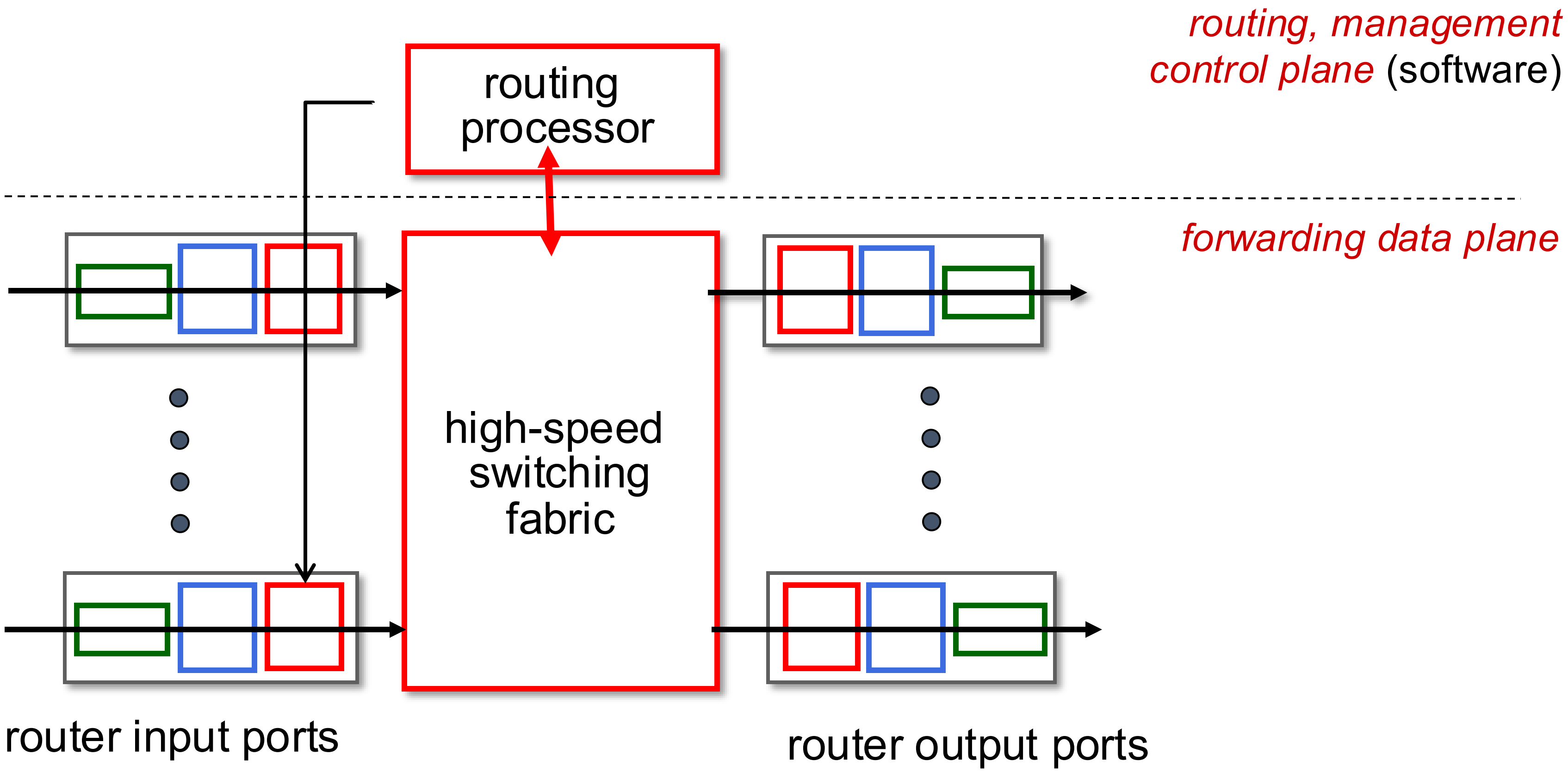
Computer Networks
COL 334/672

Software Defined Networking

Sem 1, 2025-26

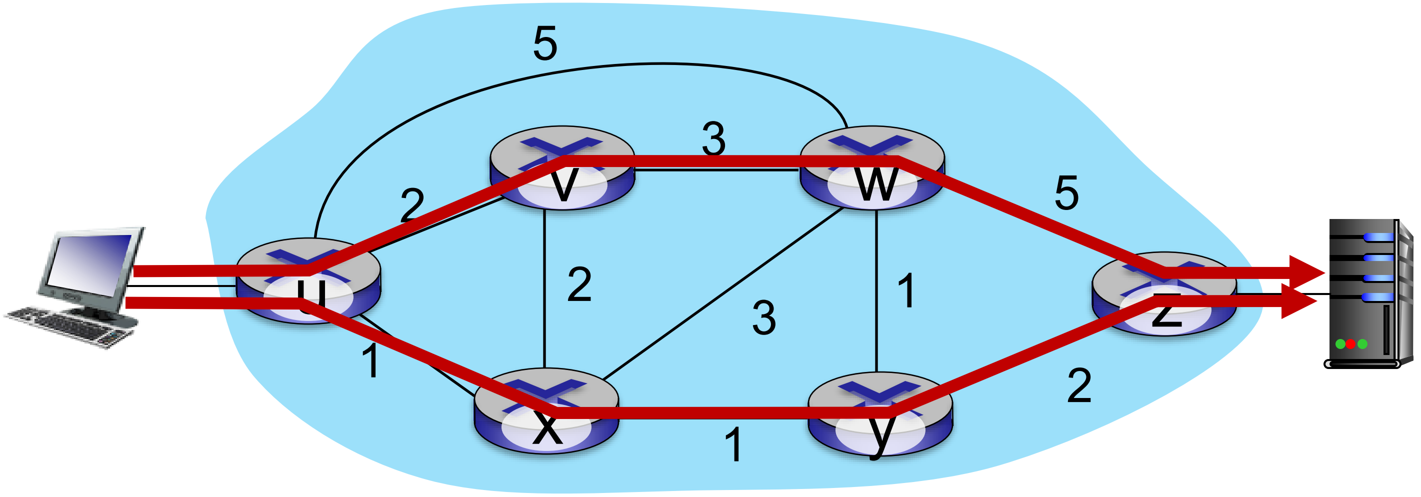
Traditional Routers

Per-router distributed control plane



Limitation: Traffic management is challenging with a distributed control plane

Traffic engineering: difficult with traditional routing

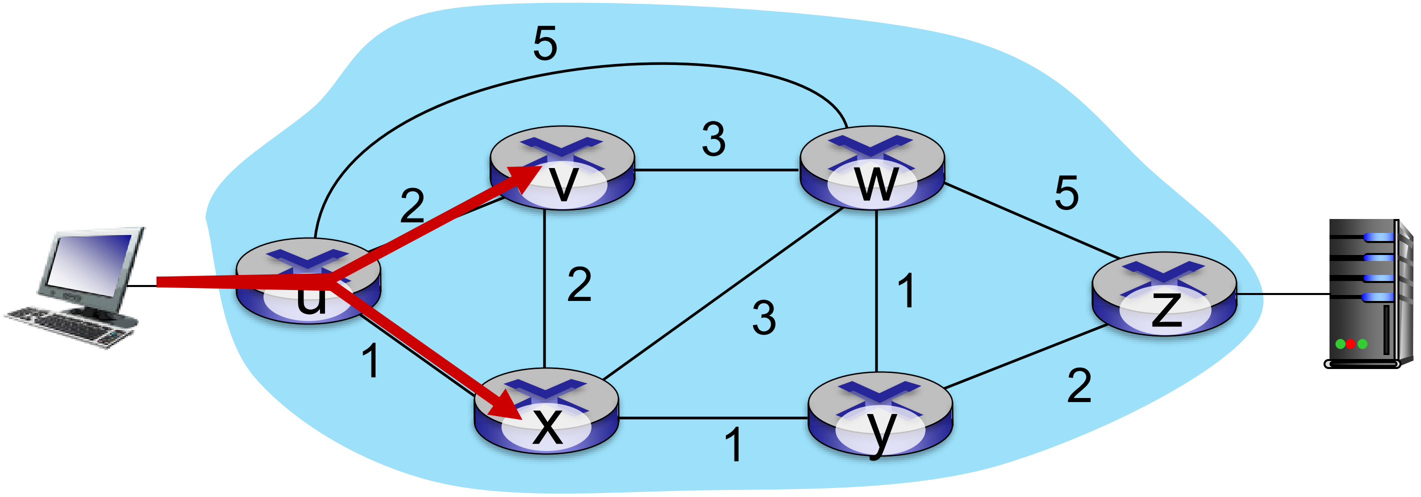


Q: what if network operator wants u-to-z traffic to flow along *uvwz*, rather than *uxyz*?

A: need to re-define link weights so traffic routing algorithm computes routes accordingly (or need a new routing algorithm)!

Indirect control: Changing weights instead of paths

Traffic engineering: difficult with traditional routing



Q: what if network operator wants to split u-to-z traffic along uvwz *and* uxyz (load balancing)?

A: can't do it (or need a new routing algorithm)

Lack of flexibility!

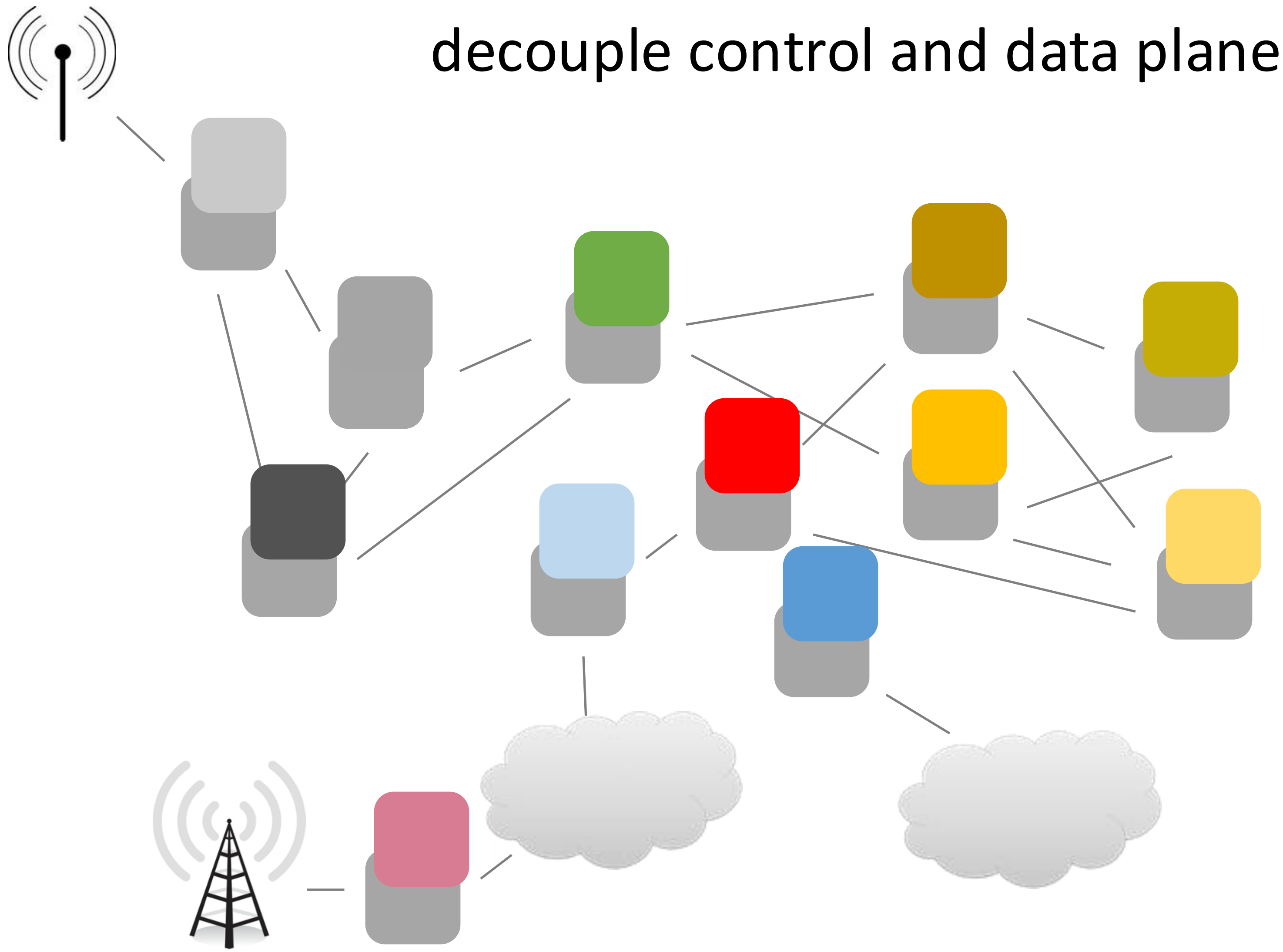
Timescales

	Data	Control
Time-scale	Packet (nsec)	Event (10 msec to sec)
Tasks	Forwarding, buffering, filtering, scheduling	Routing, circuit set-up
Location	Line-card hardware	Router software

Fundamentally different timescales!

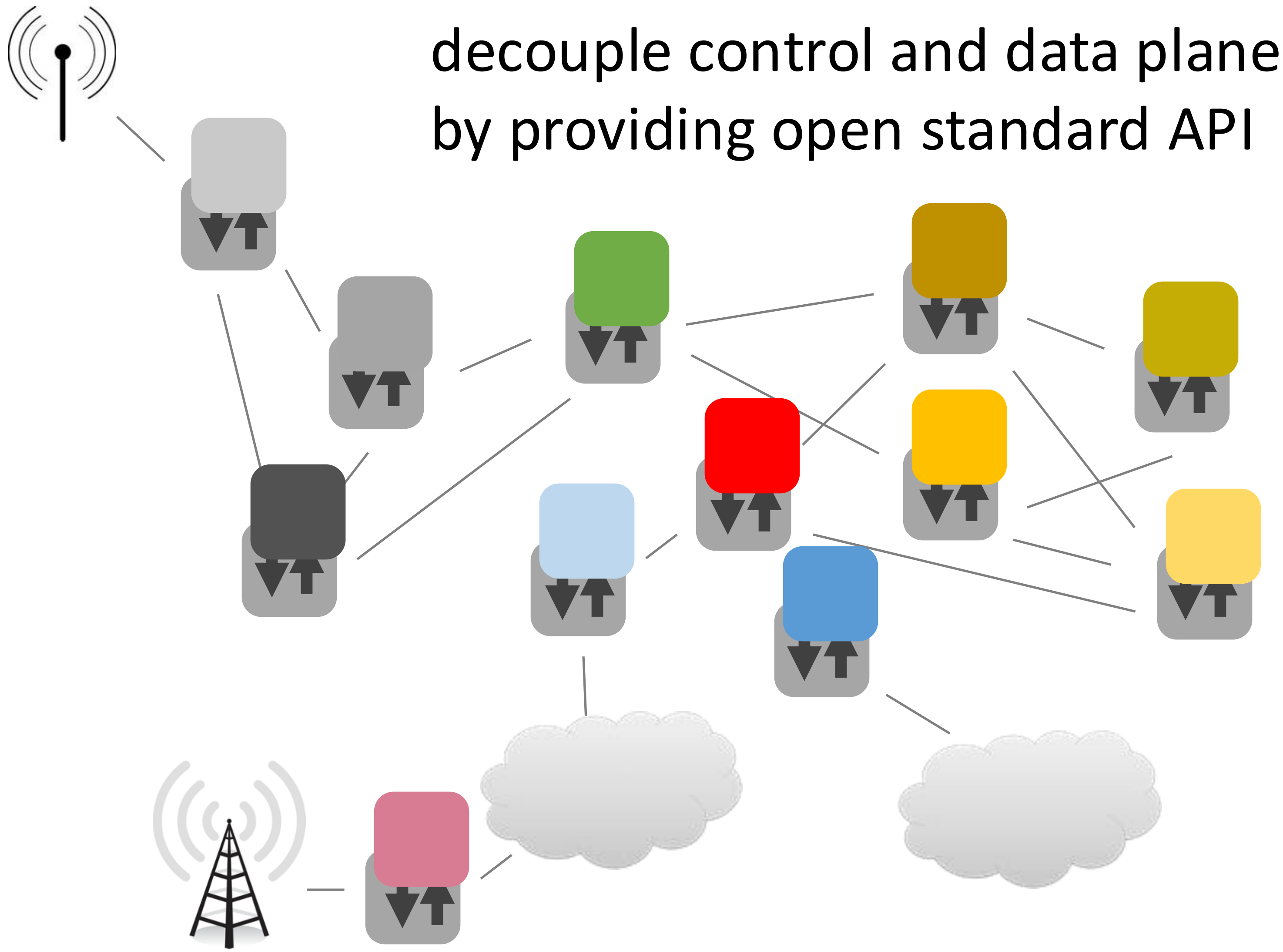
Software Defined Networks

decouple control and data planes

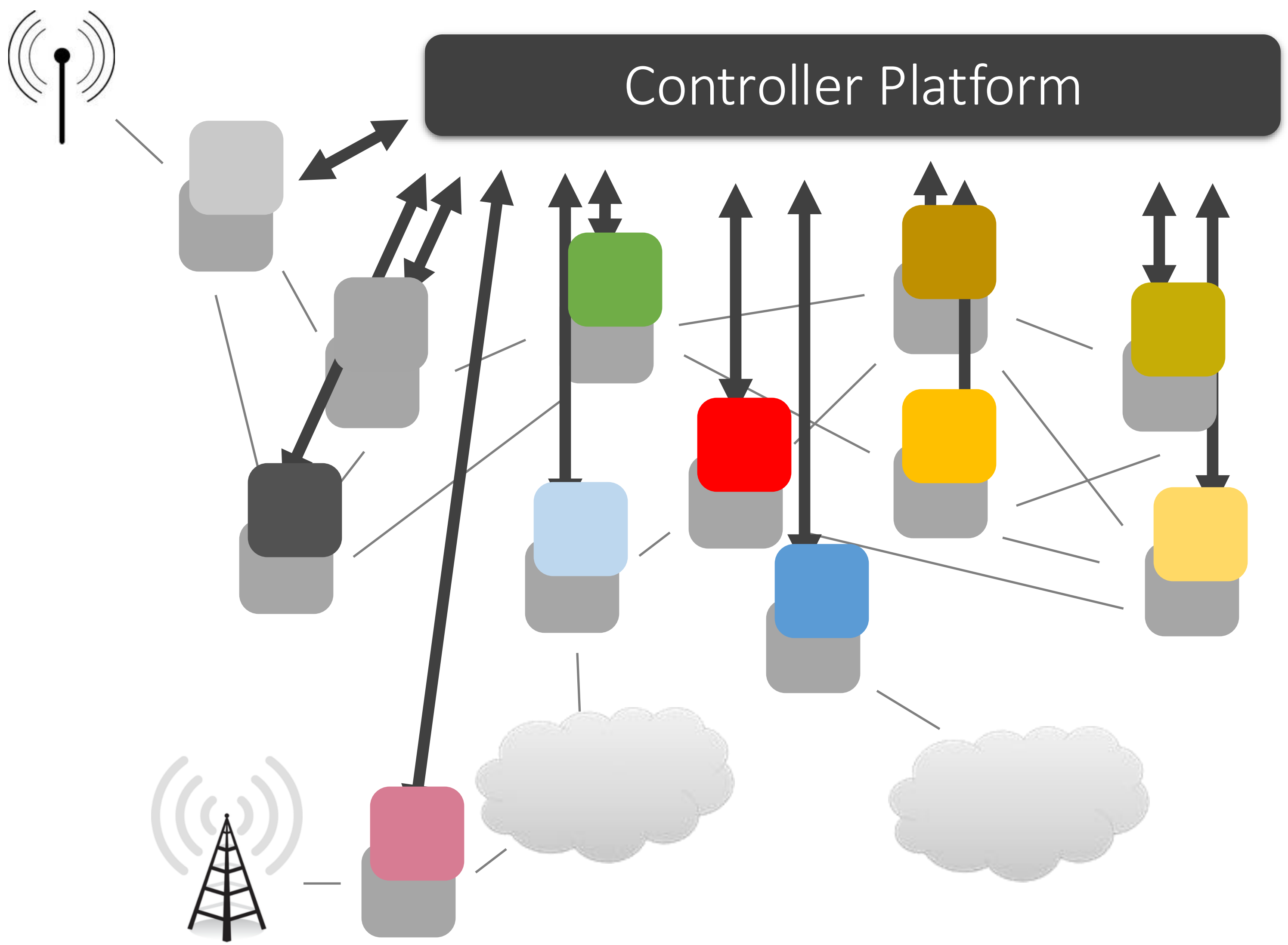


Software Defined Networks

decouple control and data planes
by providing open standard API

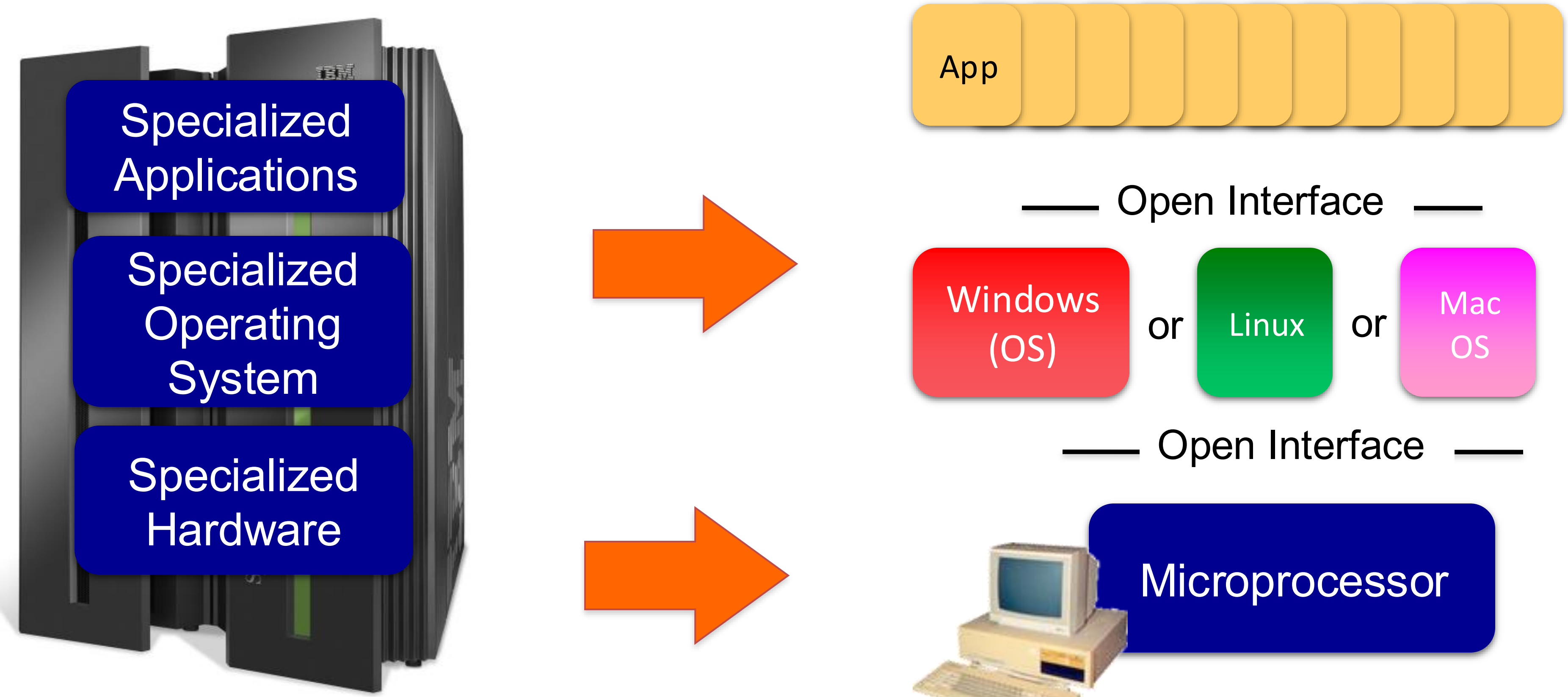


(Logically) Centralized Controller



A Helpful Analogy: Computer Systems

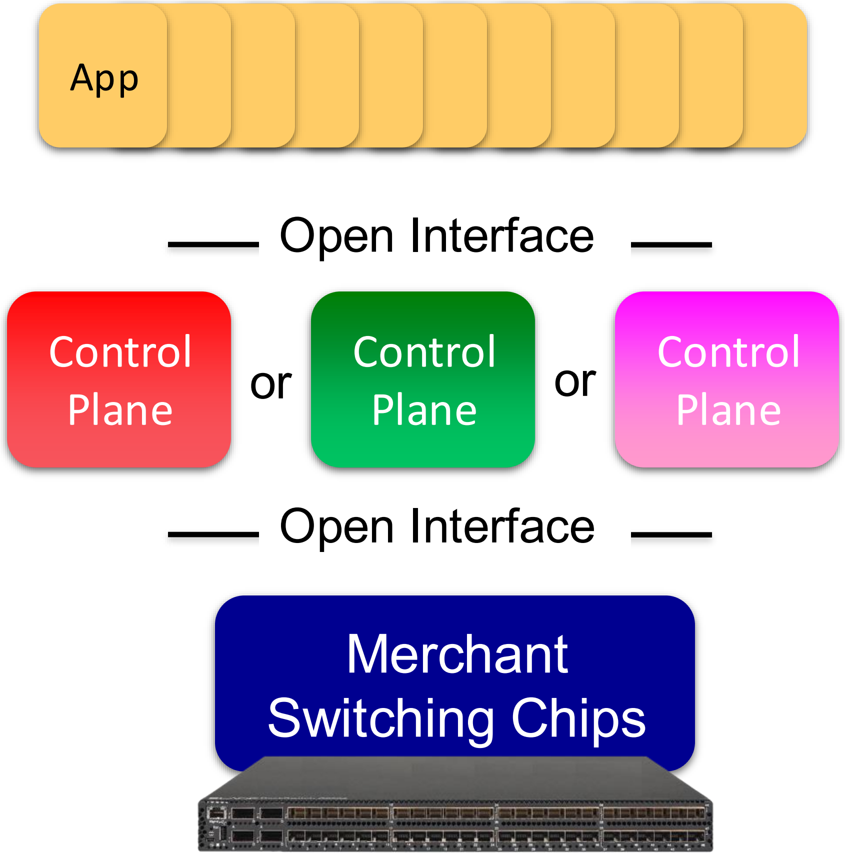
(From Nick McKeown's talk "Making SDN Work" at the Open Networking Summit, April 2012)



Vertically integrated
Closed, proprietary
Slow innovation
Small industry

Horizontal
Open interfaces
Rapid innovation
Huge industry

Network Elements



Vertically integrated
Closed, proprietary
Slow innovation

Horizontal
Open interfaces
Rapid innovation

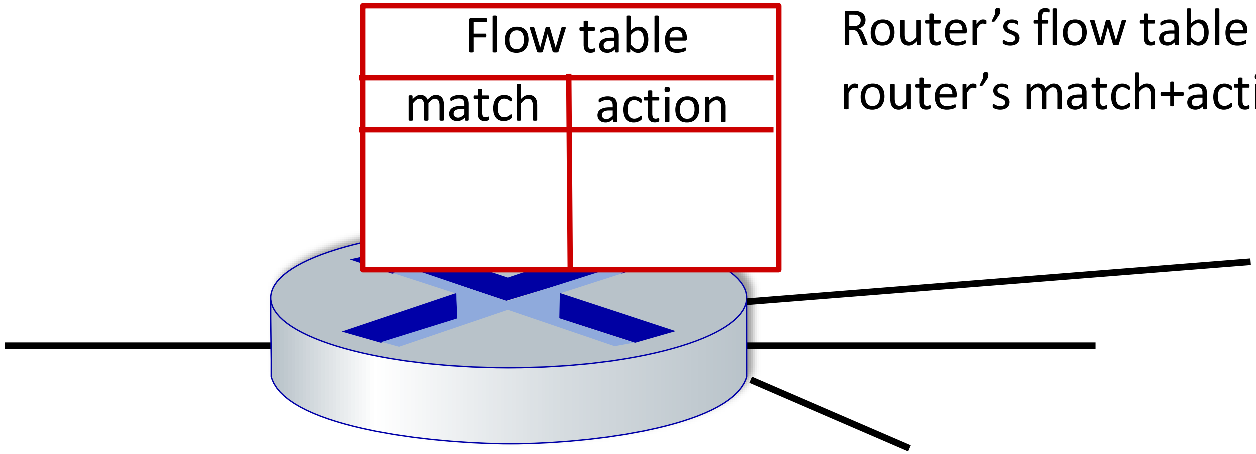
How does such a software-defined network look?

Software-defined Network Architecture

OpenFlow: Most Popular Southbound API

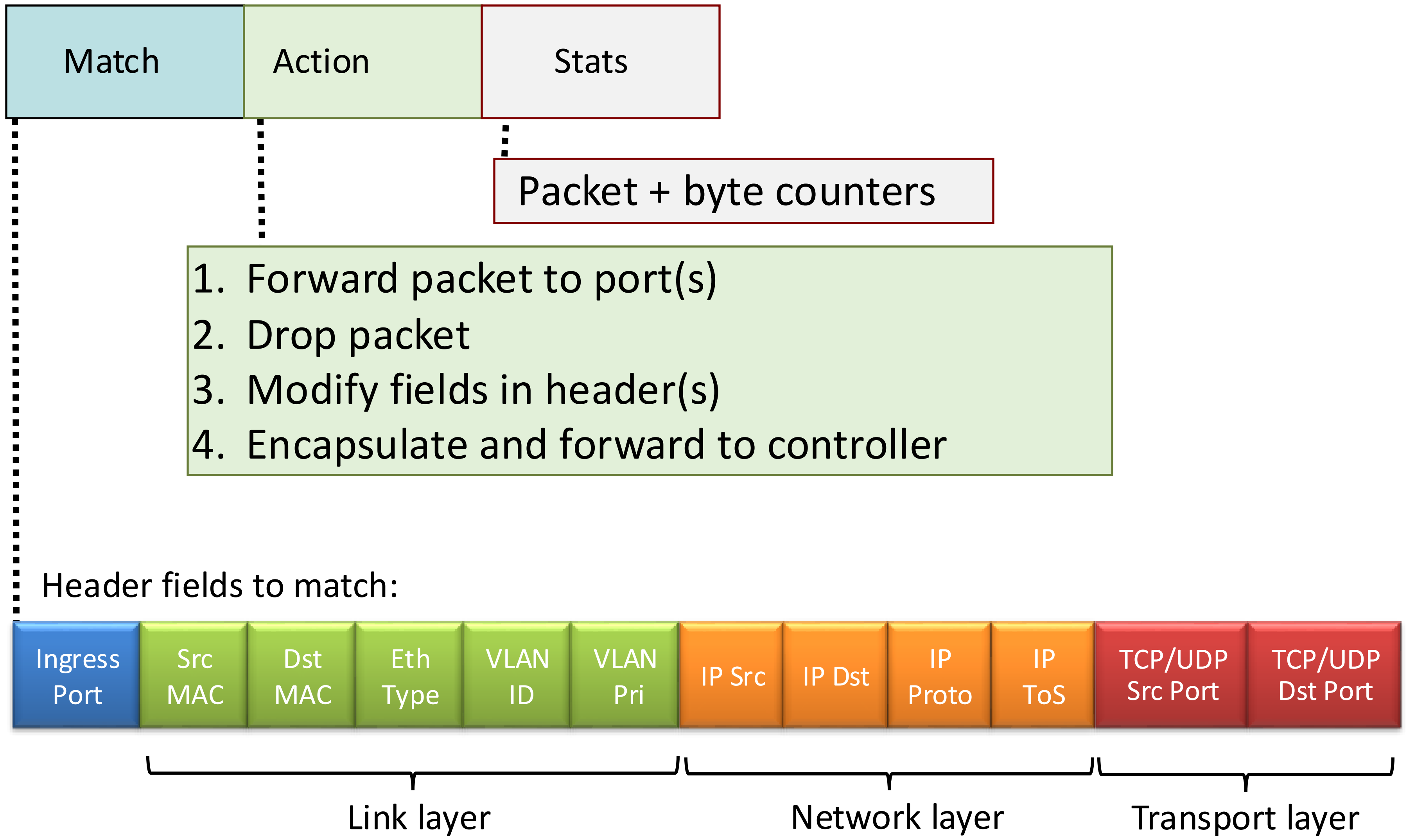
Flow table abstraction

- flow: defined by header field values (in link-, network-, transport-layer fields)
- generalized forwarding: simple packet-handling rules
  - match: pattern values in packet header fields
  - actions: for matched packet: drop, forward, modify, matched packet or send matched packet to controller
  - priority: disambiguate overlapping patterns
  - counters: #bytes and #packets



Router's flow table define router's match+action rules

OpenFlow: flow table entries



OpenFlow: examples

Destination-based forwarding:

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	VLAN Pri	IP Src	IP Dst	IP Prot	IP ToS	TCP s-port	TCP d-port	Action
*	*	*	*	*	*	*	51.6.0.8	*	*	*	*	port6

IP datagrams destined to IP address 51.6.0.8 should be forwarded to router output port 6

Firewall:

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	VLAN Pri	IP Src	IP Dst	IP Prot	IP ToS	TCP s-port	TCP d-port	Action
*	*	*	*	*	*	*	*	*	*	*	22	drop

Block (do not forward) all datagrams destined to TCP port 22 (ssh port #)

Switch Port	MAC src	MAC dst	Eth type	VLAN ID	VLAN Pri	IP Src	IP Dst	IP Prot	IP ToS	TCP s-port	TCP d-port	Action
*	*	*	*	*	*	128.119.1.1	*	*	*	*	*	drop

Block (do not forward) all datagrams sent by host 128.119.1.1

OpenFlow: examples

Layer 2 destination-based forwarding:

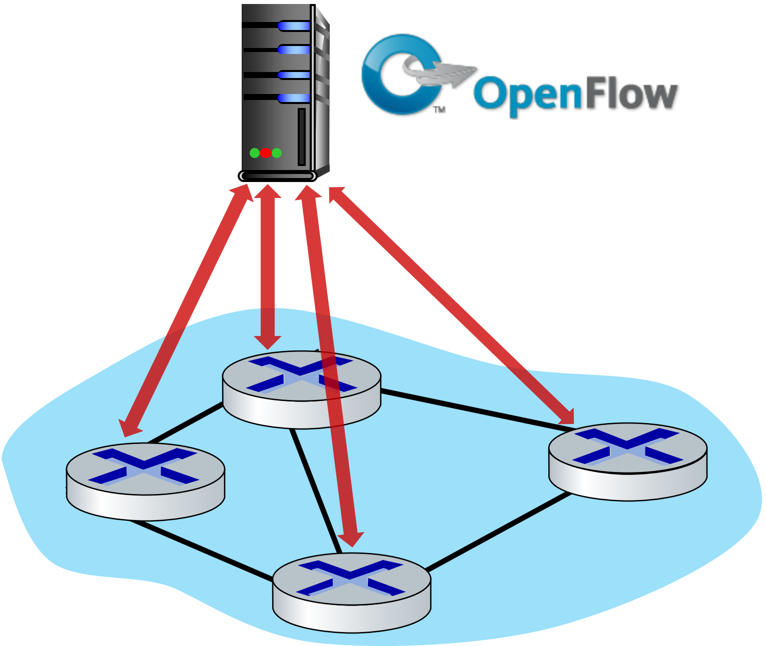
Switch Port	MAC src	MAC dst	Eth type	VLAN ID	VLAN Pri	IP Src	IP Dst	IP Prot	IP ToS	TCP s-port	TCP d-port	Action
*	*	22:A7:23: 11:E1:02	*	*	*	*	*	*	*	*	*	port3

layer 2 frames with destination MAC address 22:A7:23:11:E1:02 should be forwarded to output port 3

OpenFlow Messages

- TCP used to exchange messages
  - optional encryption
- Three classes of OpenFlow messages:
  - controller-to-switch
  - asynchronous (switch to controller)
  - symmetric (misc.)
- distinct from OpenFlow API
  - API used to specify generalized forwarding actions

OpenFlow Controller

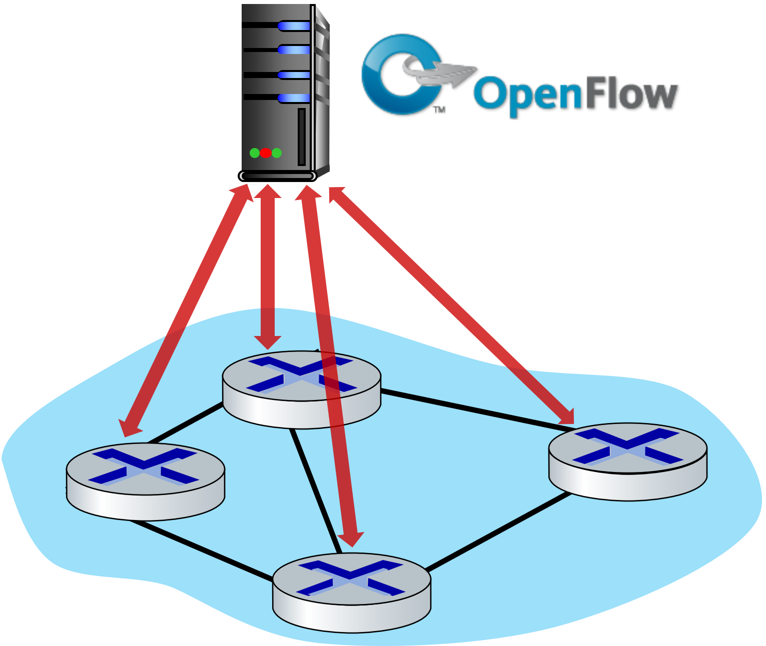


OpenFlow: controller-to-switch messages

Key controller-to-switch messages

- *features:* controller queries switch features, switch replies
- *configure:* controller queries/sets switch configuration parameters
- *modify-state:* add, delete, modify flow entries in the OpenFlow tables
- *packet-out:* controller can send this packet out of specific switch port

OpenFlow Controller



OpenFlow: switch-to-controller messages

Key switch-to-controller messages

- *packet-in:* transfer packet (and its control) to controller. See packet-out message from controller
- *flow-removed:* flow table entry deleted at switch
- *port status:* inform controller of a change on a port.

OpenFlow Controller