

National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 24 Chapter 5

21st November, 2023

Nauman Moazzam Hayat
nauman.moazzam@lhr.nu.edu.pk

Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Network layer: “control plane” roadmap

- introduction
- routing protocols
- intra-ISP routing: OSPF
- routing among ISPs: BGP
- SDN control plane
- **Internet Control Message Protocol**



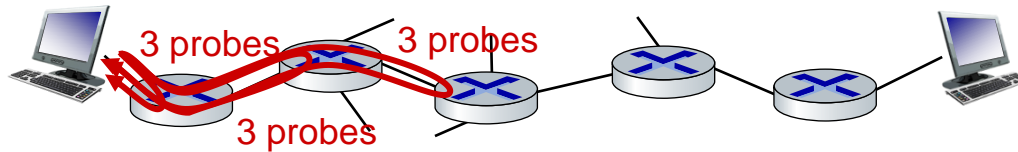
- network management, configuration
 - SNMP
 - NETCONF/YANG

ICMP: internet control message protocol

- used by hosts and routers to communicate network-level information
 - error reporting: unreachable host, network, port, protocol
 - echo request/reply (used by ping)
- network-layer “above” IP:
 - ICMP messages carried in IP datagrams
- *ICMP message*: type, code plus first 8 bytes of IP datagram causing error

<u>Type</u>	<u>Code</u>	<u>description</u>
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Traceroute and ICMP



- source sends sets of UDP segments to destination
 - 1st set has TTL =1, 2nd set has TTL=2, etc.
 - datagram in n th set arrives to n th router:
 - router discards datagram and sends source ICMP message (type 11, code 0)
 - ICMP message possibly includes name of router & IP address
 - when ICMP message arrives at source: record RTTs
- stopping criteria:
- UDP segment eventually arrives at destination host
 - destination returns ICMP “port unreachable” message (type 3, code 3)
 - source stops

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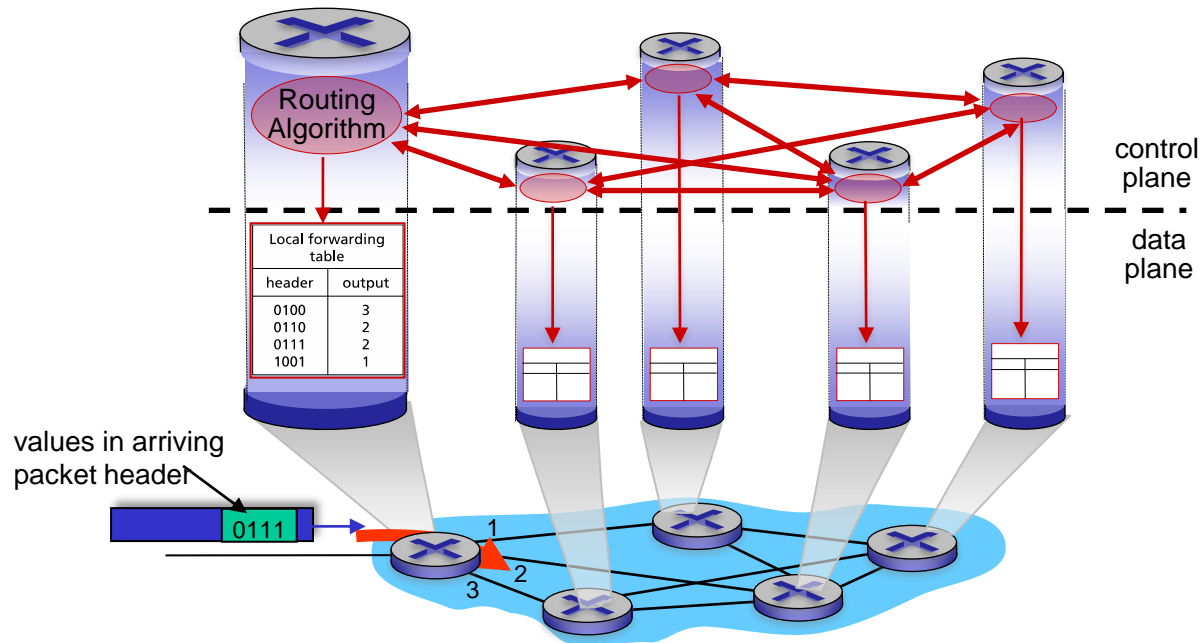
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Software defined networking (SDN)

- Internet network layer: historically implemented via distributed, per-router control approach:
 - *monolithic* router contains switching hardware, runs proprietary implementation of Internet standard protocols (IP, RIP, IS-IS, OSPF, BGP) in proprietary router OS (e.g., Cisco IOS)
 - different “middleboxes” for different network layer functions: firewalls, load balancers, NAT boxes, ..
- ~2005: renewed interest in rethinking network control plane

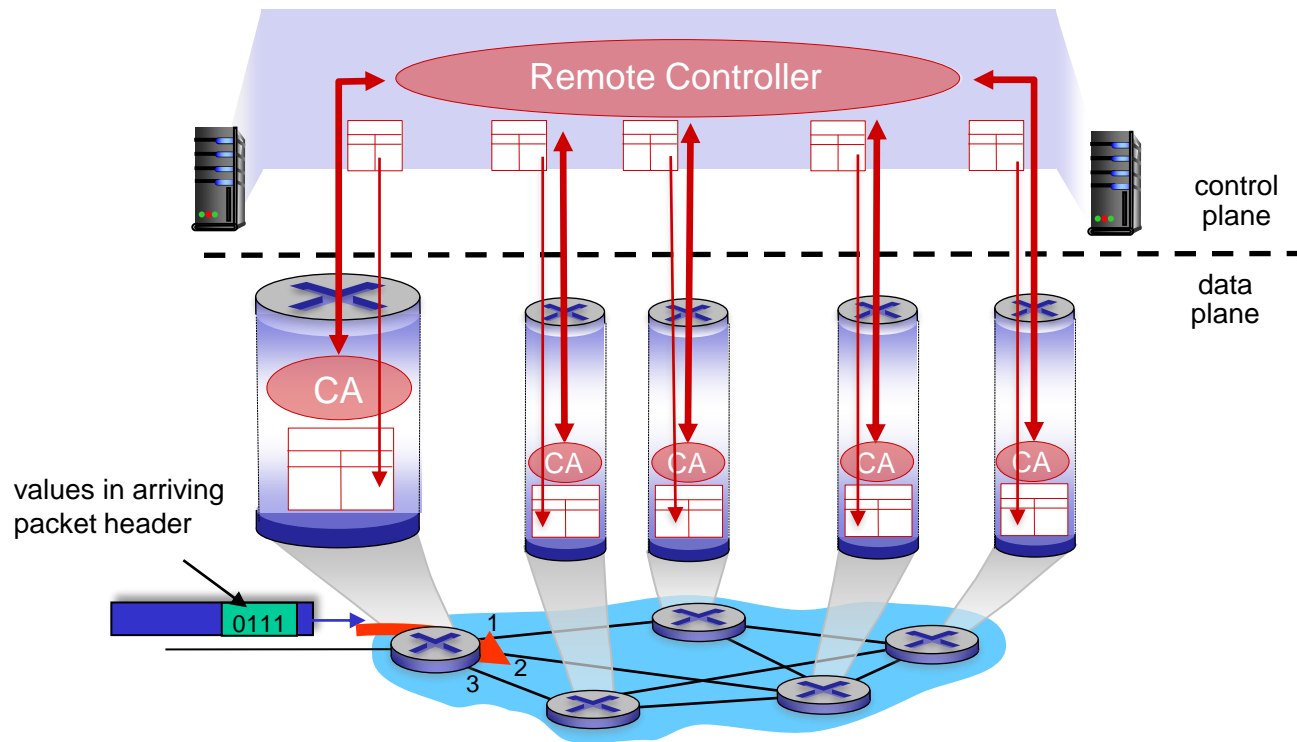
Per-router control plane

Individual routing algorithm components *in each and every router* interact in the control plane to compute forwarding tables



Software-Defined Networking (SDN) control plane

Remote controller computes, installs forwarding tables in routers

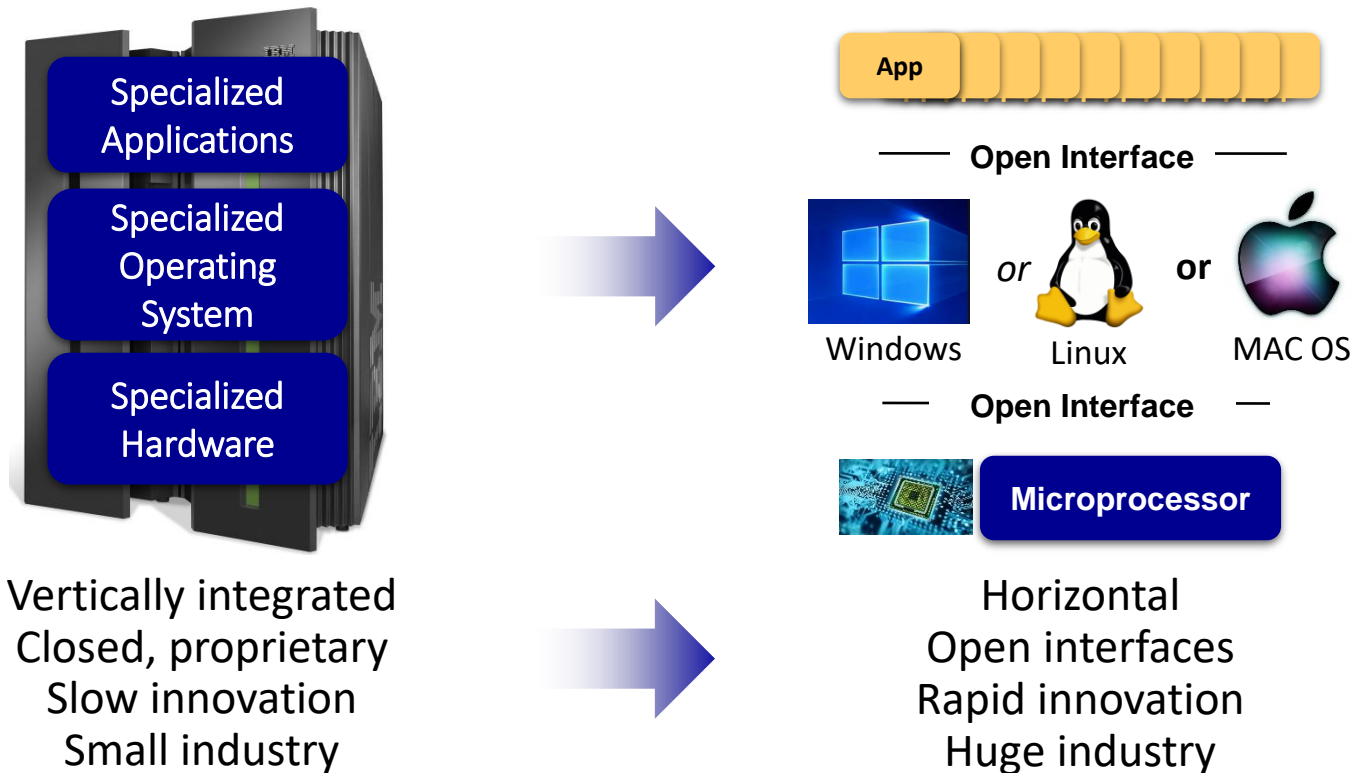


Software defined networking (SDN)

Why a *logically centralized* control plane?

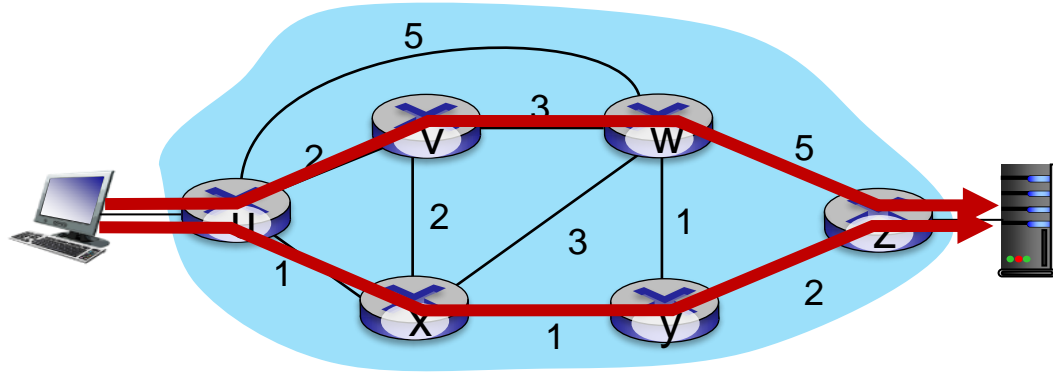
- easier network management: avoid router misconfigurations, greater flexibility of traffic flows
- table-based forwarding (recall OpenFlow API) allows “programming” routers
 - centralized “programming” easier: compute tables centrally and distribute
 - distributed “programming” more difficult: compute tables as result of distributed algorithm (protocol) implemented in each-and-every router
- open (non-proprietary) implementation of control plane
 - foster innovation: let 1000 flowers bloom

SDN analogy: mainframe to PC revolution



* Slide courtesy: N. McKeown

Traffic engineering: difficult with traditional routing

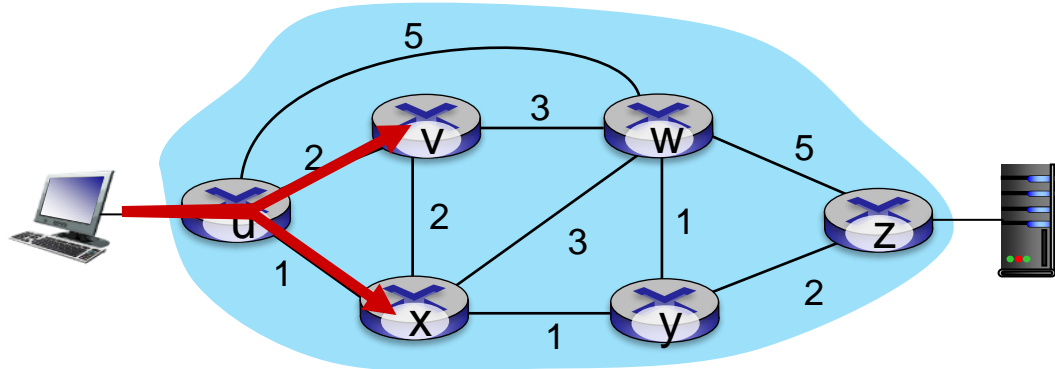


Q: what if network operator wants u-to-z traffic to flow along $uvwz$, rather than $uxyz$?

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

link weights are only control “knobs”: not much control!

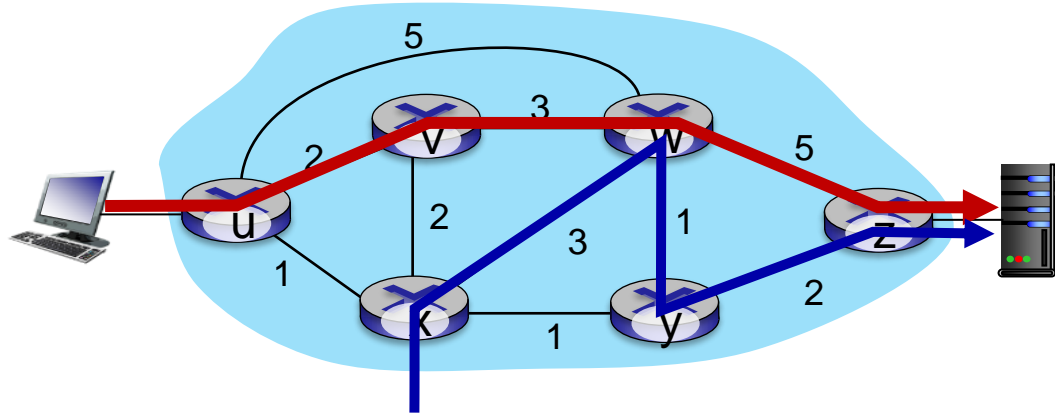
Traffic engineering: difficult with traditional routing



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)

Traffic engineering: difficult with traditional routing

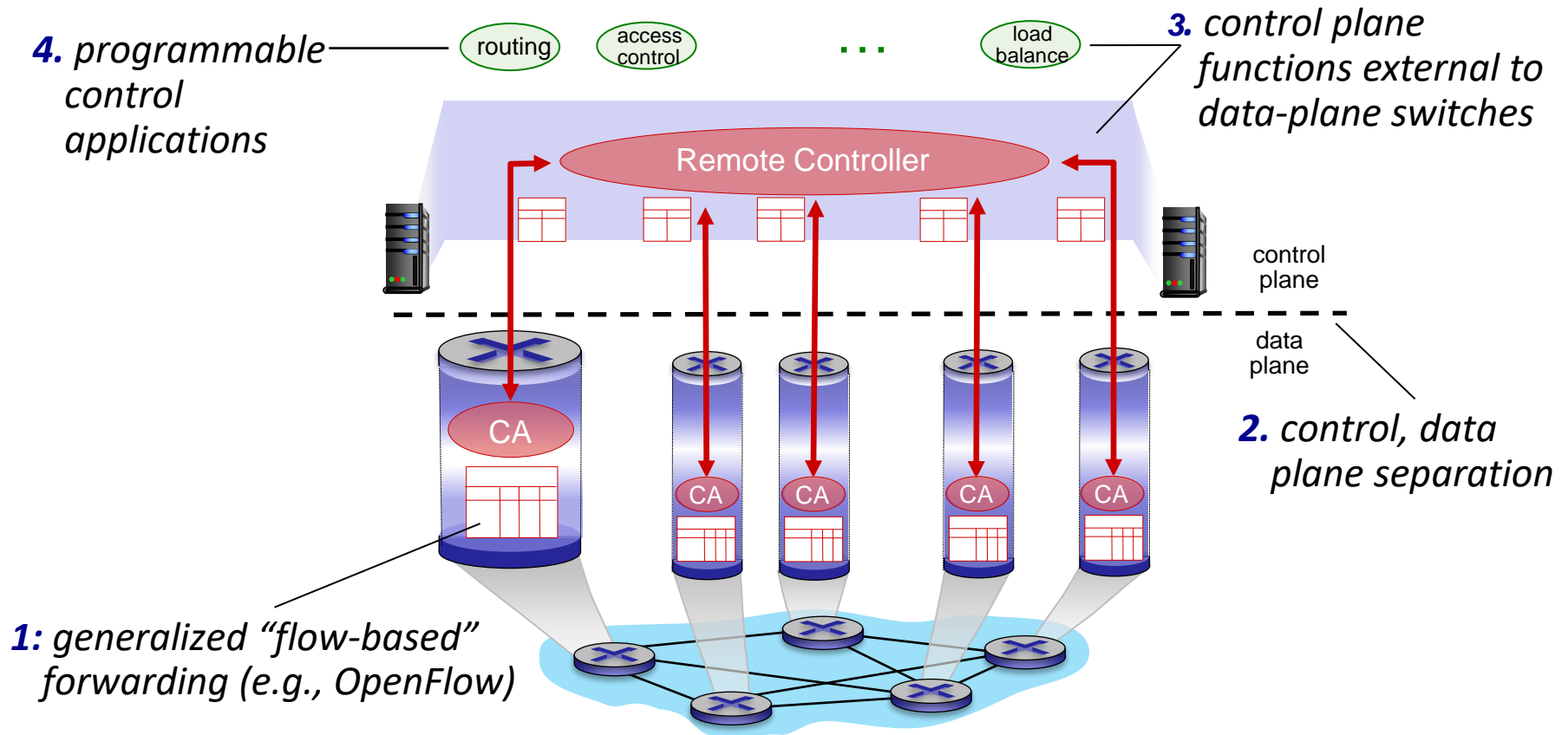


Q: what if w wants to route blue and red traffic differently from w to z?

A: can't do it (with destination-based forwarding, and LS, DV routing)

We learned in Chapter 4 that generalized forwarding and SDN can be used to achieve *any* routing desired

Software defined networking (SDN)



Network layer: Summary

we've learned a lot!

- approaches to network control plane
 - per-router control (traditional)
 - logically centralized control (software defined networking)
- traditional routing algorithms
 - implementation in Internet: OSPF , BGP
- SDN controllers
 - ~~implementation in practice: ODL, ONOS~~
- Internet Control Message Protocol
- ~~network management~~

next stop: link layer!

Network layer, control plane: Done!

- introduction
- routing protocols
 - link state
 - distance vector
- intra-ISP routing: OSPF
- routing among ISPs: BGP
- SDN control plane
- Internet Control Message Protocol



- ~~network management, configuration~~
 - ~~SNMP~~
 - ~~NETCONF/YANG~~

Assignment # 5 (Chapter - 5)

- *5th Assignment will be uploaded on Google Classroom on Tuesday, 21st November, 2023, in the Stream - Announcement Section*
- *Due Date: Tuesday, 28th November, 2023 (Handwritten solutions to be submitted during the lecture)*
- *Please read **all the instructions** carefully in the uploaded Assignment document, follow & submit accordingly*

Quiz # 5 (Chapter - 5)

- *On: Tuesday, 28th November, 2023 (During the lecture)*
- *Quiz to be taken during own section class only*