IOWA

CS3640

Research: Software Defined Networking

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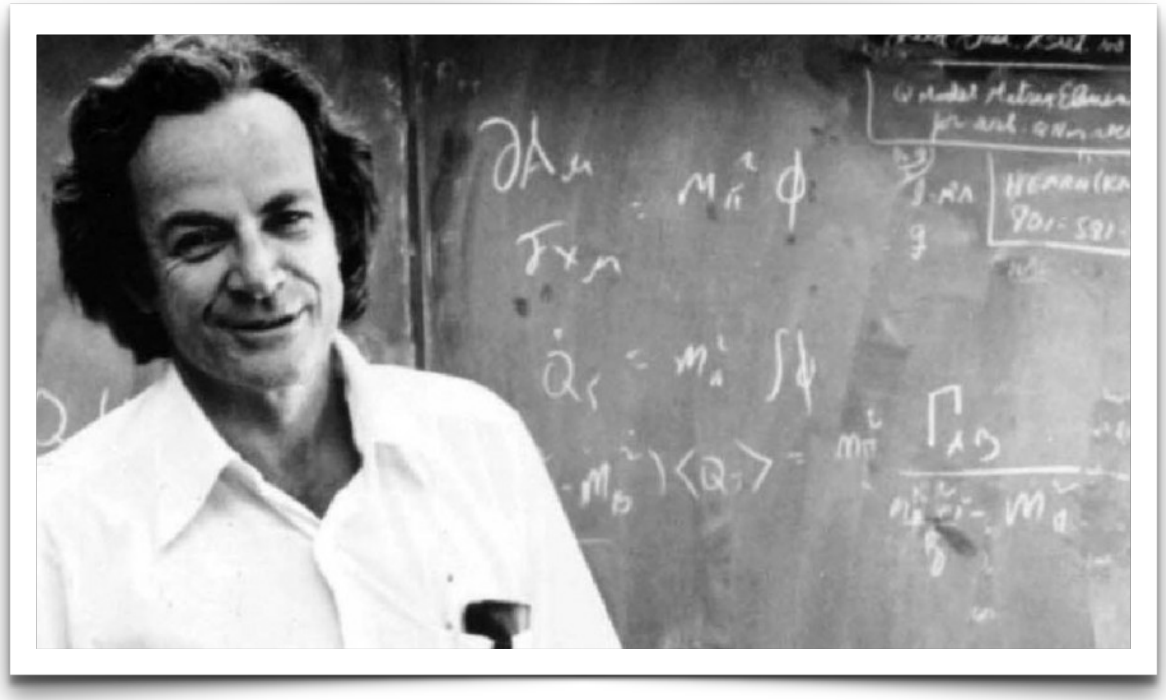
Computer Science
The University of Iowa

Reflections on our semester



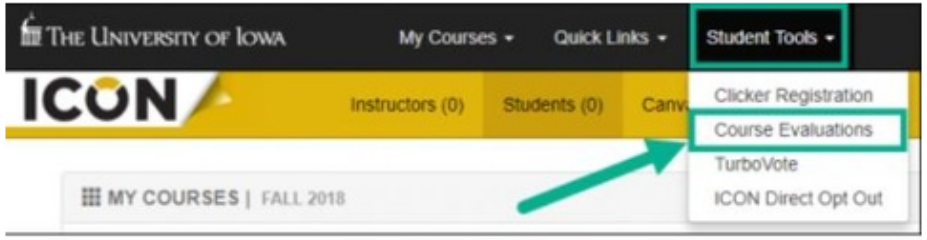
“ Students don't need a perfect teacher. Students need a happy teacher, who's gonna make them excited to come to school and grow a love for learning ”

– Richard Feynman

Now it is our turn to “ACE”

Access ACE Online from ICON:

1. In a browser (Chrome or Firefox preferred), go to icon.uiowa.
2. Drop down "Student Tools."
3. Click on "Course Evaluations."
4. Enter your Hawk ID and password.



Access ACE Online from MyUI:

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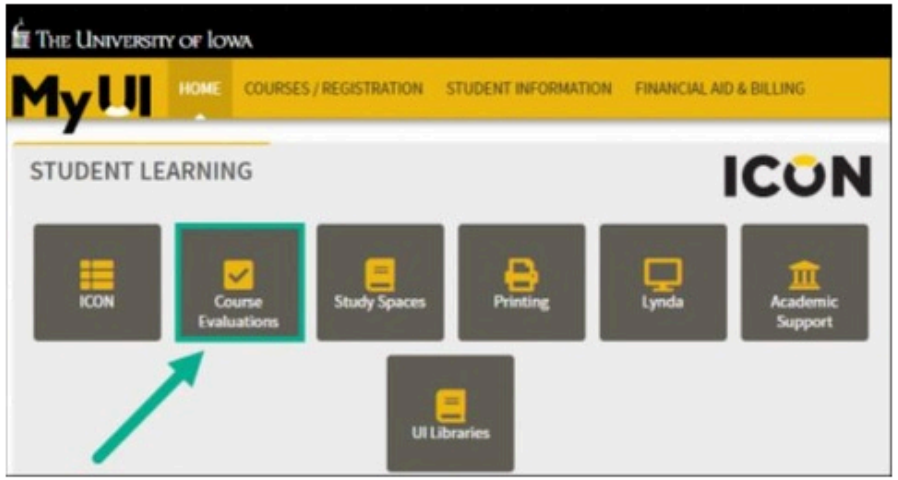
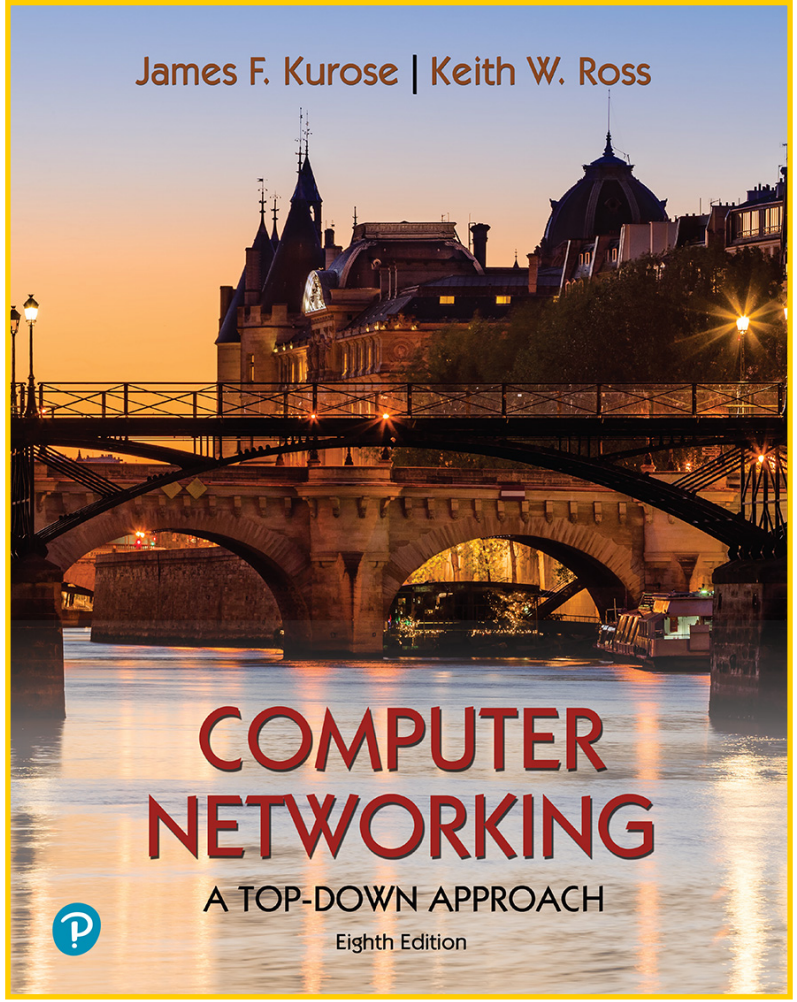


Lecture goals

Evolution of core networking platform from being pre-programmed and hardware-driven to flexible and software-driven

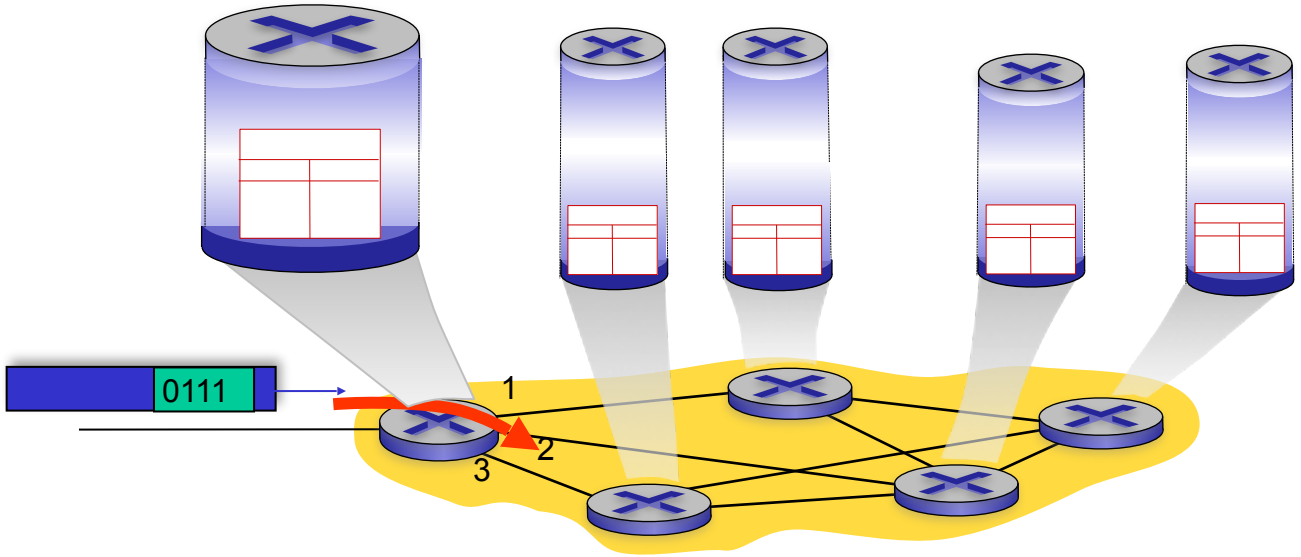
- *Software Defined Networking*
- *OpenFlow*
- *Case study: Google SDN*



Chapters 4.4, 5.5

IOWA

Previously on CS3640…



Each router contains a ***forwarding table*** *and uses it to implement* ***destination-based*** *forwarding of IP datagrams*

Research question: ***Could this abstraction be generalized?***

- IP datagram header contain many fields (in addition to destination address)
- Many actions could be taken on the packet: forward, drop, copy, modify, log, etc.

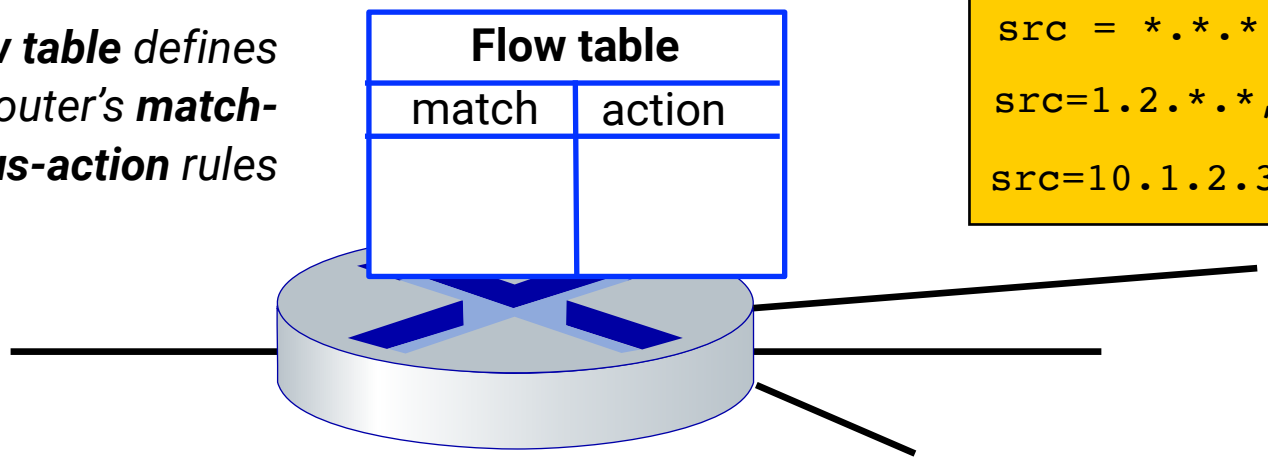
New Abstraction: match-plus-action

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: drop, forward, modify or send to controller*
- *priority: disambiguate overlapping patterns*

***Flow table** defines the router's **match-plus-action** rules*



an example flow table

`src = *.*.*.*, dest=3.4.*.*`	`forward(2)`
`src=1.2.*.*, dest=*.*.*.*`	`drop`
`src=10.1.2.3, dest=*.*.*.*`	`send to controller`

OpenFlow

How it started

OpenFlow: Enabling Innovation in Campus Networks

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

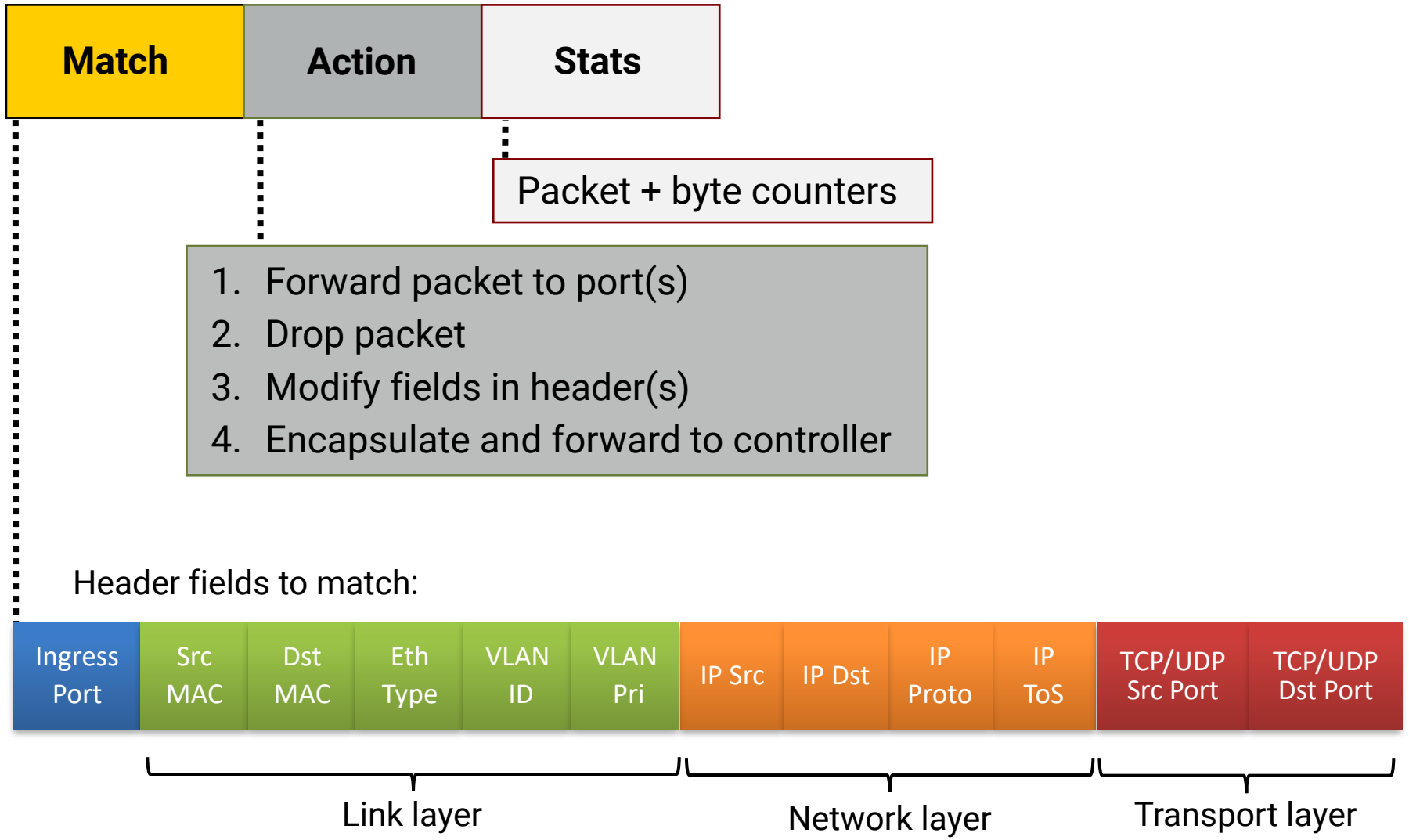
Jonathan Turner
Washington University in St. Louis

How it's going

$32+ Billion Worldwide Software-Defined Networking Market to 2025 - Featuring Cisco, Huawei & VMware Among Others

August 18, 2020 06:33 ET | Source: Research and Markets

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.*	*	*	*	*	*	drop

Block (do not forward) all datagrams sent by host 128.119.1.*

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

Generality of OpenFlow

match-plus-action abstraction unifies different kinds of devices

Router

- **match**: longest IP prefix
- **action**: forward out a link

Firewall

- **match**: IP addr and/or TCP/UDP ports
- **action**: permit or drop

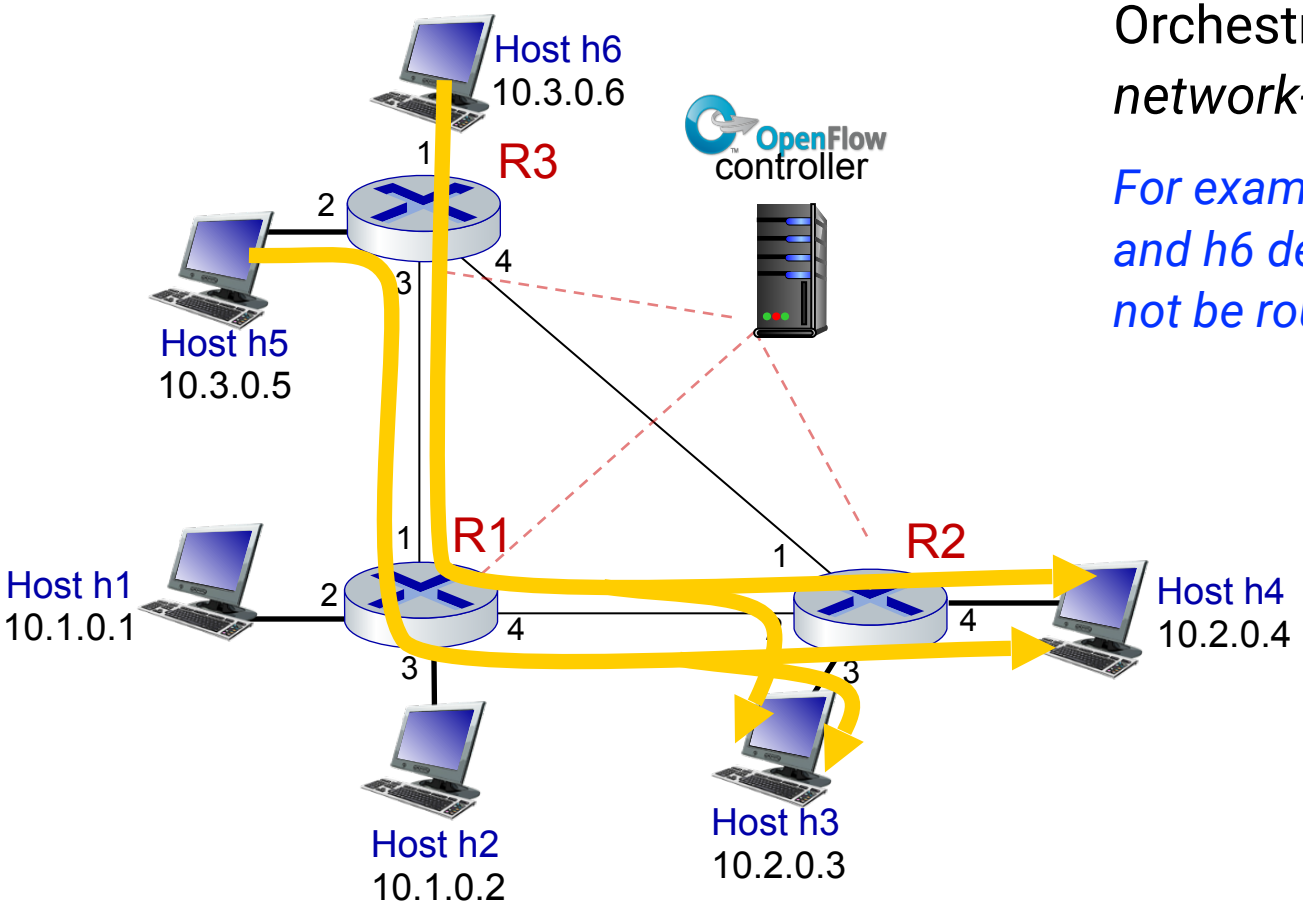
Switch

- **match**: destination MAC
- **action**: forward or flood

NAT

- **match**: IP addr and/or TCP/UDP ports
- **action**: rewrite IP addr and ports

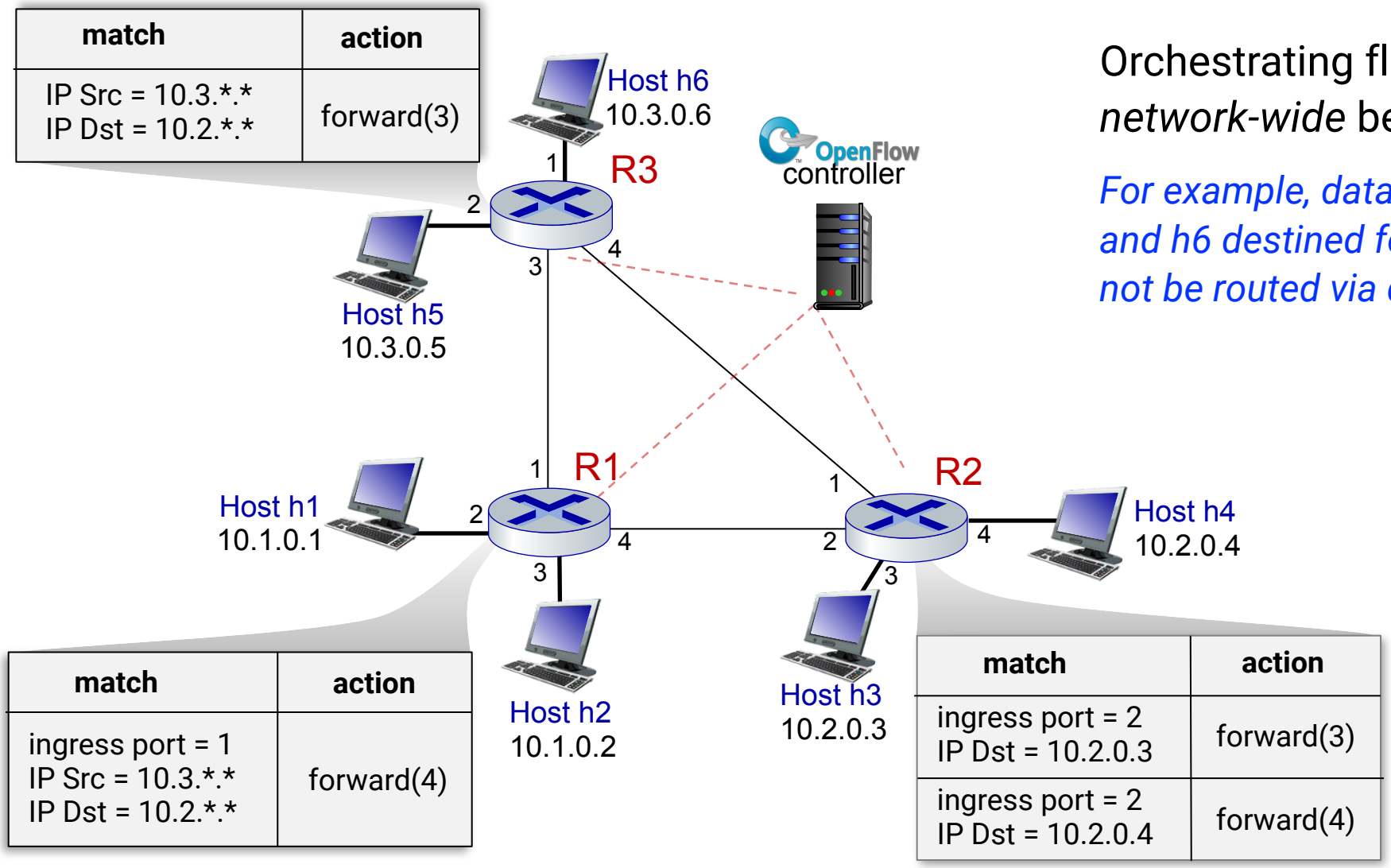
OpenFlow Controller



Orchestrating flow tables to create *network-wide* behavior

For example, datagrams from hosts h5 and h6 destined for h3 or h4, should not be routed via direct link R3-R2

OpenFlow Controller

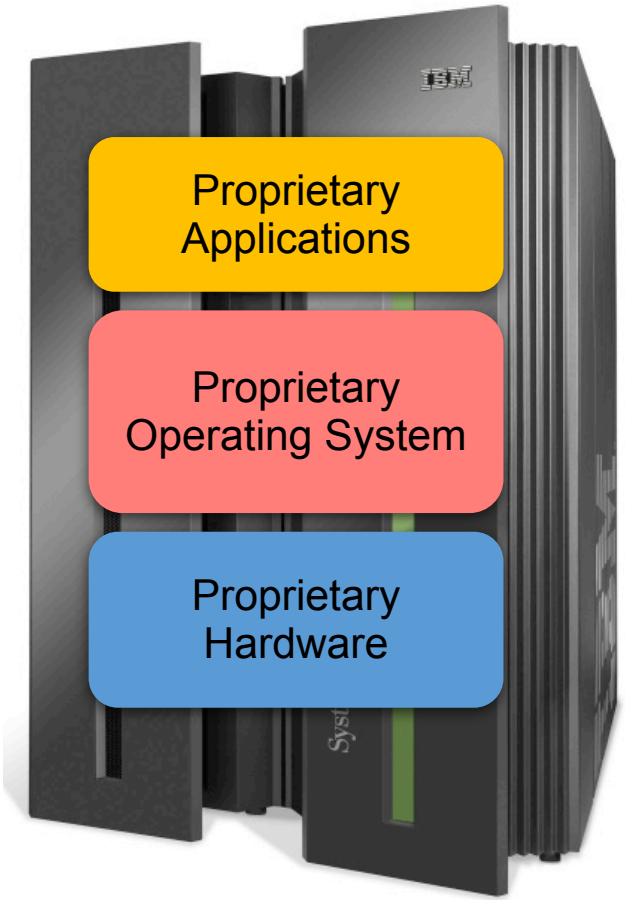


Orchestrating flow tables to create *network-wide* behavior

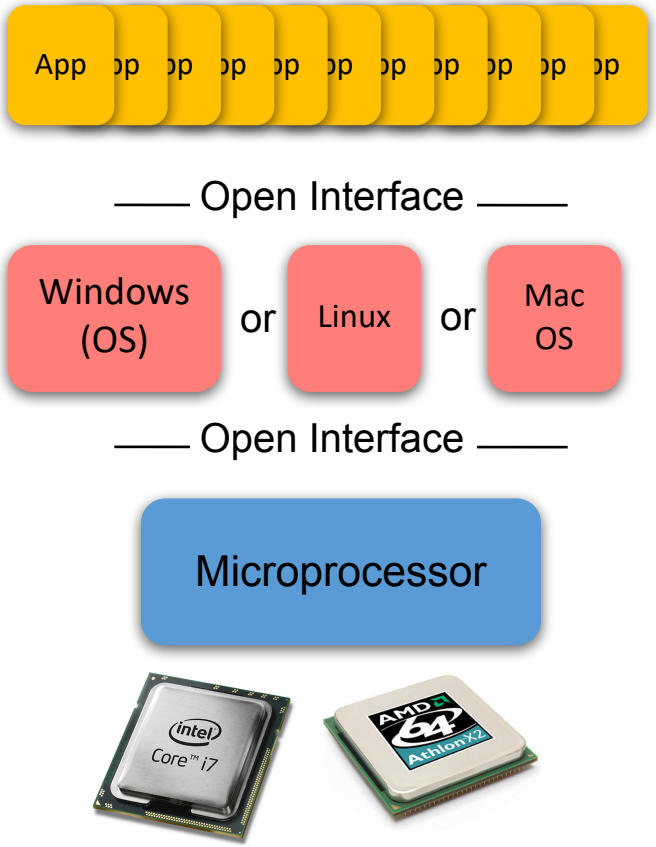
For example, datagrams from hosts h5 and h6 destined for h3 or h4, should not be routed via direct link R3-R2

Google + SDN

Transformation in Computing Industry (circa 1980)

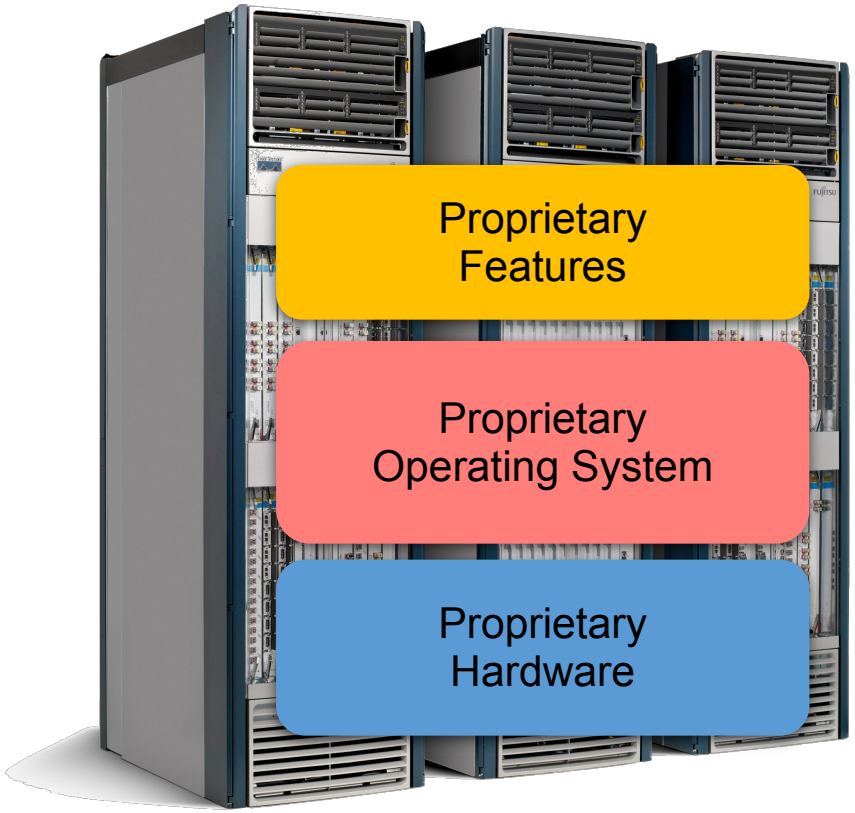


Disaggregation



Courtesy: Nick McKeown, http://yuba.stanford.edu/~nickm

Transformation in Networking Industry (circa 2010)



Disaggregation

App App App App App App App App App App

Open Interface

NOX | Beacon | ONIX | POX | ONOS | Flood light

Open Interface

Merchant
Switch Chips

Courtesy: Nick McKeown, http://yuba.stanford.edu/~nickm

Google’s network footprint

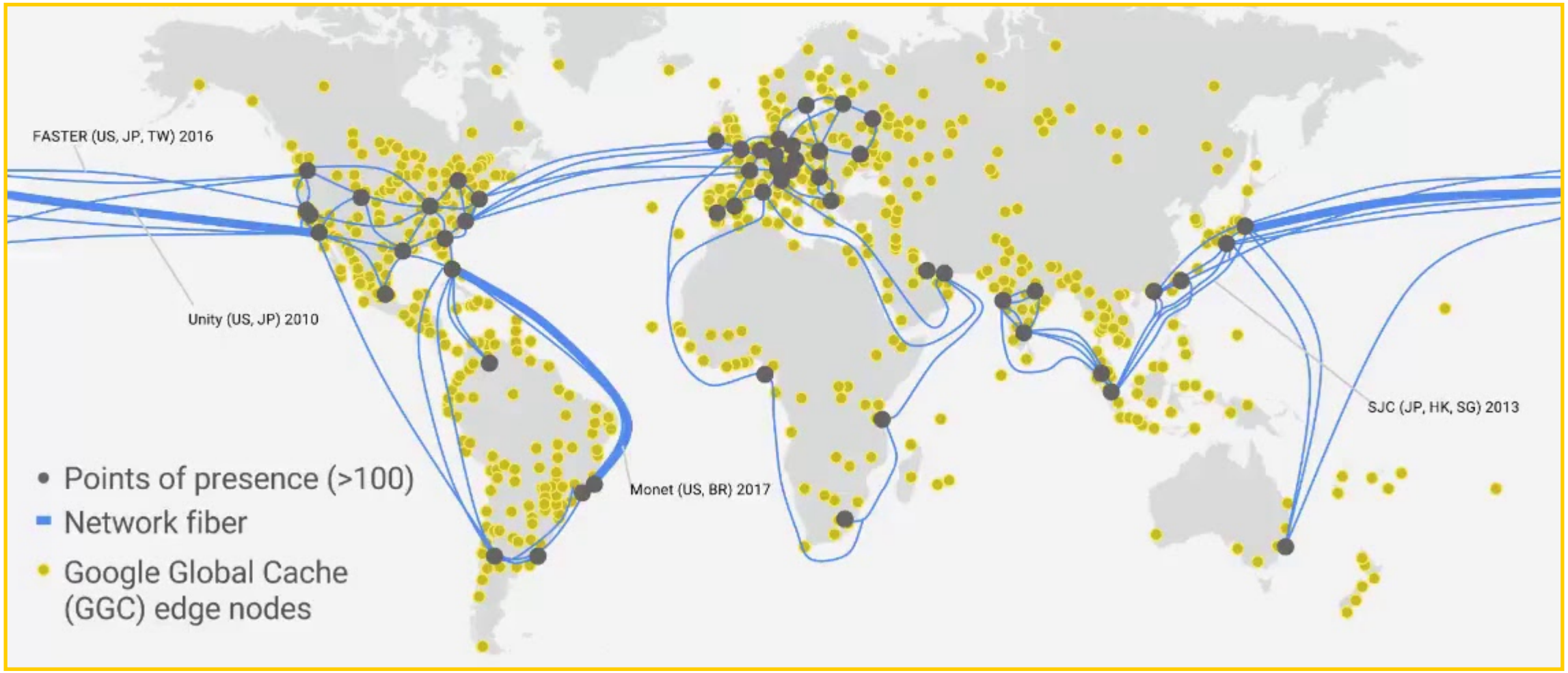
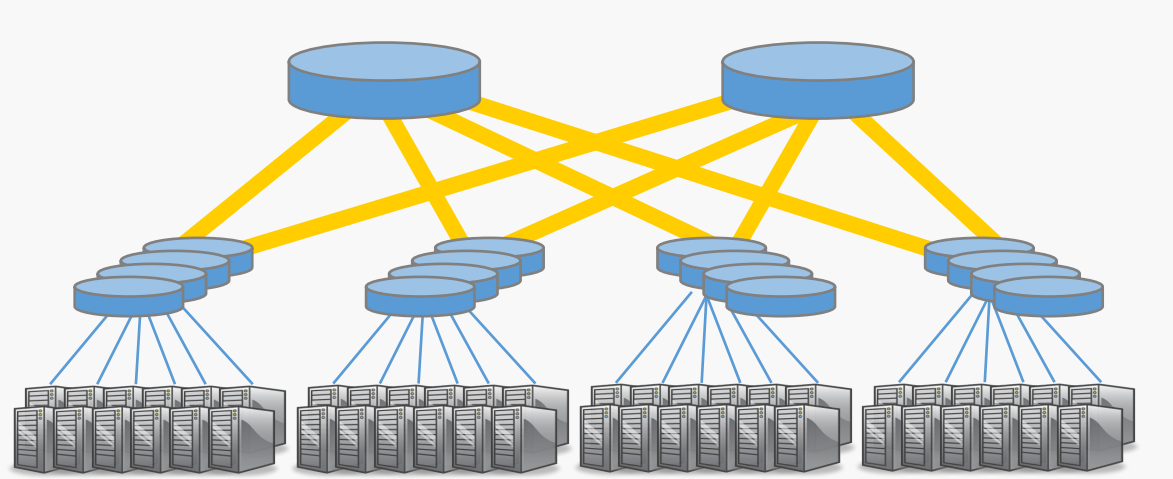


Image courtesy: Google cloud

SDN's Impact on Datacenters



Cost

500,000 servers & 25,000 switches

$10k per legacy switch = $250M

$2k per SDN switch = $50M

Savings in 5 data centers = $1Bn

Control

Centralized control is easier to manage

Customized, differentiated network

Home grown traffic engineering

50% utilization → 95% utilization

Suggested Reading

***A Purpose-Built Global Network**: Google's Move to SDN* [CACM 2016]

- *Perspectives from Vahdat, Clark, and Rexford*
- *Transitioning networking research into real world*
- *How SDN solved Google's scale challenges*
- *Also: https://youtu.be/FaAZAII2x0w&t=90s*

Spot Quiz (ICON)