CSCI 466: Networks

Network Layer – Data Plane

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Fall 2023

Announcements

Wireshark Lab 2 due on Friday

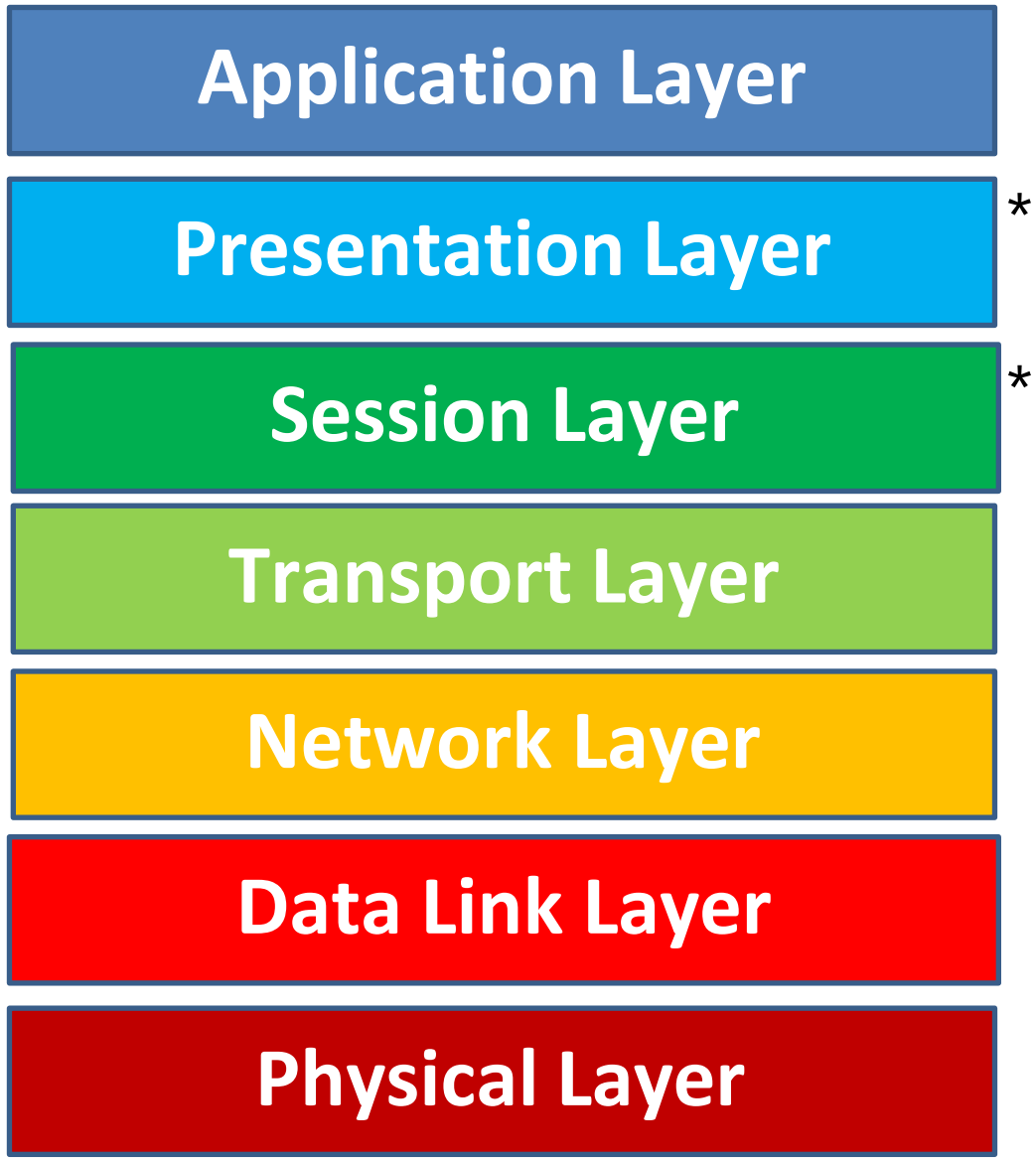
Quiz 4 also on Friday

“Who is congesting the network???”

UDP:

meme made by reese

OSI Model



Application Layer

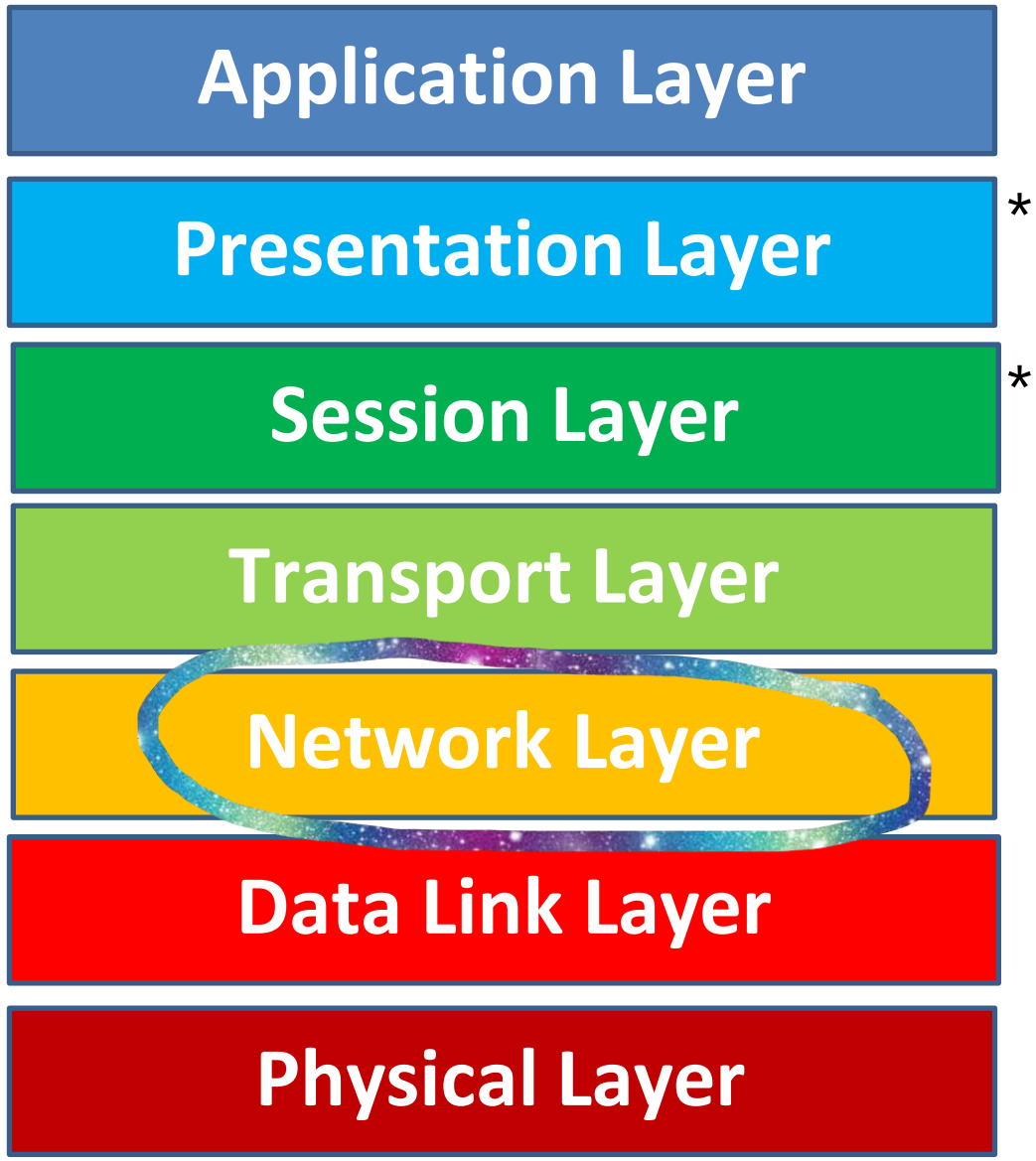
Messages from Network Applications

Physical Layer

Bits being transmitted over a medium

**In the textbook, they condense it to a 5-layer model, but 7 layers is what is most used*

OSI Model



Application Layer

Messages from Network Applications

Physical Layer

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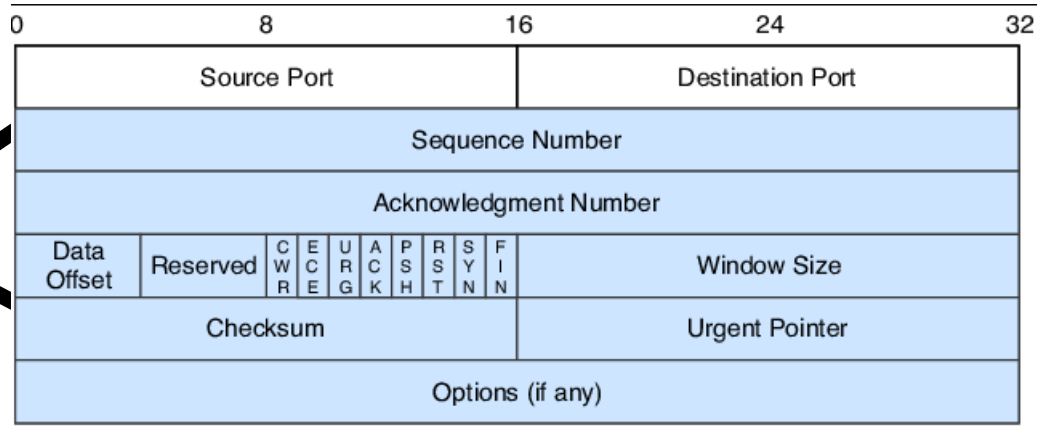
Application Layer

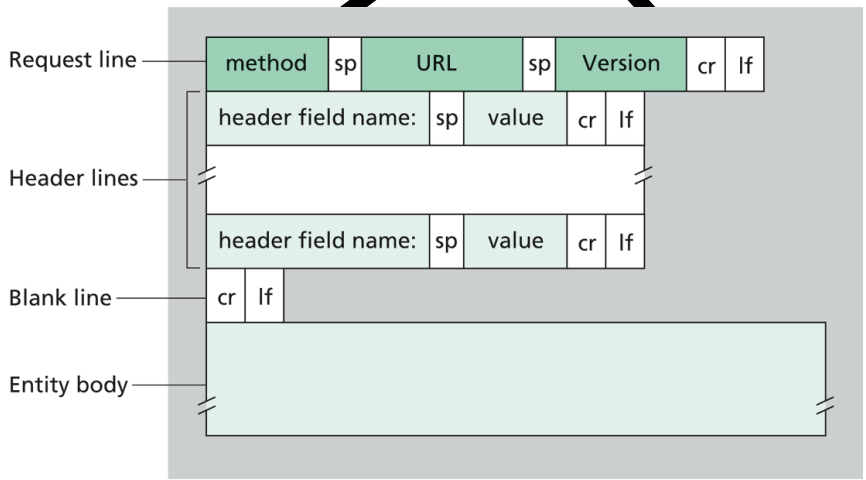
Transport Layer

Our packet of information so far…

"Segment"



Transport Layer Protocol (ex. **TCP**)

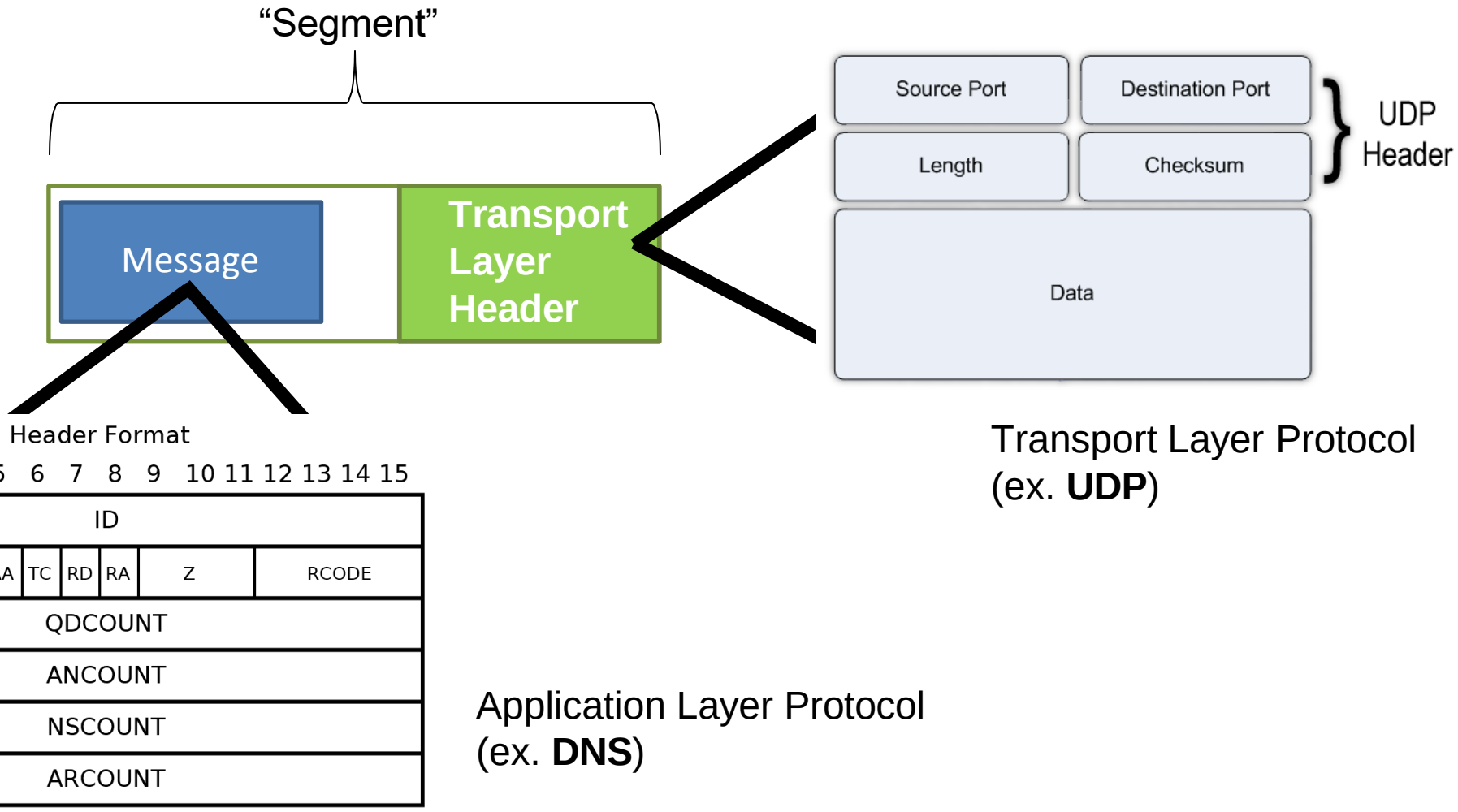


Application Layer Protocol (ex. **HTPP**)

Application Layer

Transport Layer

Our packet of information so far…



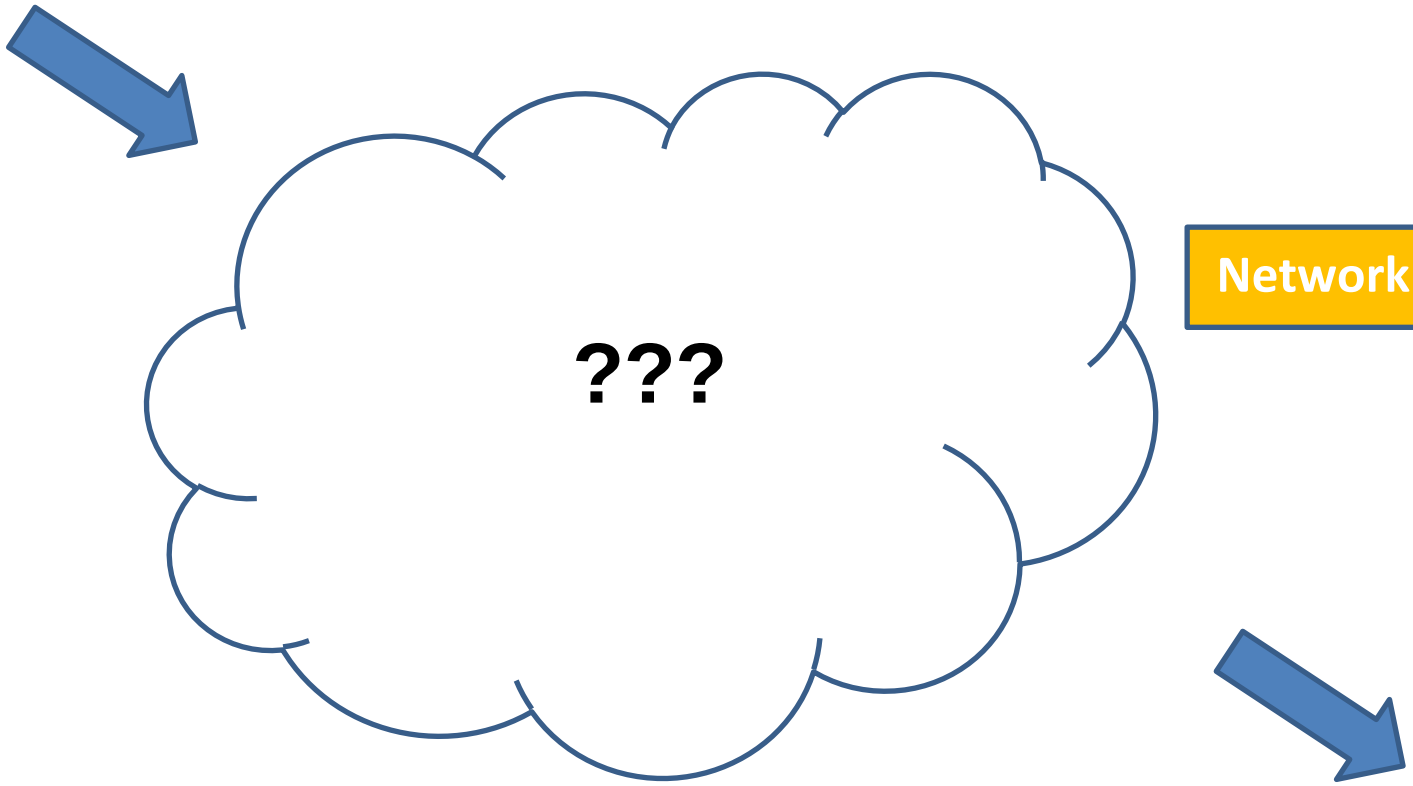
Transport Layer Protocol (ex. **UDP**)

Application Layer Protocol (ex. **DNS**)

Application Layer

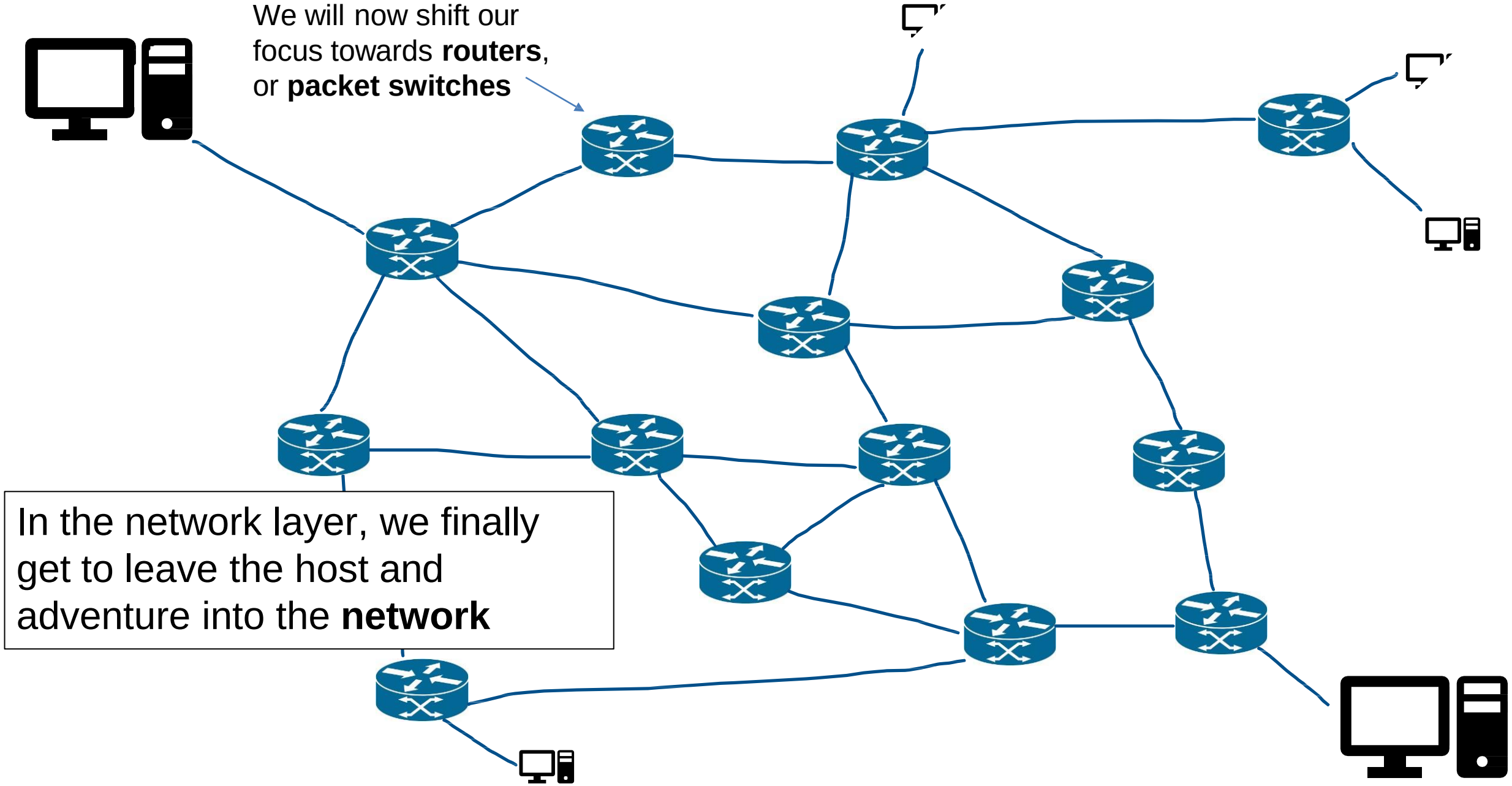
Transport Layer

We've only looked at protocols that are running on some **host**

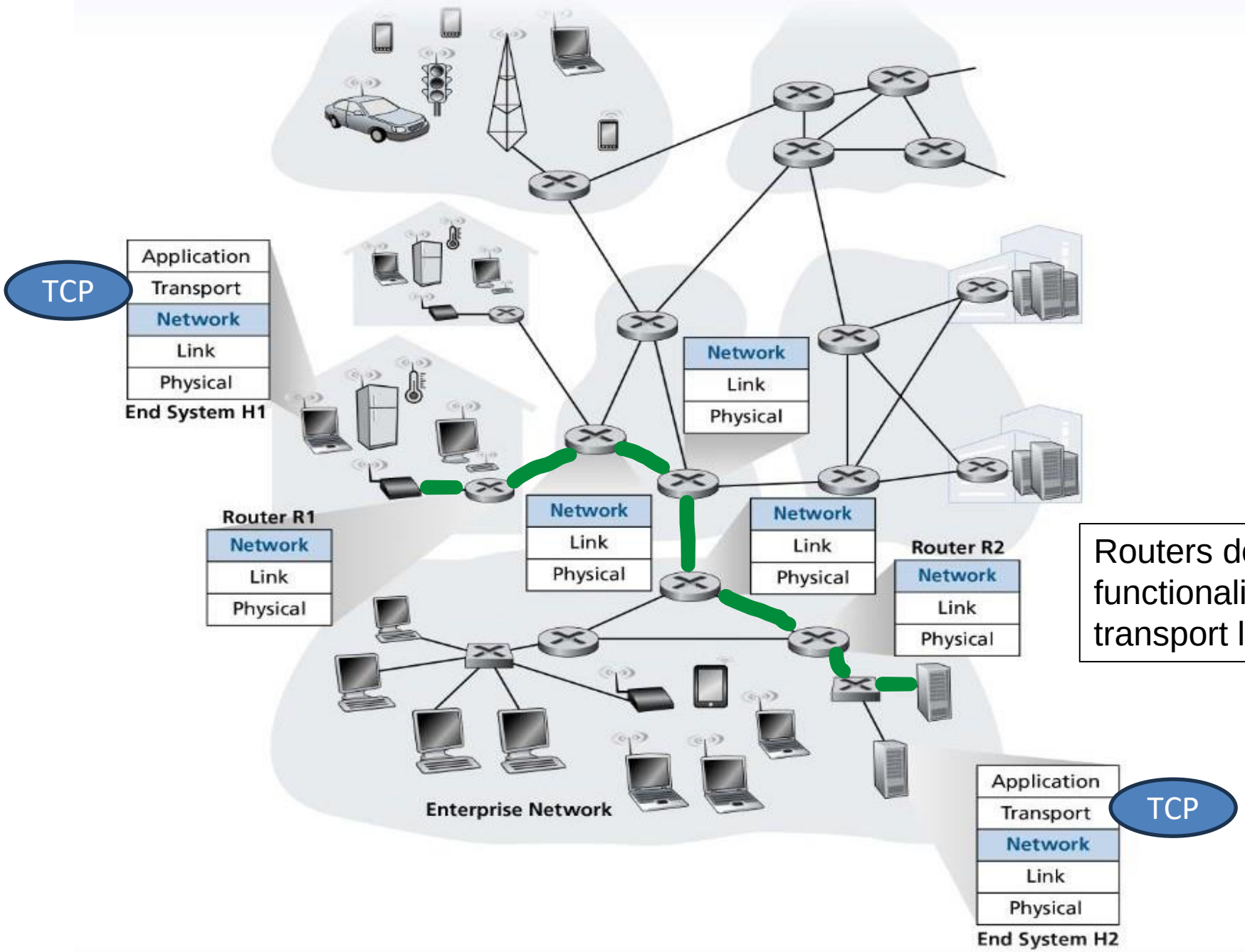


Network Layer

We will now shift our focus towards **routers**, or **packet switches**

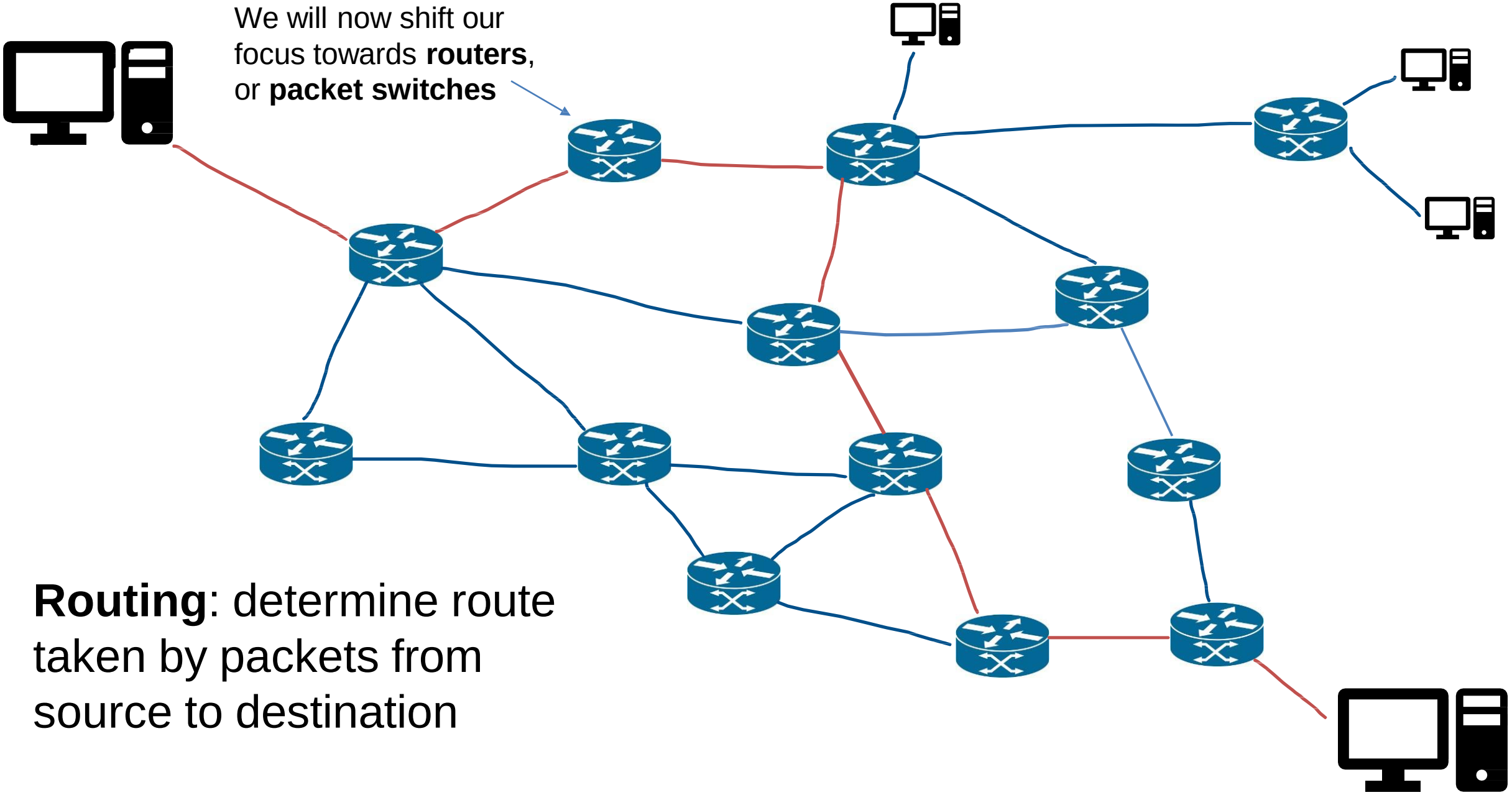


In the network layer, we finally get to leave the host and adventure into the **network**



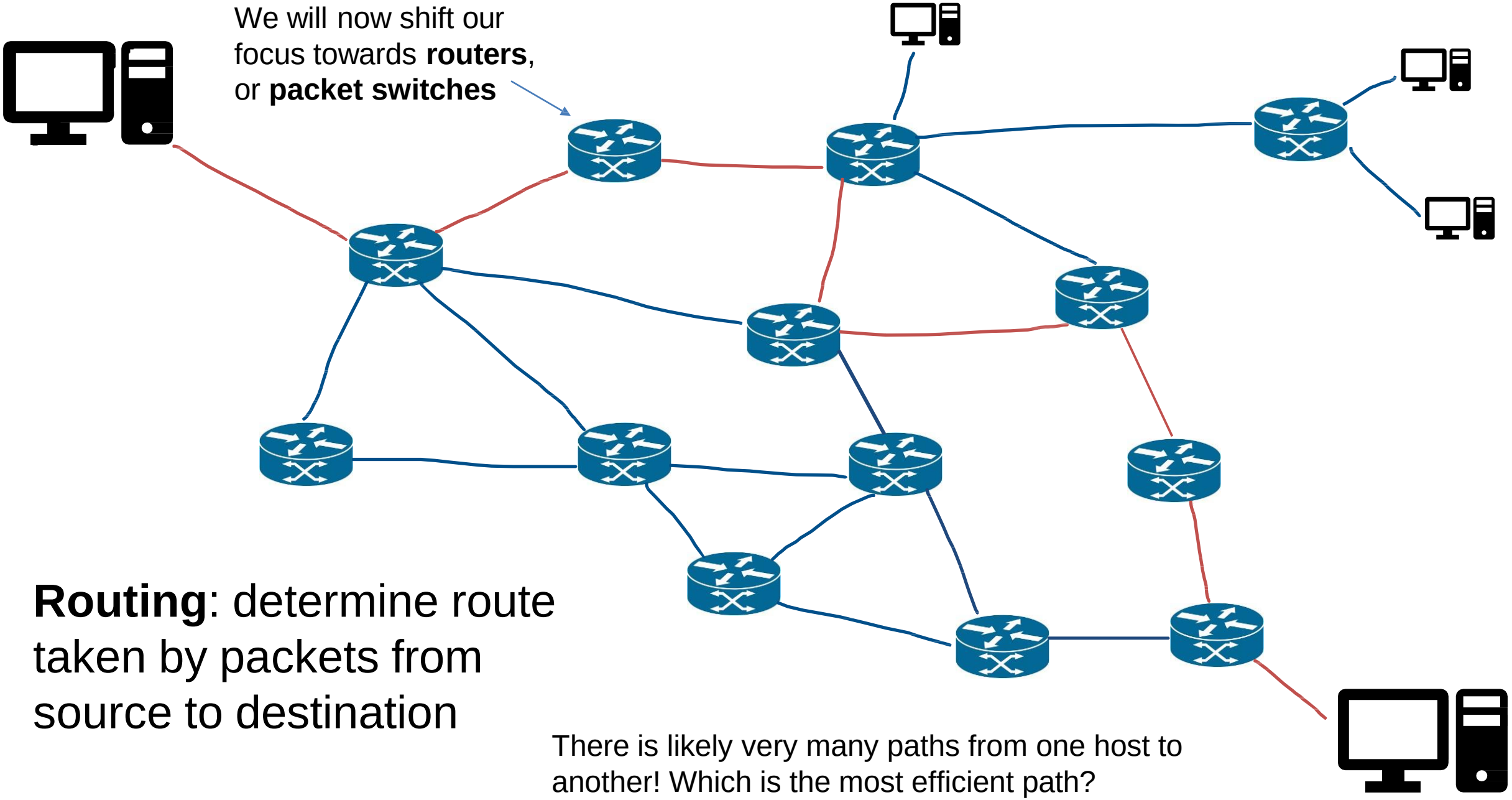
Routers do not have functionality for application & transport layer protocols

We will now shift our focus towards **routers**, or **packet switches**



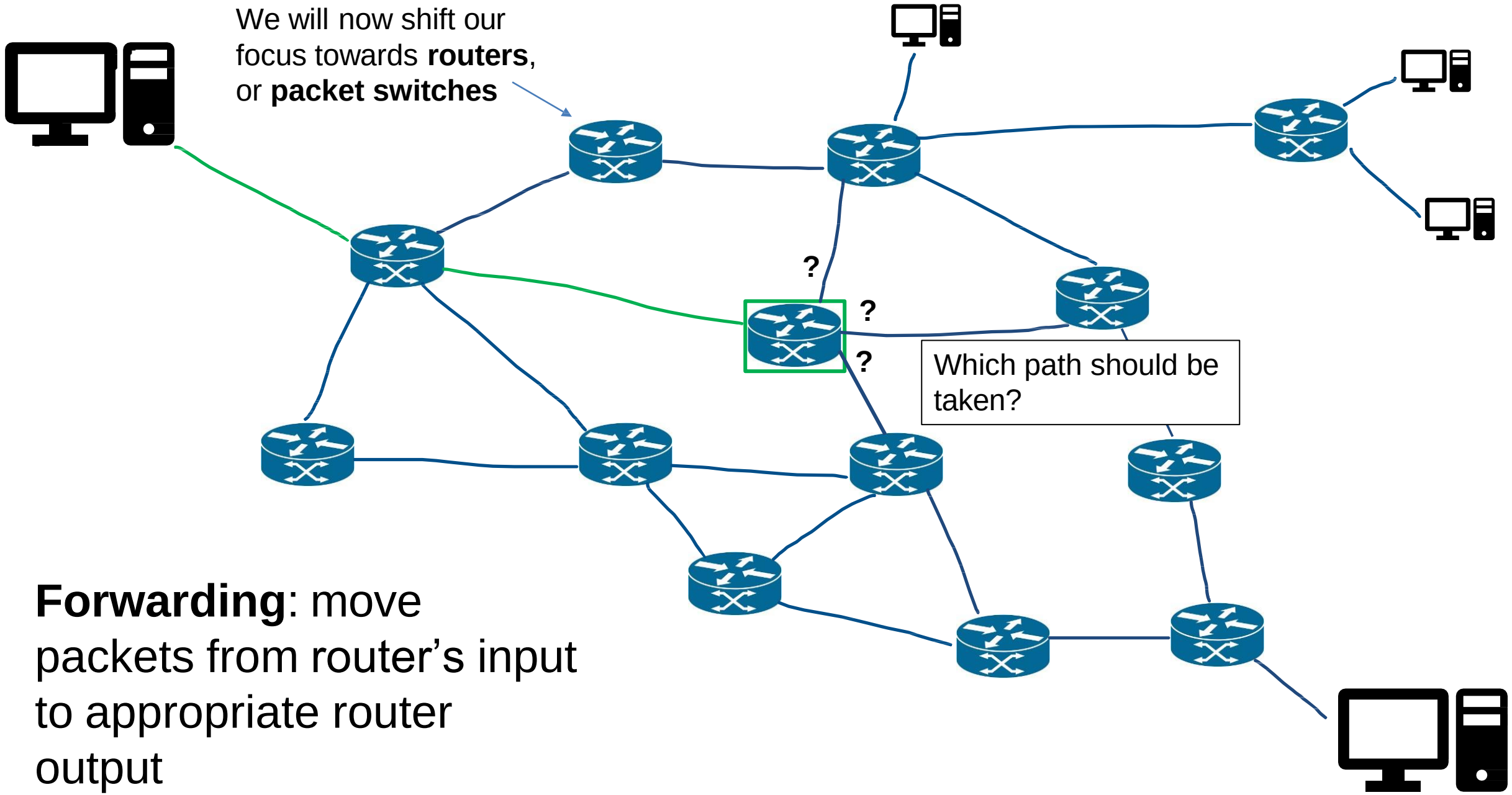
Routing: determine route taken by packets from source to destination

We will now shift our focus towards **routers**, or **packet switches**



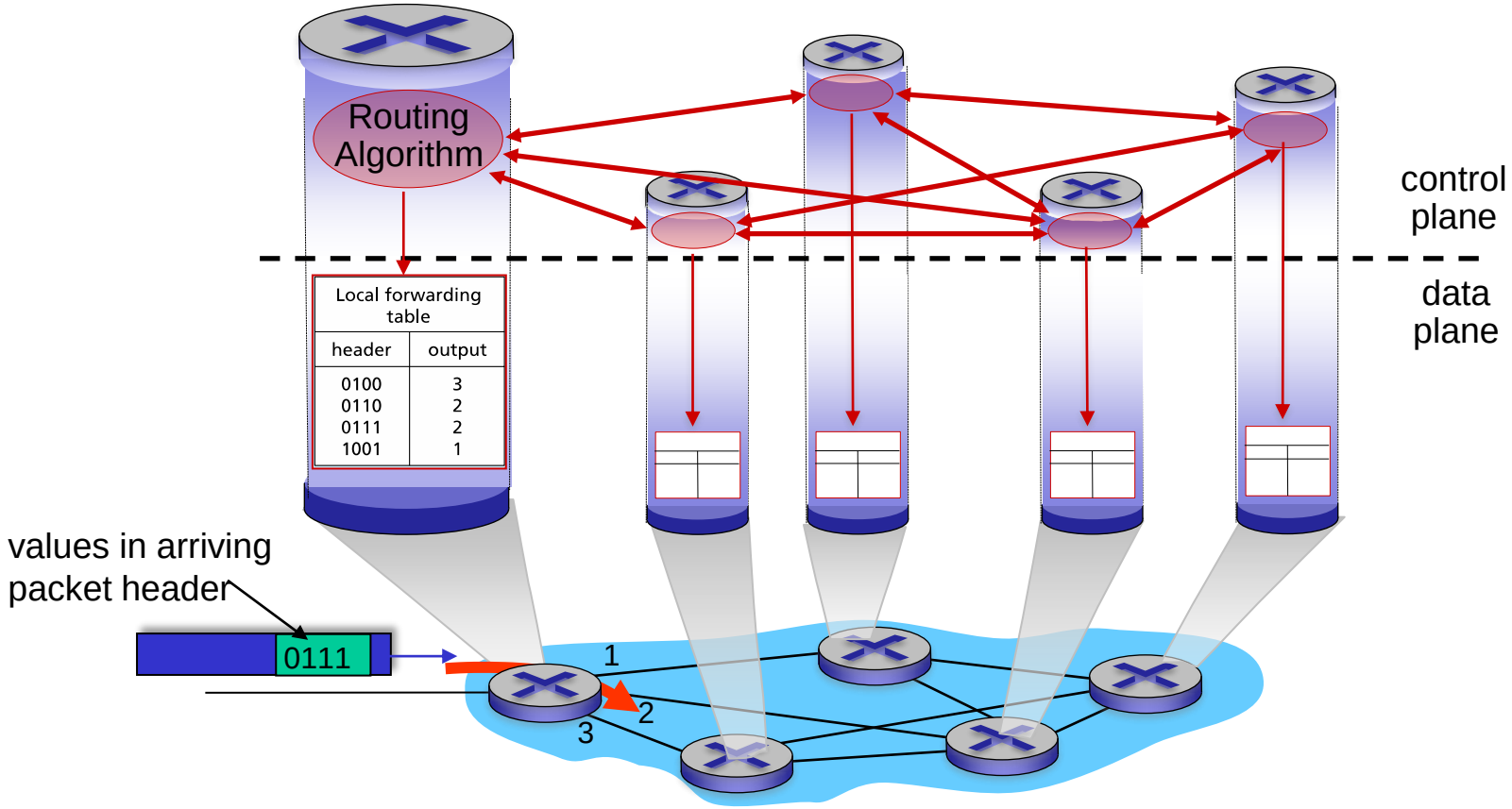
Routing: determine route taken by packets from source to destination

There is likely very many paths from one host to another! Which is the most efficient path?



Forwarding: move packets from router's input to appropriate router output

Individual routing algorithm components *in each and every router* interact in the control plane



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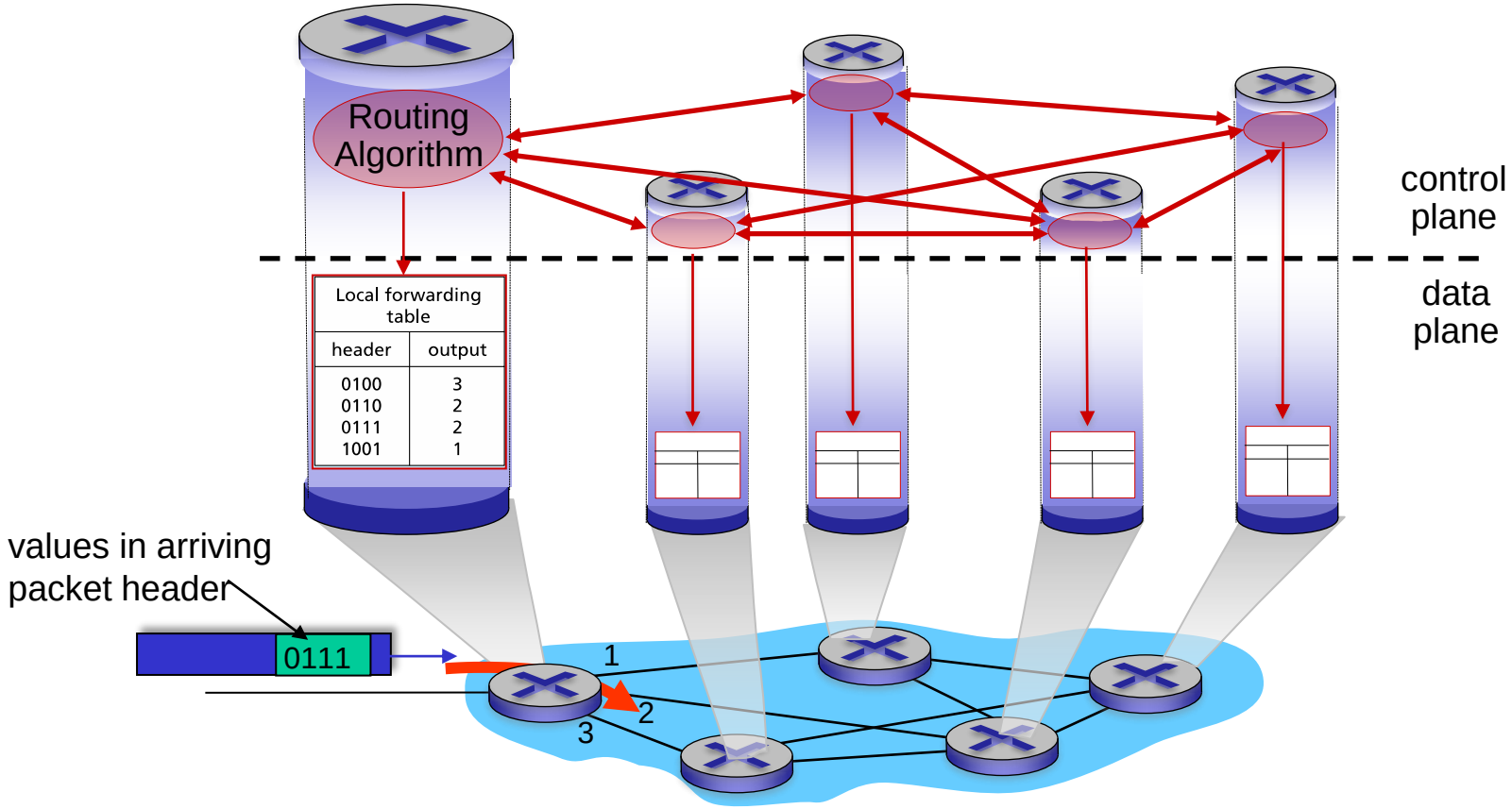
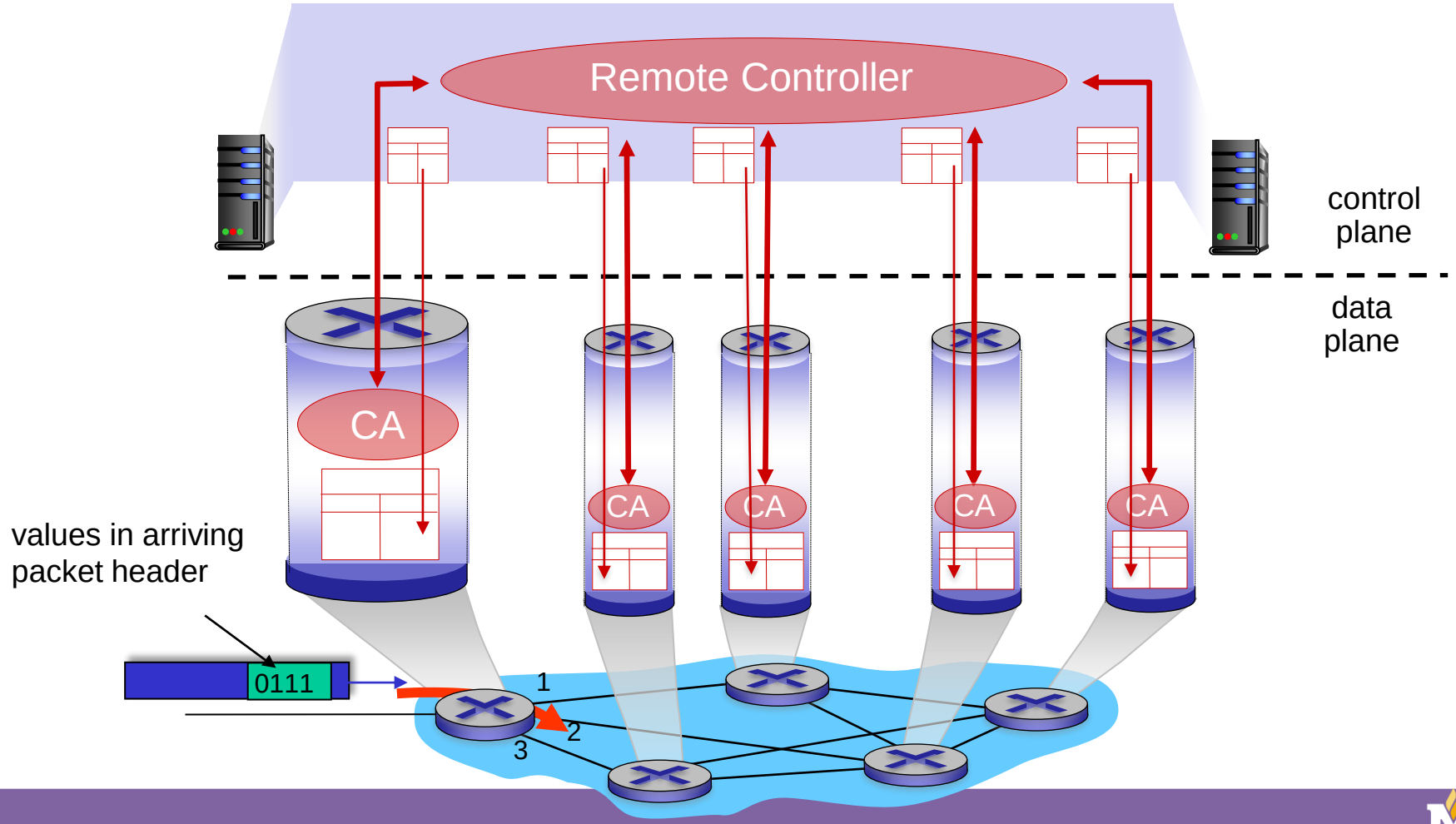


Software-Defined Networking (SDN) control plane

Remote controller computes, installs forwarding tables in routers



Network Layer

Responsible for the delivery of data through a network

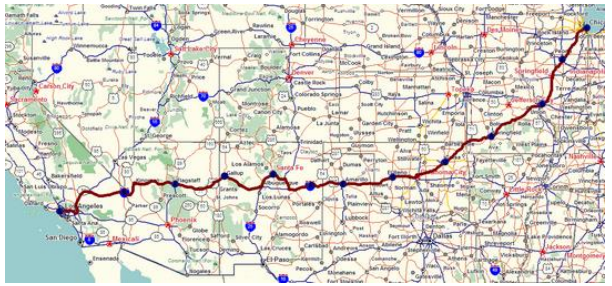
Forwarding

Data Plane

forwarding

Routing

Control Plane



routing

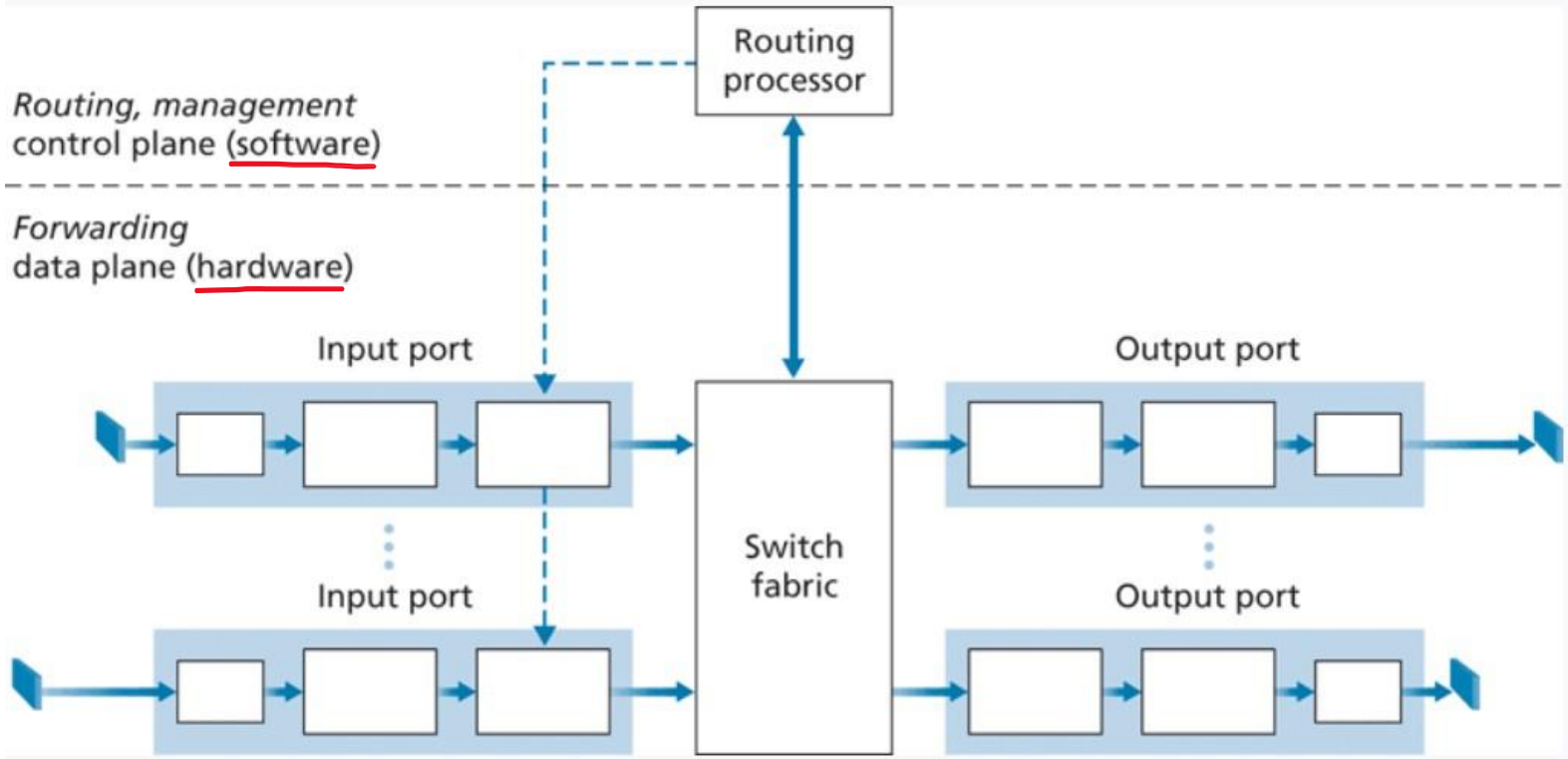
Network Layer

Internet "best effort" service model

No guarantees on:

i. successful datagram delivery to destination
ii. timing or order of delivery
iii. bandwidth available to end-end flow

Router Architecture Overview



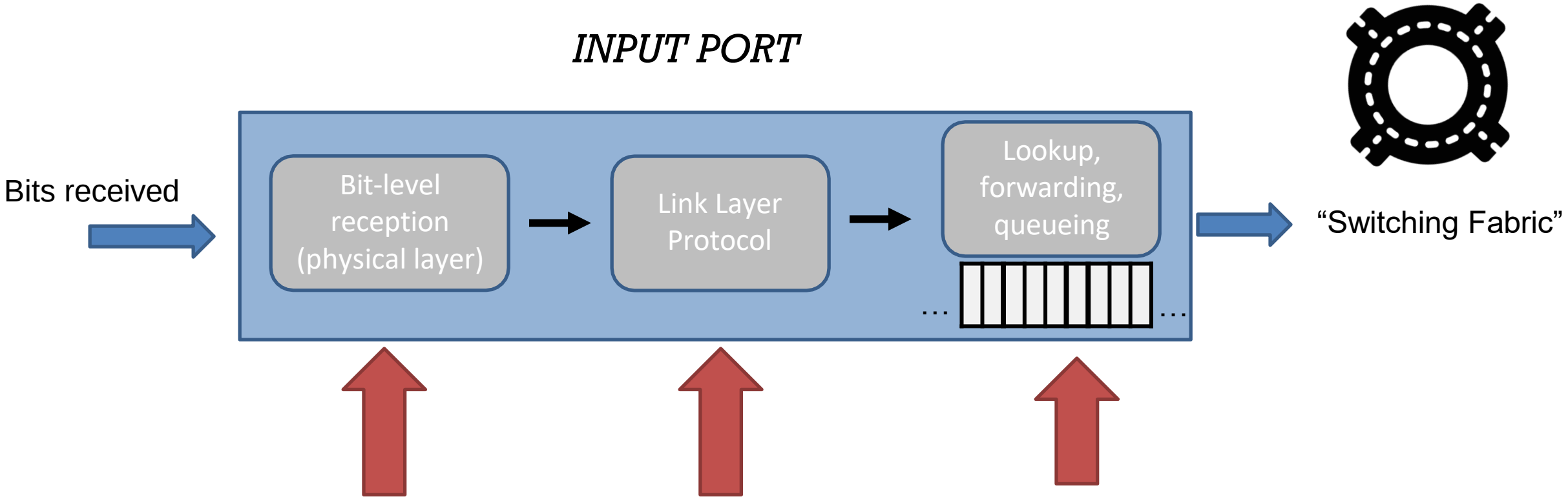
1. Destination-based forwarding

- Forwarding decisions are based on the **destination** of the packet

2. Generalized forwarding

- Forwarding decisions based on any set of header field values

Router Architecture Overview



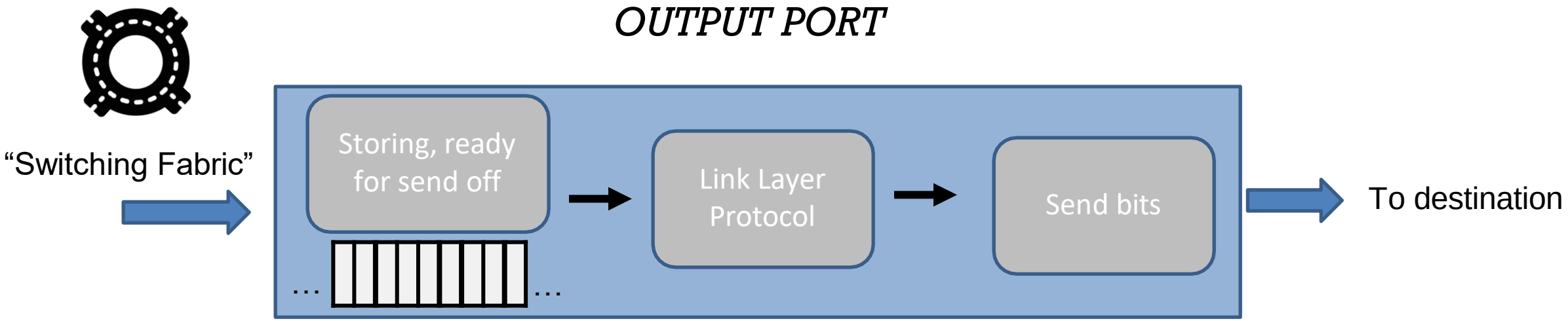
Such as over the wire or through the air

Next layer of OSI model
Ex. Ethernet

Evaluate header field values, lookup output port using forwarding table in memory

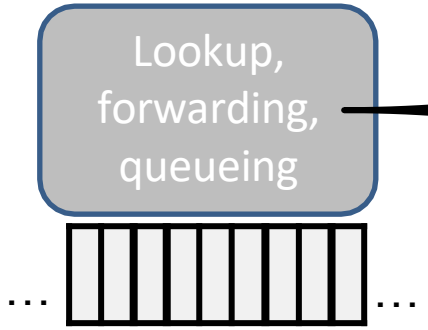
Queueing will occur if datagrams arrive faster than forwarding rate into the switching fabric

Router Architecture Overview



Forwarding Techniques

- Connection-less
- does not require startup,
- Has no idea where the final destination is



Routing Table

Address range	Interface (output link)
128.11.52.0 – 128.11.52.255	1
153.90.2.0 – 153.90.2.255	2
153.90.2.87 – 153.90.2.89	3

This routing table could get very big…
IP addresses need 32/64 bits of memory each

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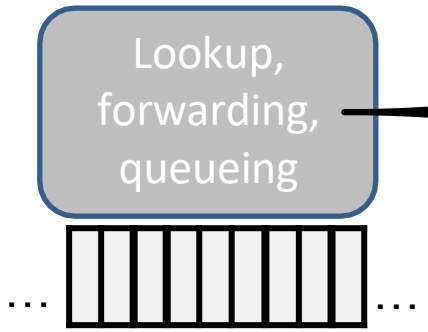
Ranges of IP Addresses

Lookup, forwarding, queueing

Prefix	Link Interface
11001000 00010111 00010	0
11001000 00010111 00011000	1
11001000 00010111 00011	2
Otherwise	3

Prefix of IP addresses

Forwarding Techniques



Longest prefix matching

Address range	Interface (output link)
11001000 00010111 00010*** *********	1
11001000 00010111 00011000 *********	2
11001000 00010111 00011*** ********	3
otherwise	4

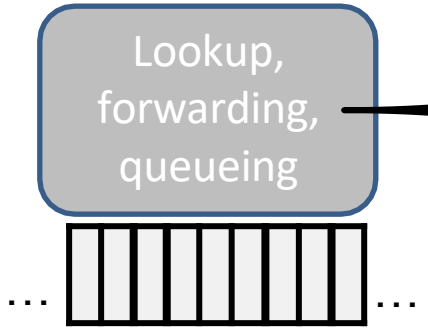
when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address

examples:

DA: 11001000 00010111 000**10110 10100001** which interface?

DA: 11001000 00010111 000**11000 10101010** which interface?

Forwarding Techniques



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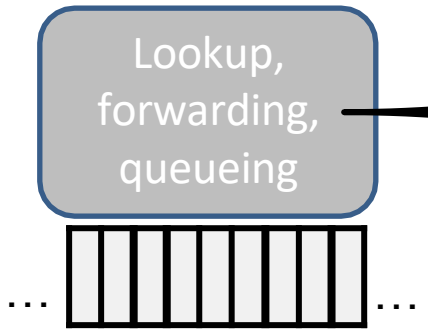

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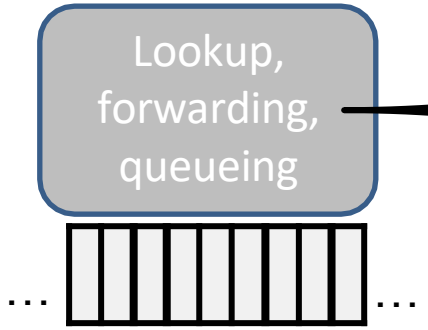

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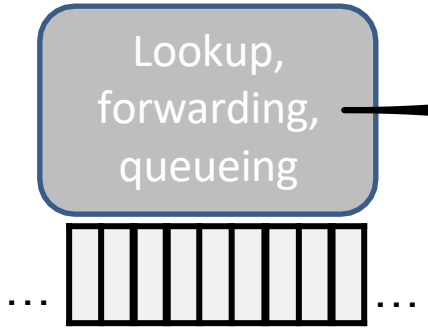

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These lookups need to happen in nanoseconds for our network to function

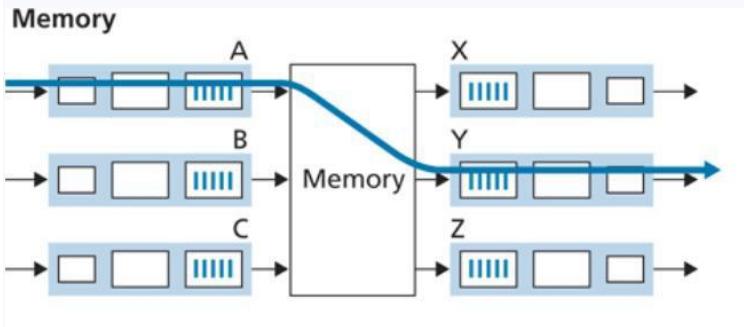
Ternary content addressable memories (TCAMs) are used in modern routers to do **LPM**

Cisco routers can carry millions of TCAM entries in their routers

Fabric Switch and Switching

Switching fabric: Mechanism that forwards data from an input port to output port

Switching via memory:



Handled by a CPU (routing processor)

Cannot forward data in parallel

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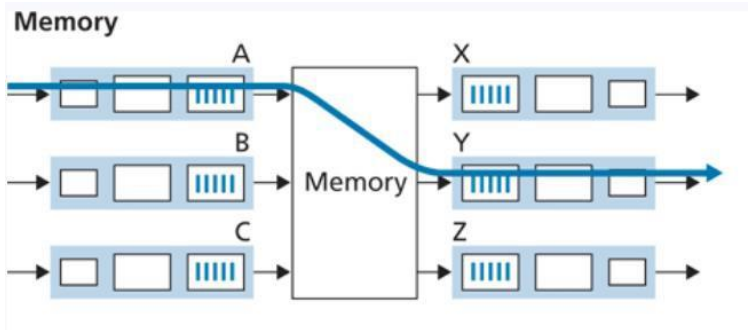

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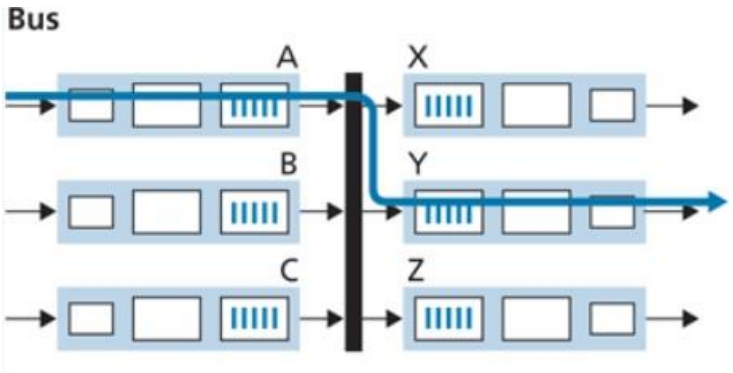
Switching via bus:



Datagrams are prepended with a header

A “bus” transports input port datagrams to output ports

“keep going around the roundabout until you find your port”

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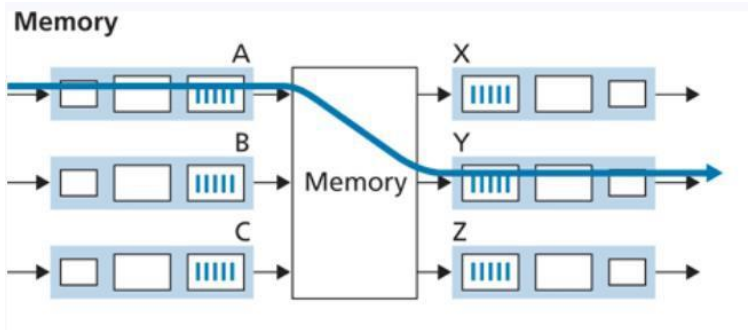

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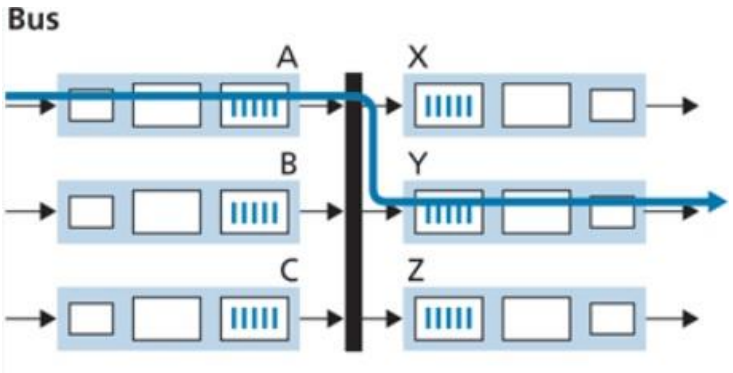

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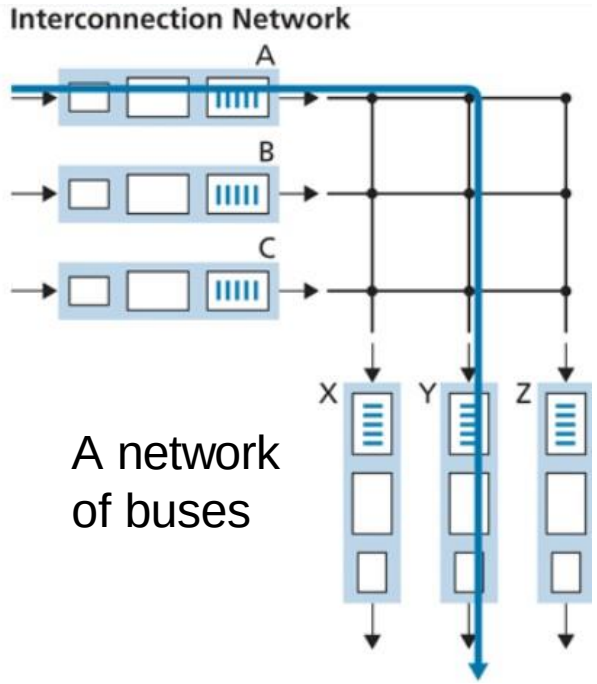
A “bus” transports input port datagrams to output ports

“keep going around the roundabout until you find your port”

One shared bus, but can only fit one datagram

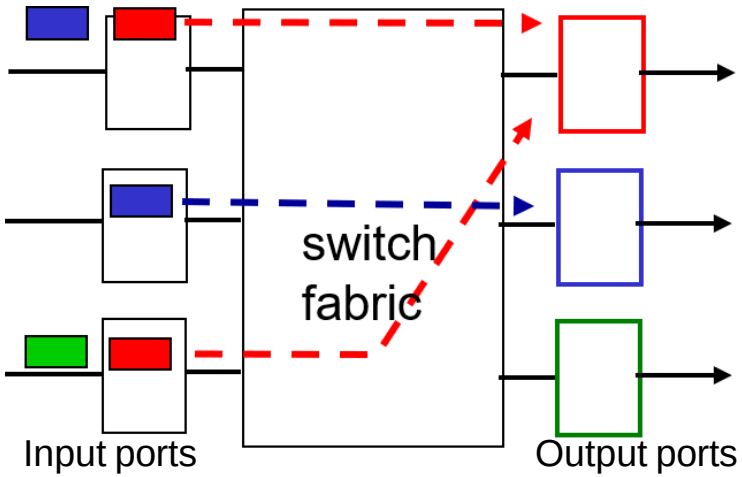
Switching via network:



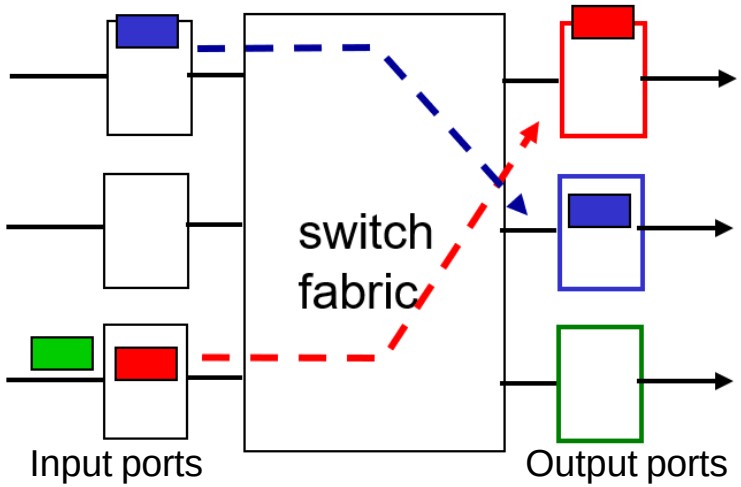
A network of buses

Input Queueing

fabric slower than input ports combined ➔*queueing may occur at input queues*



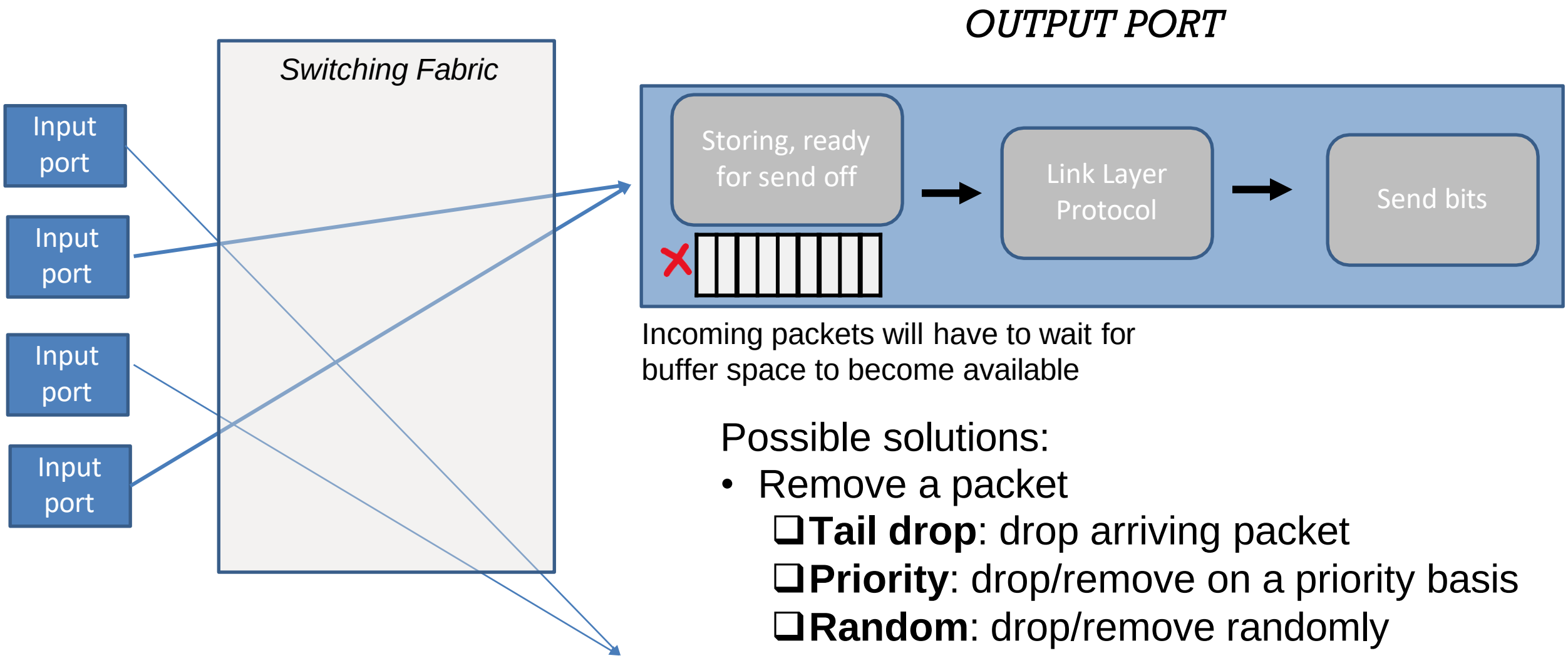
output port contention:
only one red datagram can be transferred.
lower red packet is blocked



one packet time later:
green packet experiences HOL blocking

Head-of-the-Line (HOL) blocking: queued datagram at front of queue prevents others in queue from moving forward

Output Queueing



Incoming packets will have to wait for buffer space to become available

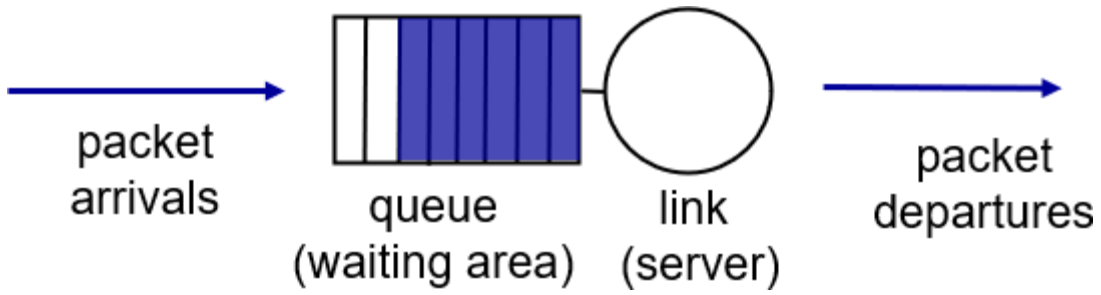
Possible solutions:

- Remove a packet
  - ❑ **Tail drop**: drop arriving packet
  - ❑ **Priority**: drop/remove on a priority basis
  - ❑ **Random**: drop/remove randomly

Packet Scheduling

Scheduling is used to determine the next packet to send on the link

FIFO (first in first out): Send in order of arrival to queue



Packet Scheduling

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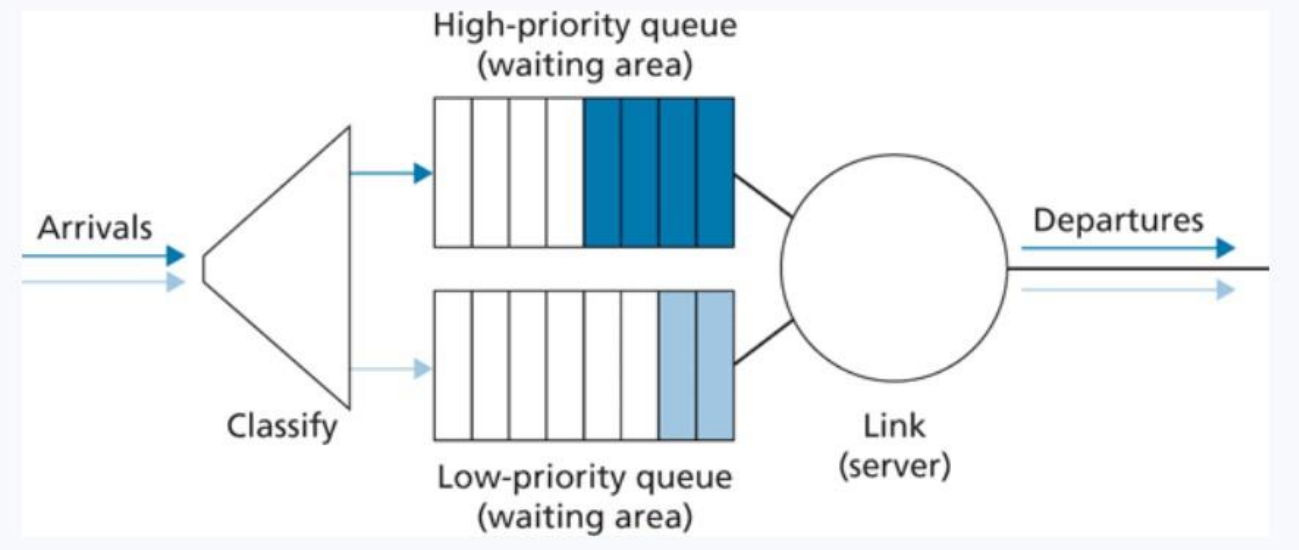
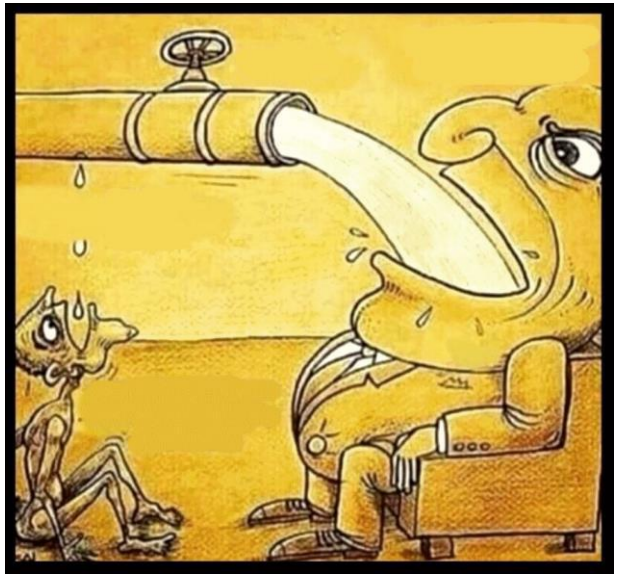
Priority: packets are classified into priority classes. High priority = sent over link first

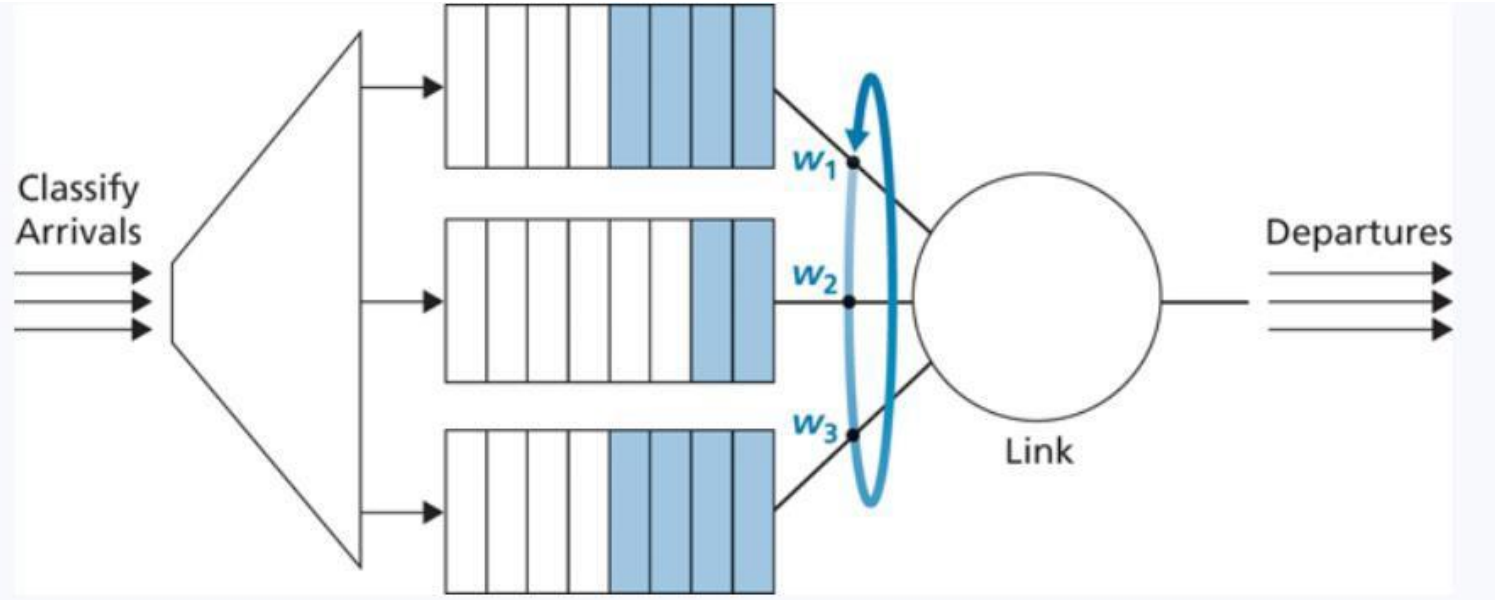




Packet Scheduling

Scheduling is used to determine the next packet to send on the link

Round robin weighted fair queueing: packets are classified into priority classes. Each class gets to send one packet during a “cycle”



Packet from the priority group gets sent

Packet from the middle class gets sent

Packet from the plebian class gets sent