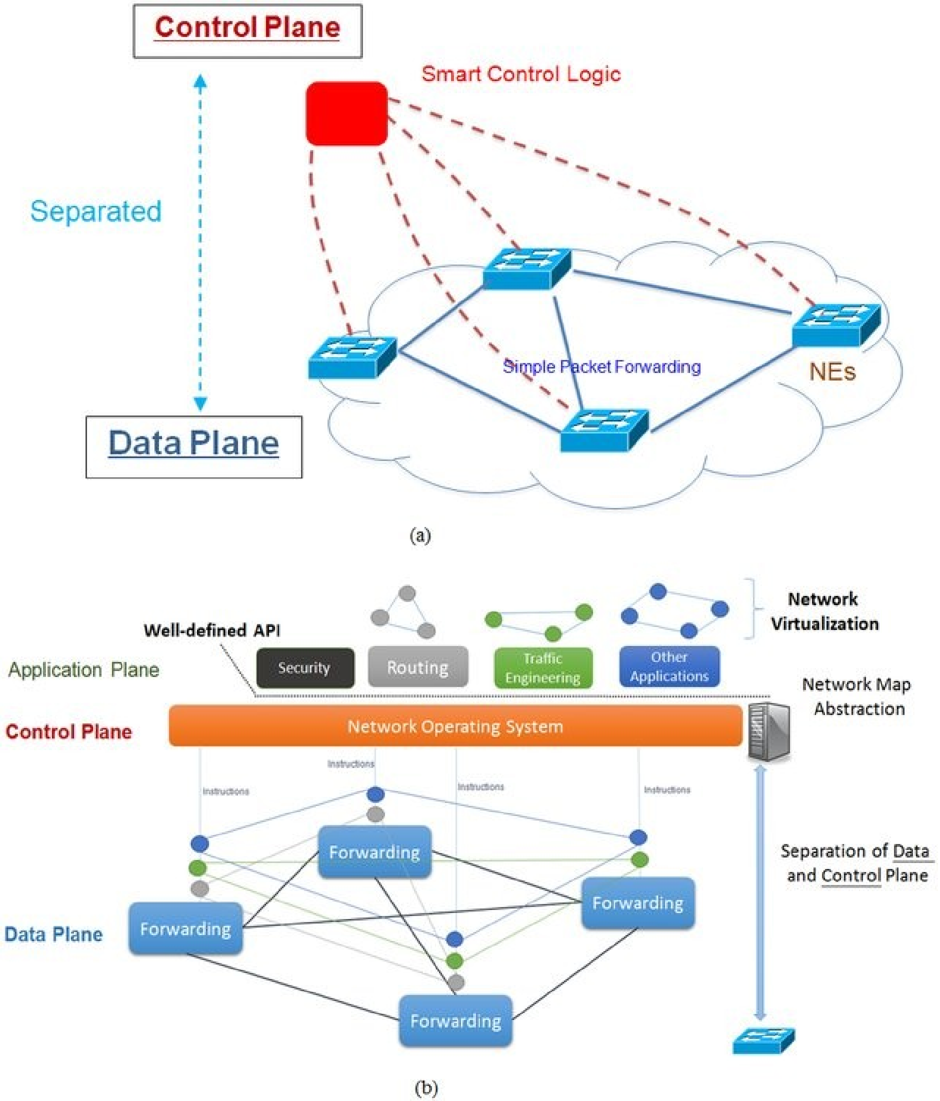
Control vs Data Plane



(a)

(b)

In traditional networks, they are in the same device.

Problems?

Difficult to change
Difficult to deploy new protocols
Many vendors and so on

https://www.researchgate.net/publication/309917884_An_adaptive_load_monitoring_solution_for_logically_centralized_SDN_controller/figures?lo=1

SDN

- What is Software-Defined Networking?
  - Networking paradigm where control and forwarding plane are decoupled
  - Network intelligence is (logically) centralized and physically separate from forwarding devices

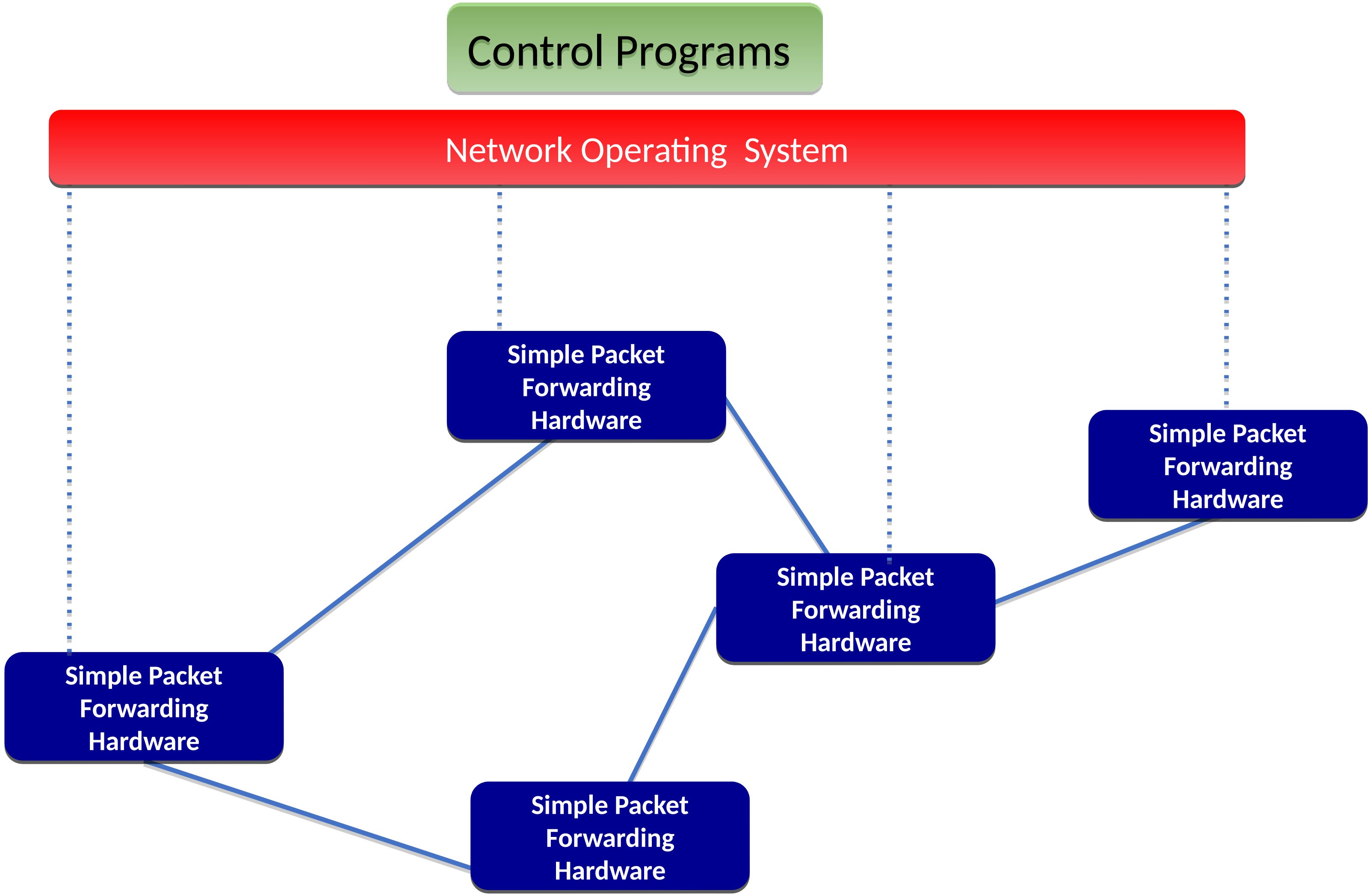
- Controller/forwarding device model
  - Controller is the network intelligence!
  - Forwarding device is “dumb”
  - Forwarding device asks the controller how to forward traffic

Why SDN?

- (Distributed) Networks are hard to manage/configure nowadays
  - Massive scale
  - Many different stakeholders
  - Many vendors with their own implementations

- Simplify network configuration and management
  - Centralize the management/configuration entity in a network
  - Create a network Operating System (OS)
  - Much higher uptime
  - Days vs years to deploy new protocols
  - Problem solved?

Idea: An OS for Networks

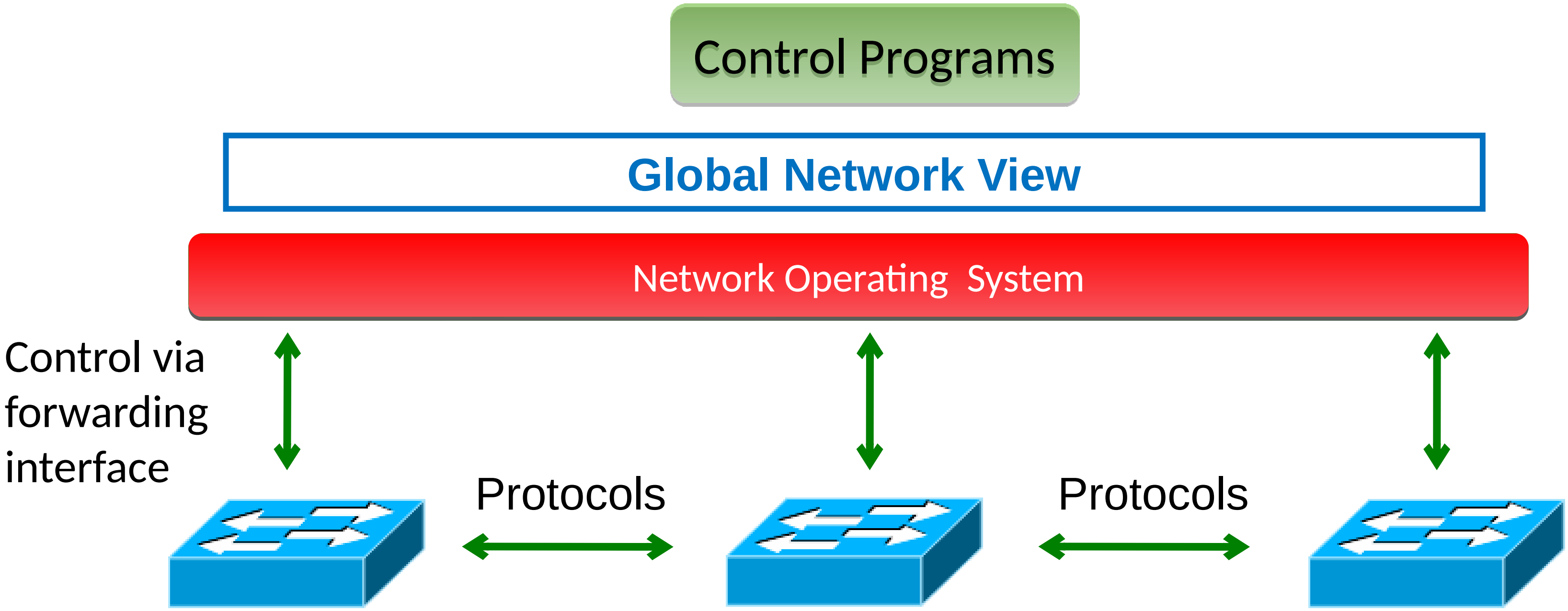

Control Programs
Network Operating System
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware
Simple Packet Forwarding Hardware

Centralized intelligence

- ***No more distributed protocols!***
  - Network intelligence is centralized
  - Easier to implement, write code for, debug, maintain..

- Network OS is the fundamental control block (the “abstraction”)
  - Global view of the network

Global Network View



The Future of Networking, and the Past of Protocols, Scott Shenker, *with Martin Casado, Teemu Koponen, Nick McKeown*

Does SDN solve TCP/IP’s problems?

- SDN is centralized!
- SDN works well for enterprise networks (a single data-center, etc.)
  - Small (to medium)-scale networks operated by a single stakeholder
  - Mostly stable, protected, well-managed environments

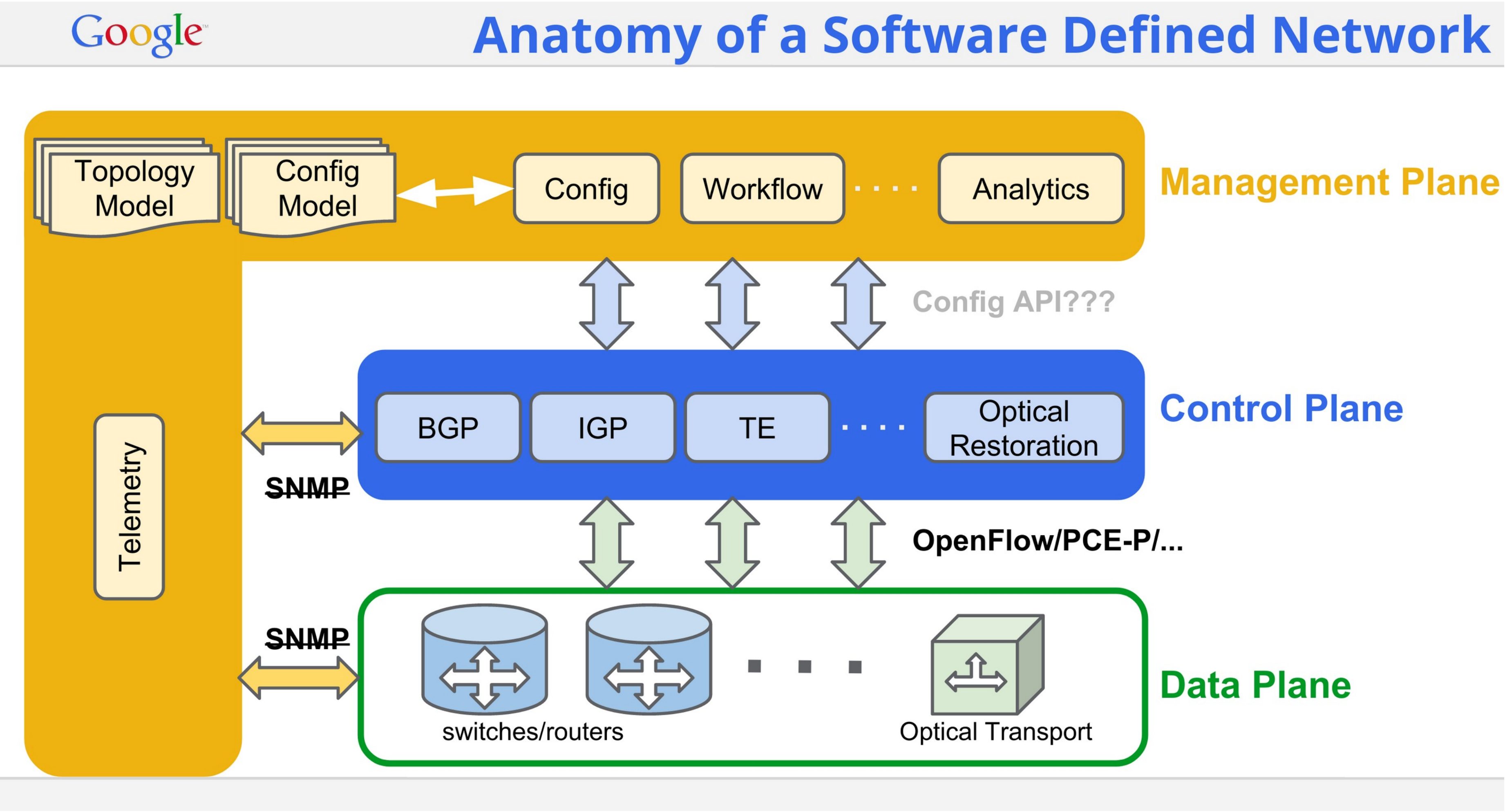
- Can it be deployed across the Internet?
- Does it work across networks of different stakeholders?
- What about fault tolerance? ← Important!

Fault tolerance tradeoffs

- Central controller → Bottleneck and Single point of failure
  - Can have multiple central controllers
    - But how do you synchronize?
  - Hierarchy of controllers
    - Single point of failure still exists

- Works well when you have control over your network
  - Google data centers

Speaking of Google



Google

Anatomy of a Software Defined Network

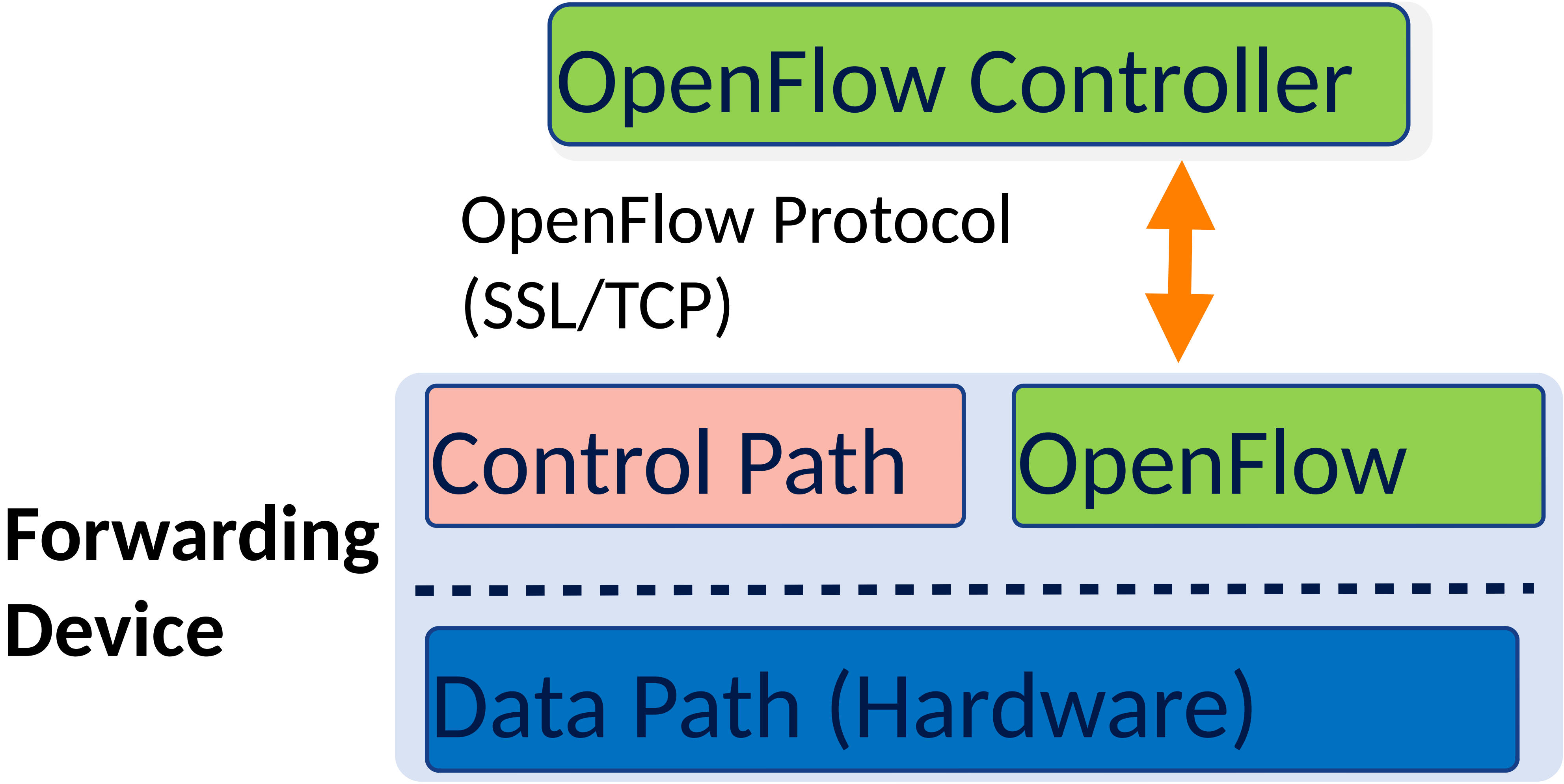
https://static.googleusercontent.com/media/research.google.com/en//pubs/archive/

OpenFlow

- Part 1: Protocol for network controllers to communicate with forwarding devices and vice versa
  - Common language between controllers and devices

- Part 2: Devices ask the controller how to forward the traffic they receive
  - They categorize traffic into flows
  - They ask the controller how to forward a flow, then cache this decision for some amount of time

Architecture

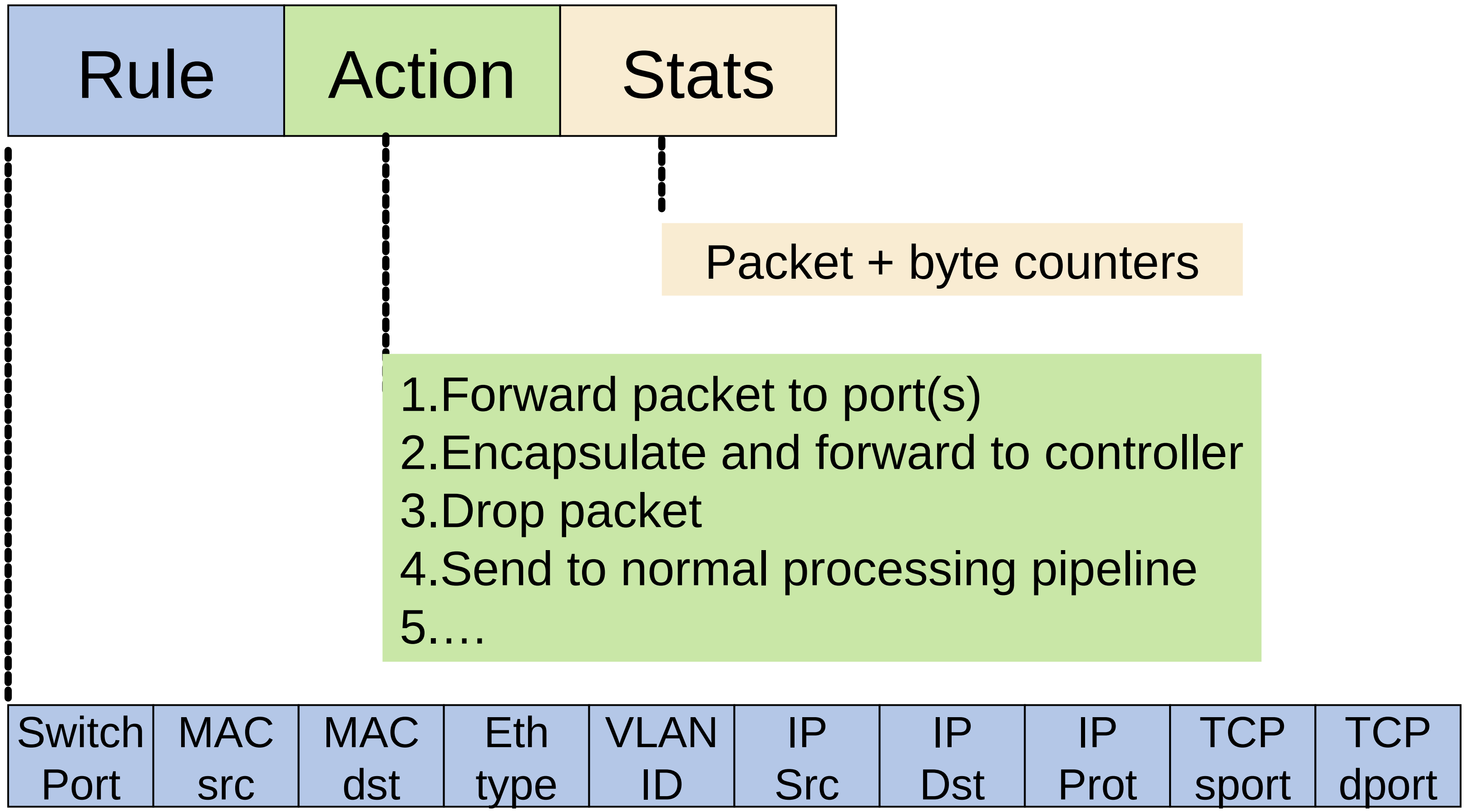


Flow table & traffic flows

- Each forwarding device (switches) maintains a flow table
  - Specifies the actions to take for each traffic flow
  - Override a “class” ← networking device capability
  - Use one of the many data structure available in modern devices to store additional information

- Creation of flows of packets is based on L2-L4 header fields
  - Combinations of MAC src, MAC dst, IP src, IP dst, TCP sport, TCP dport, etc.

Flow table entry



Rule	Action	Stats

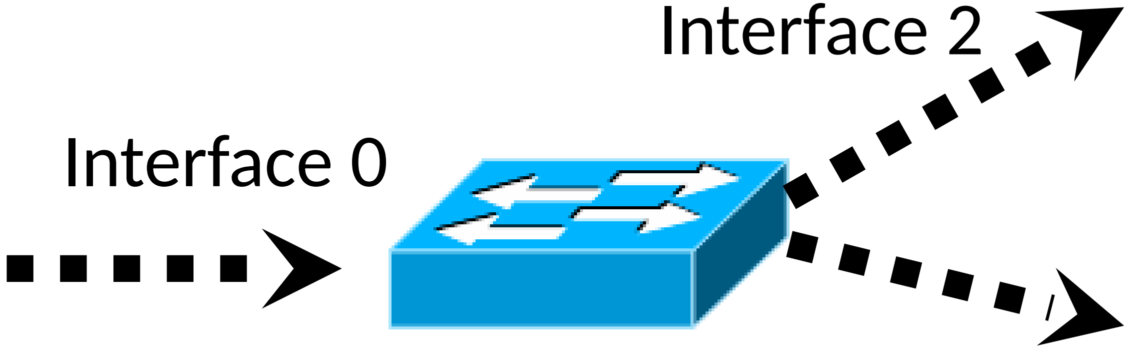
Packet + byte counters

1. Forward packet to port(s)
2. Encapsulate and forward to controller
3. Drop packet
4. Send to normal processing pipeline
5. …

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	IP Src	IP Dst	IP Prot	TCP sport	TCP dport

Example of operation

Controller



Interface 2

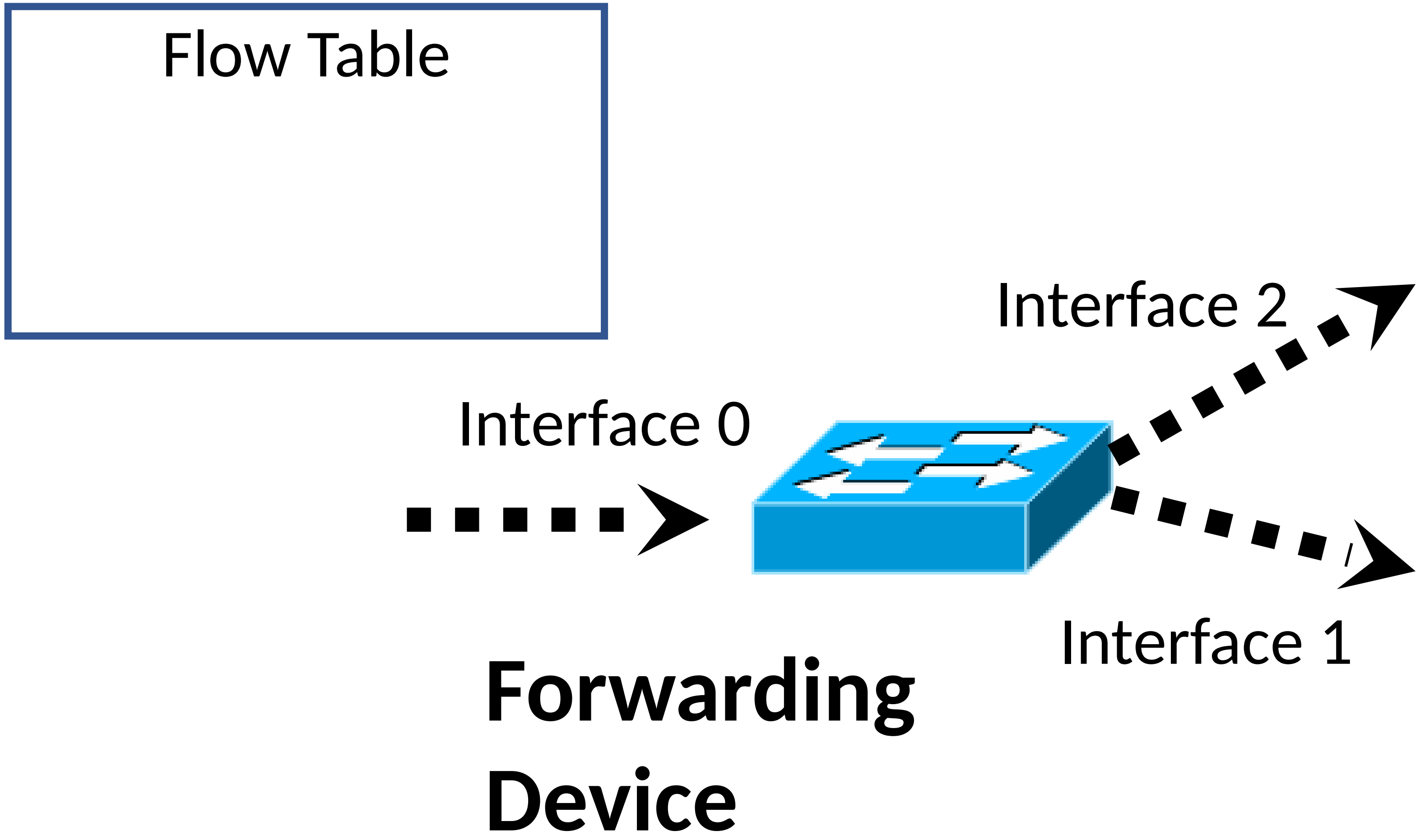
Interface 0

Interface 1

Forwarding Device

Example of operation

Controller



Flow Table

Interface 0

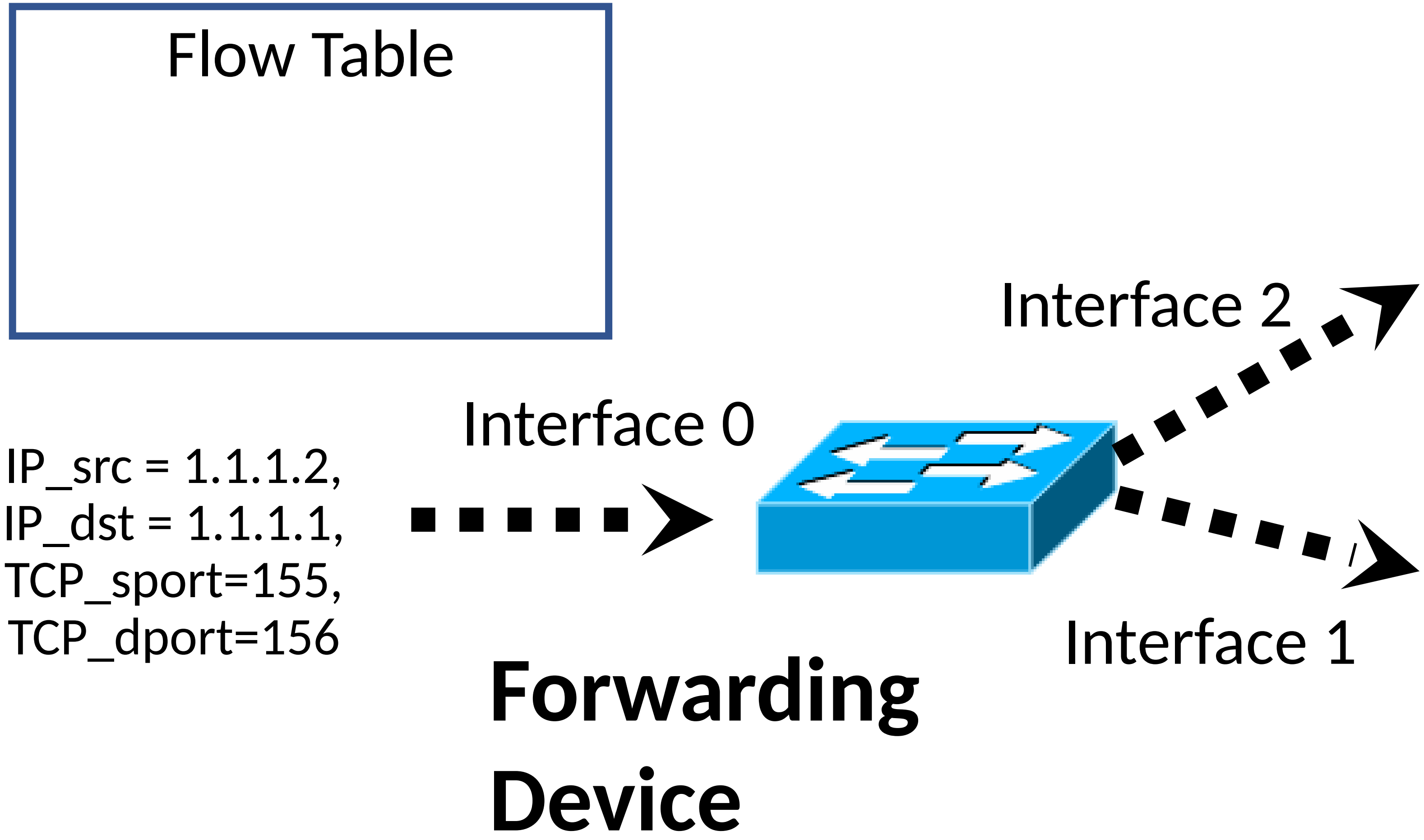
Interface 2

Interface 1

Forwarding Device

Example of operation

Controller



Flow Table

IP_src = 1.1.1.2,
IP_dst = 1.1.1.1,
TCP_sport=155,
TCP_dport=156

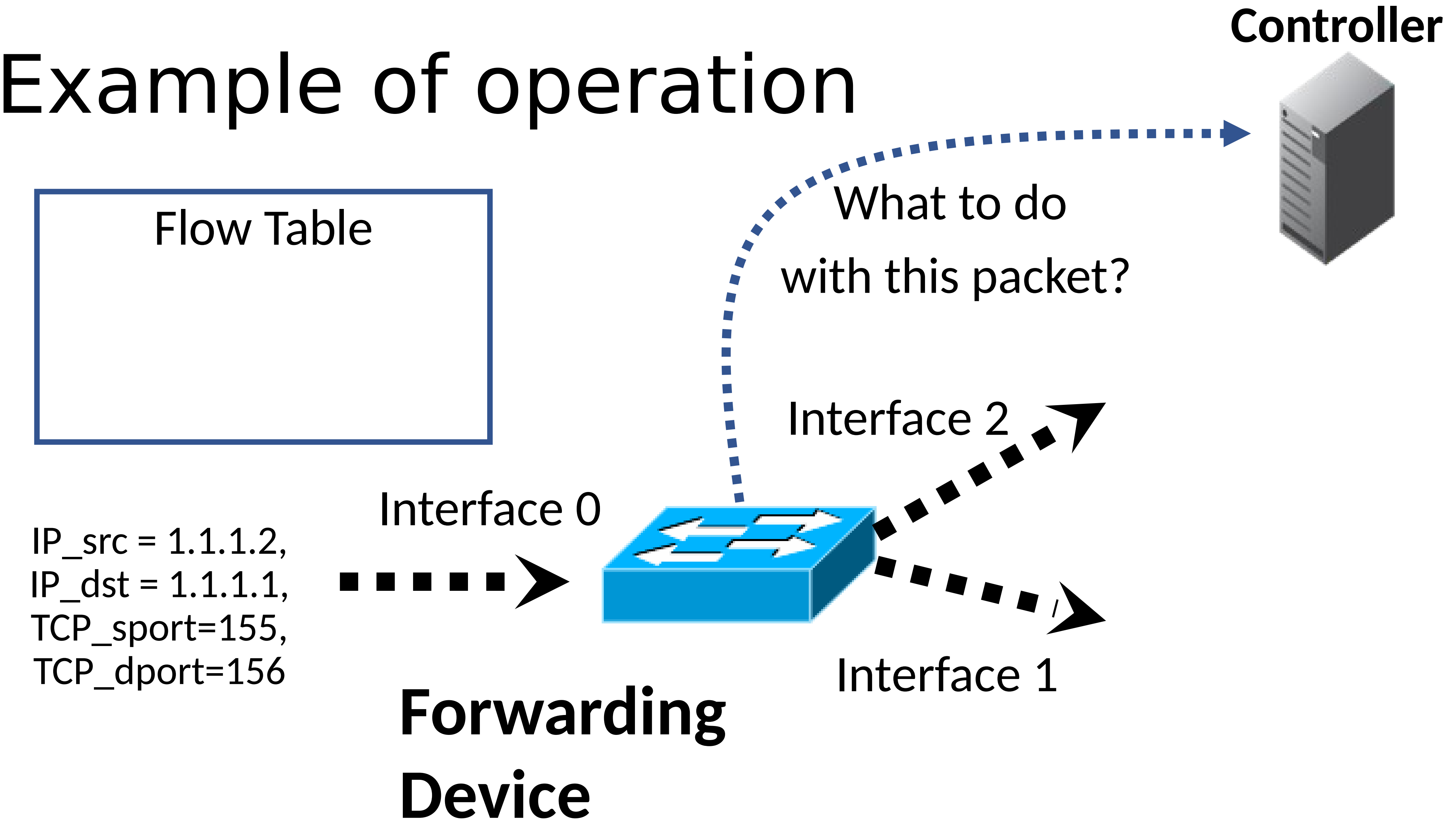
Interface 0

Interface 2

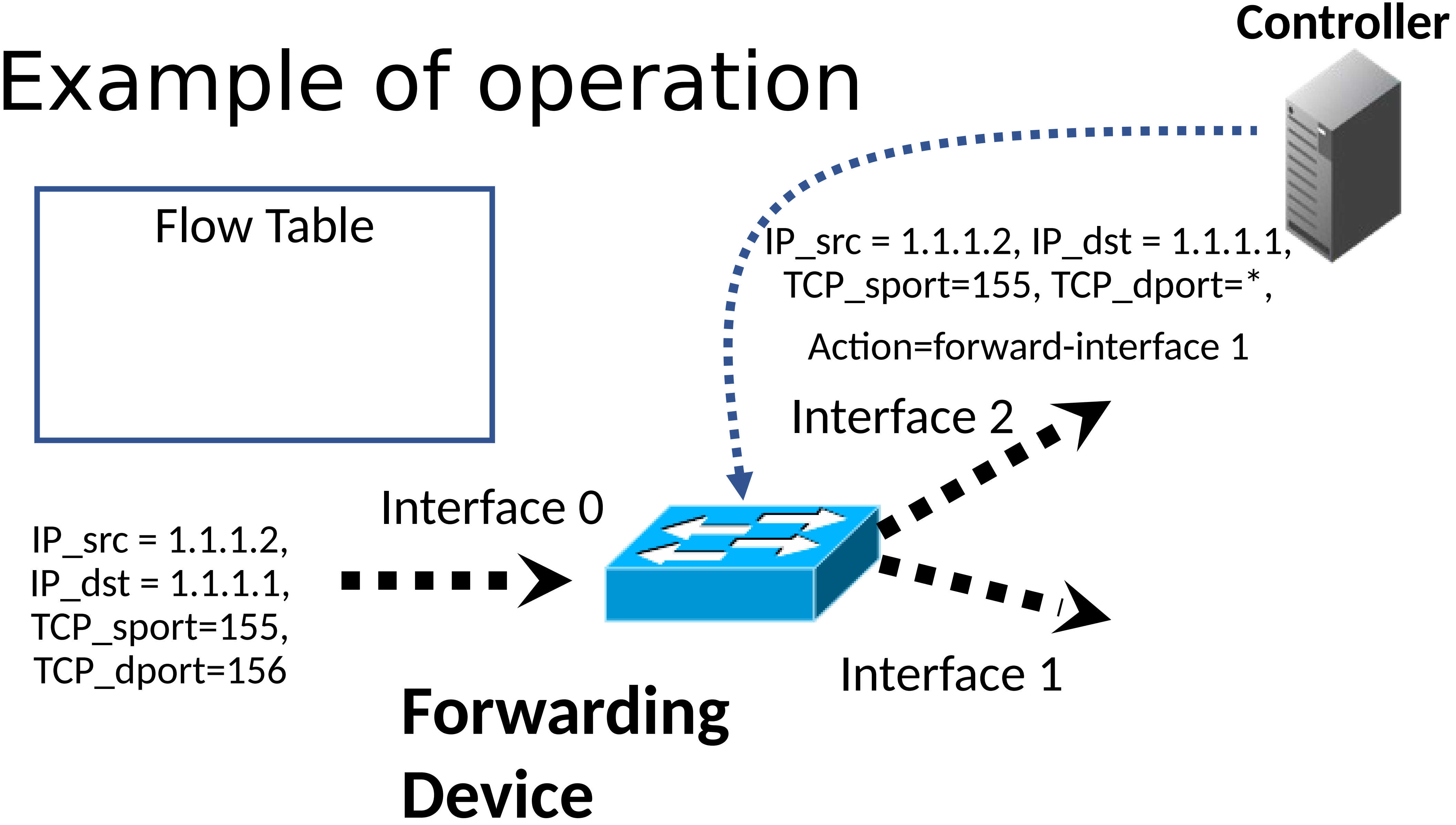
Interface 1

Forwarding Device

Example of operation



Example of operation



Flow Table

Controller

IP_src = 1.1.1.2, IP_dst = 1.1.1.1,
TCP_sport=155, TCP_dport=*,

Action=forward-interface 1

Interface 2

Interface 0

IP_src = 1.1.1.2,
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Interface 1

Forwarding Device

Example of operation

Controller

Flow Table

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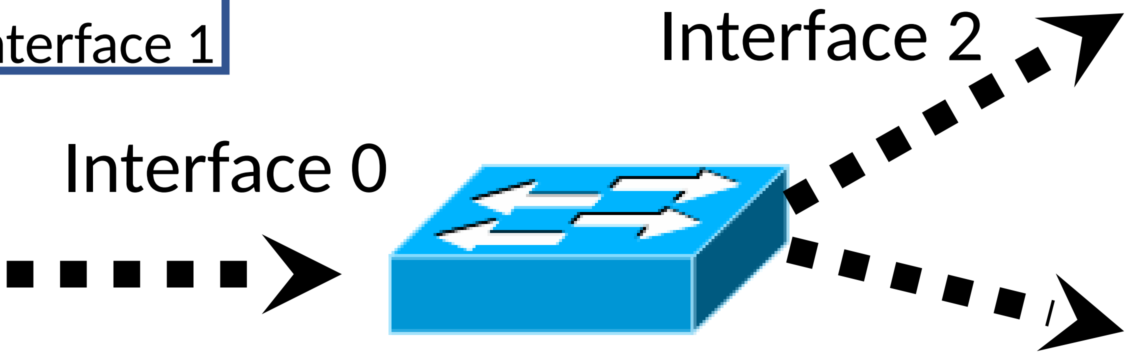

Forwarding Device

Example of operation

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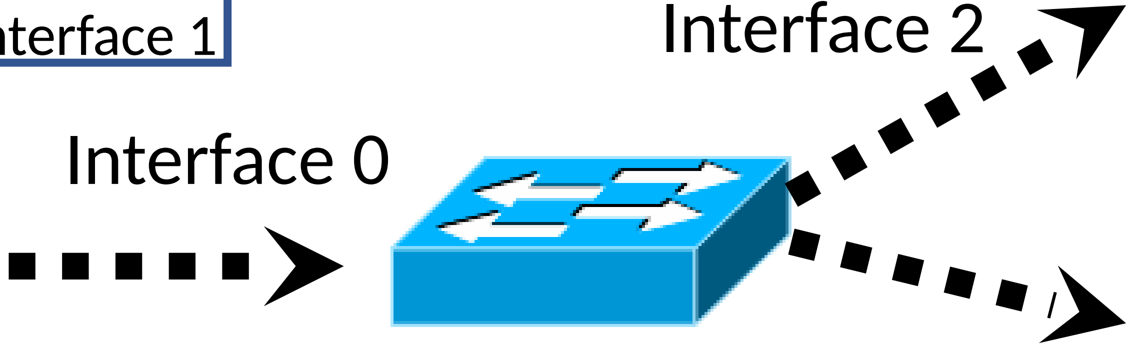
Controller



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Forwarding Device

Example of operation

Controller

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IP_src = 1.1.1.2,
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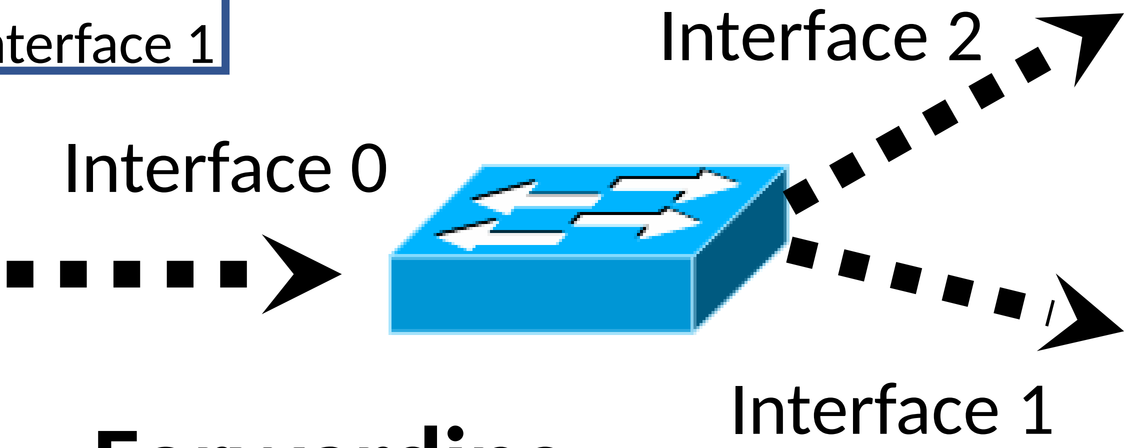
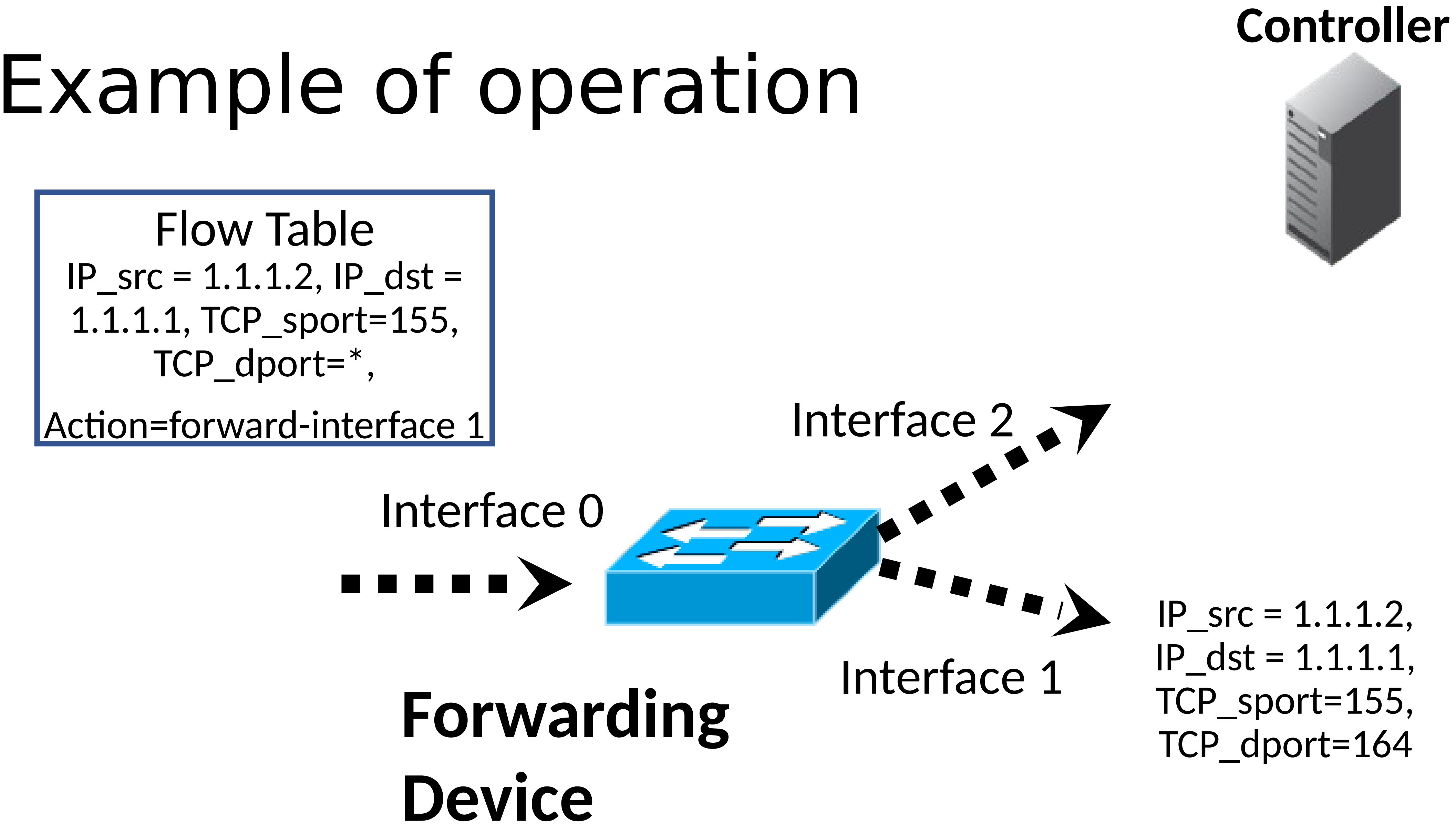
TCP_sport=155,
TCP_dport=164



Forwarding Device

Example of operation



Controller

Flow Table

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Action=forward-interface 1

Interface 0

Interface 2

Interface 1

IP_src = 1.1.1.2,
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TCP_sport=155,
TCP_dport=164

Forwarding Device

Network programmability

- Users create their own flow rules
  - They write code to define how the network should handle their traffic
  - Rules are installed by the controller into the forwarding devices
- Users can change their rules over time
  - Rules on the devices expire (soft state)
  - Devices request updated rules from controller over time

Industry adoption/deployment

- A number of vendors exist
  - Widely vary in capability and implementation
    - Expect things to break and not work!
    - Everyone rolls their own deployment
- SDN hardware support

Juniper MX-series

NEC IP8800

WiMax (NEC)

HP Procurve 5400

Netgear 7324

PC Engines

Why companies have bought in?

- SDN/OpenFlow solves problems in enterprise networks
  - People understand it since it is based on TCP/IP
  - Centralized intelligence has its origins in telephony (even before TCP/IP)..

- Single point of control/intelligence
  - Network verification/management/deployment are hard problems
  - SDN makes them easier..

- SDN works well in environments with:
  - Stable connectivity
  - (Minor to no) fault tolerance (or other means to achieve fault tolerance)
  - A single administrative entity

When SDN does not work well?

- Environments with:
  - Intermittent connectivity – if you can't connect to the controller
  - Fault tolerance as an absolute requirement (or with no other means to achieve fault tolerance)
  - Multiple administrative entities

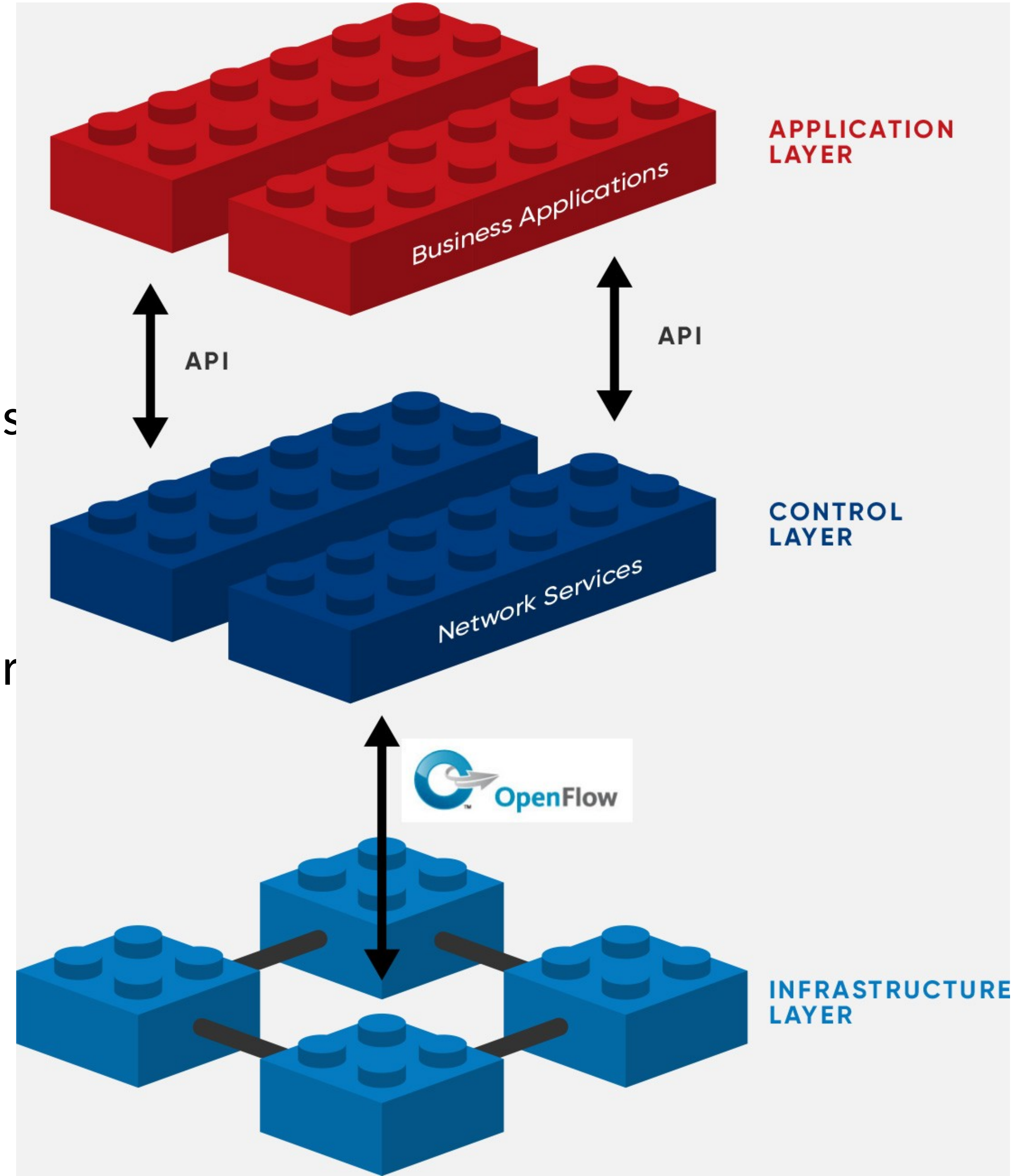
- SDN is an incremental patch to TCP/IP
  - Makes management easier!
  - Adds one more dependency (i.e., the controller)
  - Does not change any of the fundamentals
    - Flows are end-to-end, no security

Security Concerns?

- DDoS the controller, your whole network becomes defunct!
- Man-in-the-middle attacks
- Authentication vulnerability
- And many others….

Conclusion

- SDN: Programmable control plane
  - Users write their own control programs
  - Controller installs packet forwarding rules to forwarding elements
  - OpenFlow is a protocol that facilitates communication between the controller and the forwarding elements



Next Lecture

- Survey due tomorrow
- Next Tuesday –
  - Presentations – Bulbul and Vaibabh
- Next Thursday -
  - Quiz on NDN
  - Presentation - Grant