CSC4200/5200 – COMPUTER NETWORKING

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NAT, ROUTING

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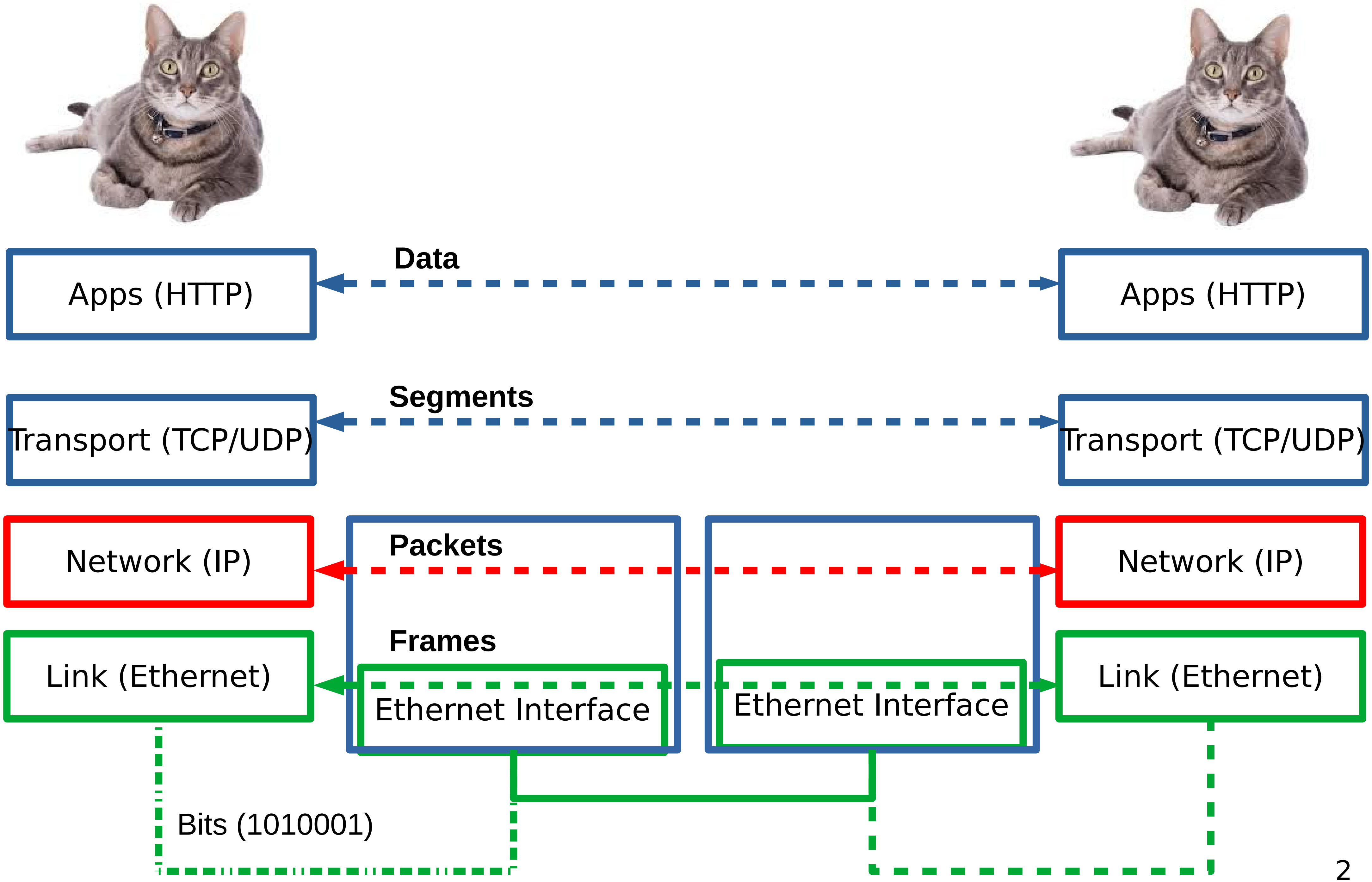
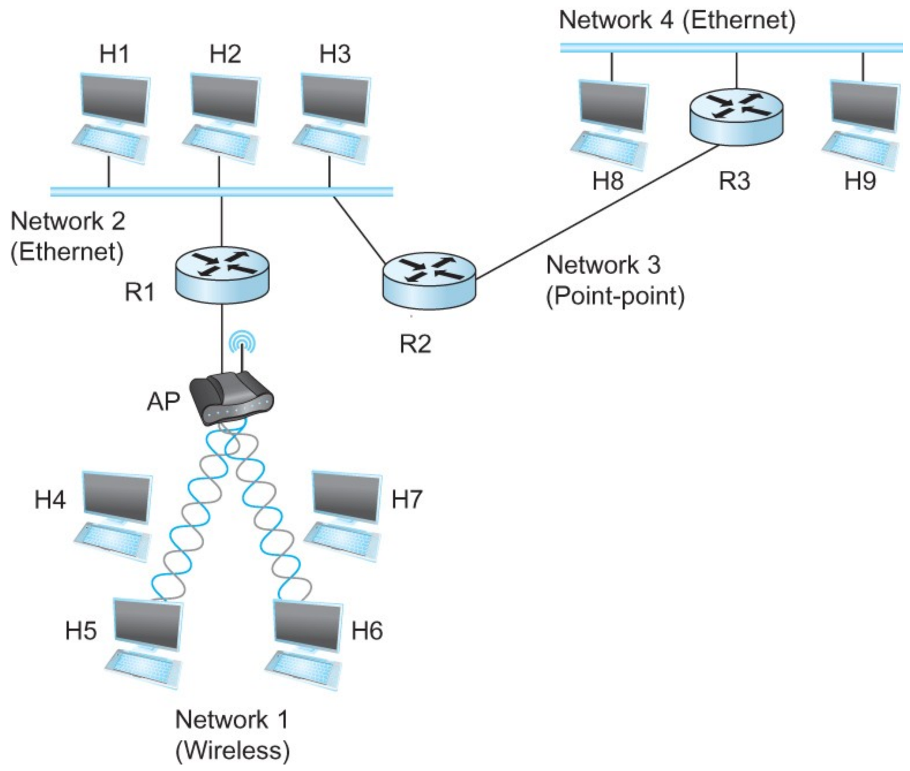
Tennessee TECH


Data
Apps (HTTP)
Apps (HTTP)
Segments
Transport (TCP/UDP)
Transport (TCP/UDP)
Packets
Network (IP)
Network (IP)
Frames
Link (Ethernet)
Ethernet Interface
Ethernet Interface
Link (Ethernet)
Bits (1010001)

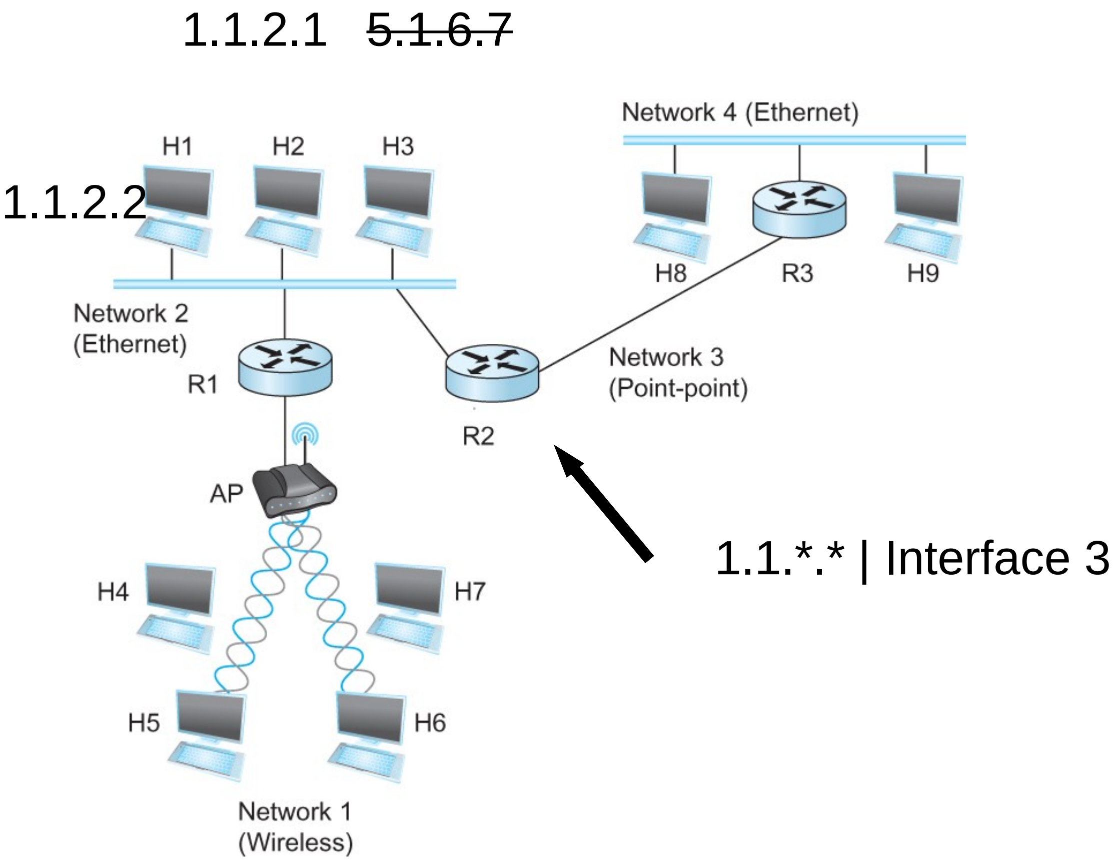
Internetworking Protocol (IP)

- What is an internetwork?
  - An arbitrary collection of networks
  - provide some sort of host-host to packet delivery service



IP addresses are in Network + Host

- 1.1.2.1 →
  - 1.1 → Network part
  - 2.1 → host part
- Each octet can range from 1- 255
- Hierarchical address

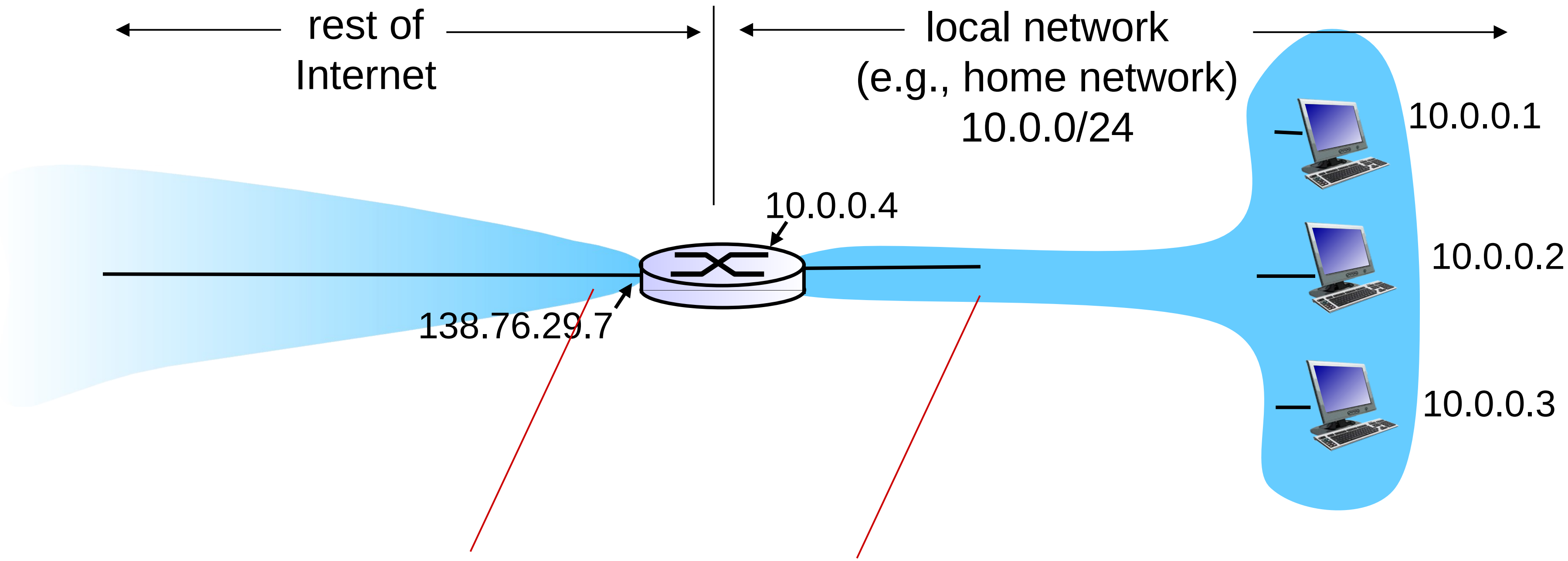


129.82.138.254

10000001.01010010.10001010.11111110

Network part (24 bits). Host part(8 bits)

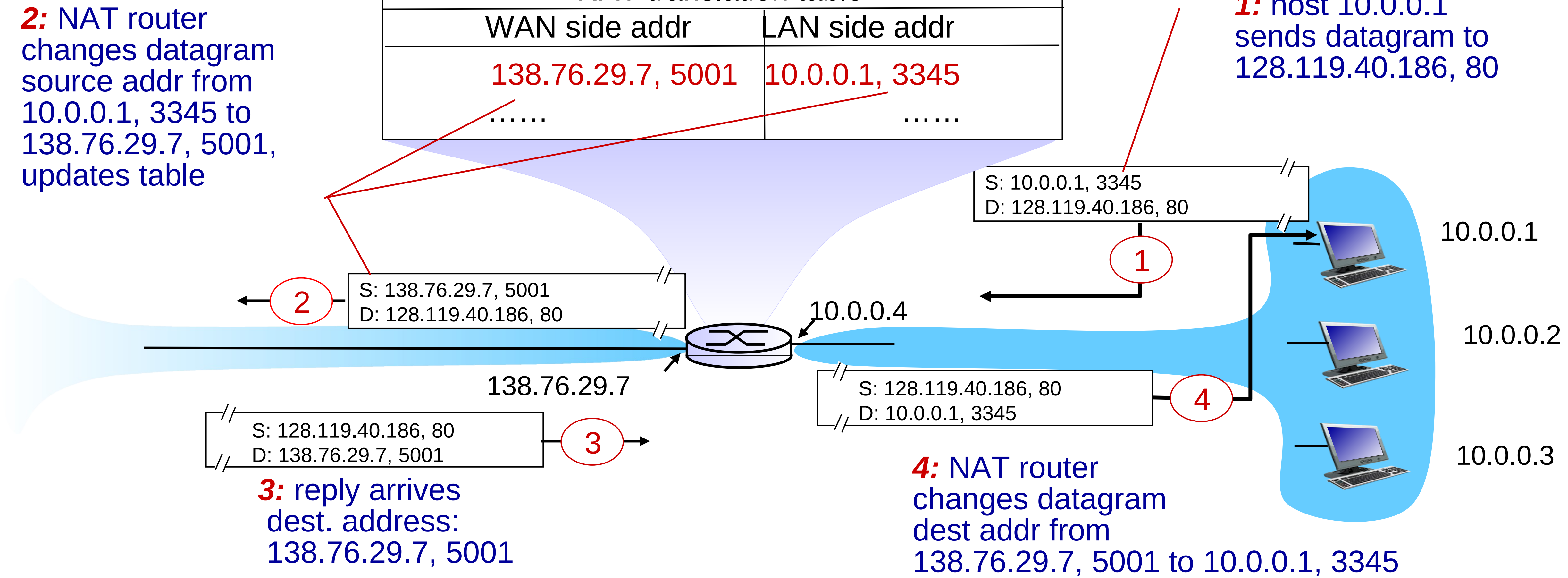
NAT: network address translation



datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

NAT: network address translation

NAT translation table	
WAN side addr	LAN side addr
138.76.29.7, 5001	10.0.0.1, 3345
……	……

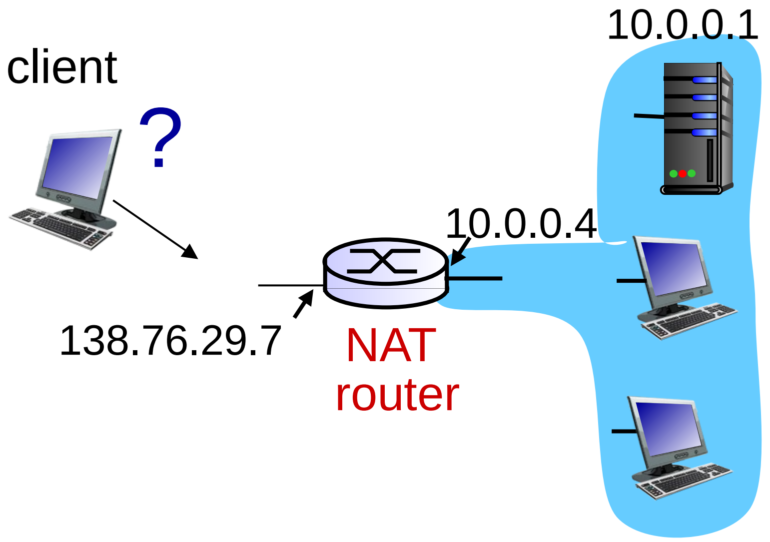


NAT

- One IP address for all devices
  - Addresses the address space problem

- Can change local addresses without involving the ISP

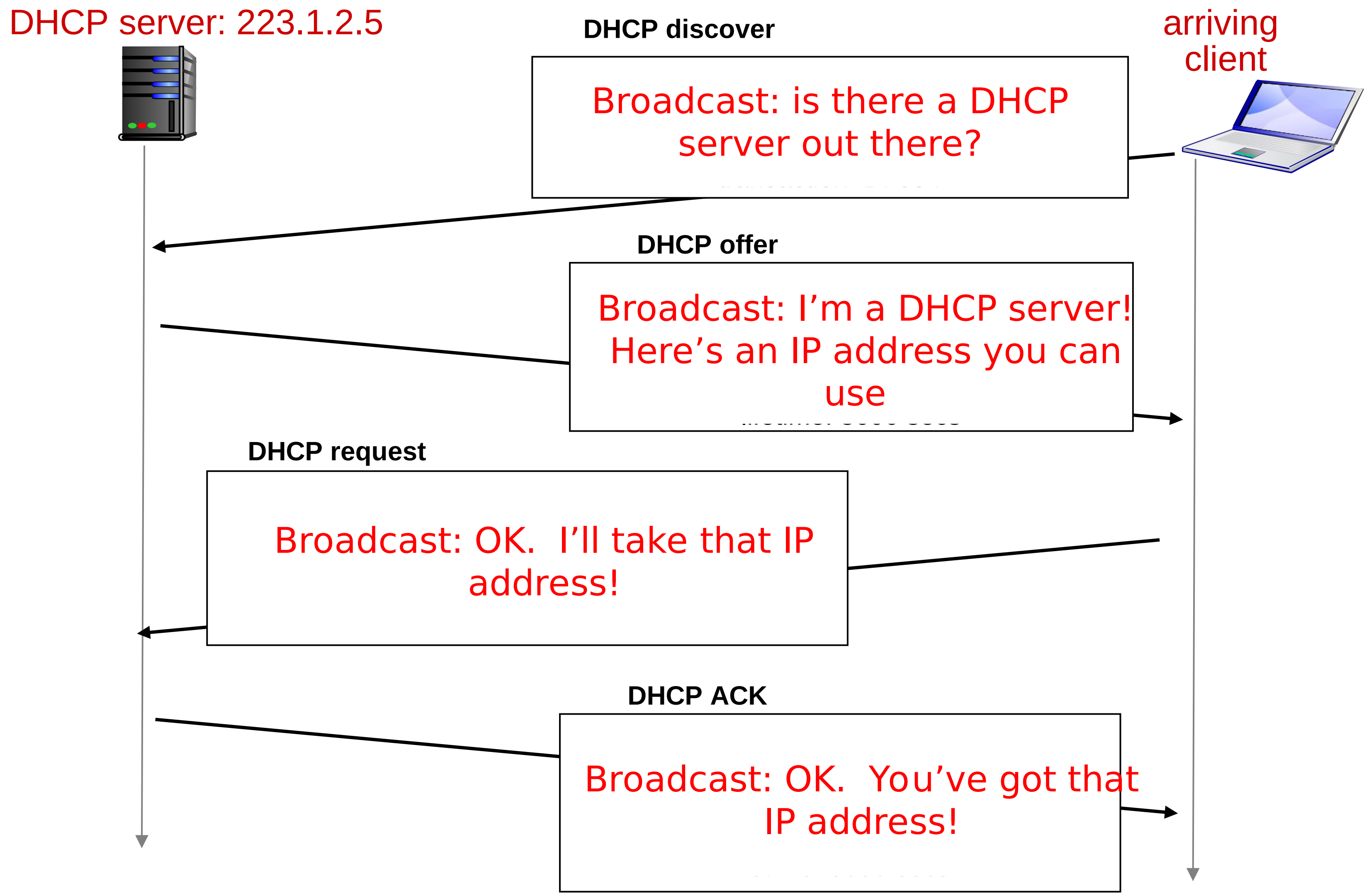
- NAT traversal problem
  - Is a server is behind NAT, how does the client talk to it?



DHCP

- **New laptop joins a network**
  - Does not have source address
  - Does not know who to ask
  - Does not know other network parameters like DNS or Gateway router information

DHCP client-server scenario



kurose/ross

DHCP Server

- A local central database with a list of IP addresses
  - 10.0.0.1/8
- Offers an available IP to a client for a period of time
  - Lease time – 24 hours, 1 hour, configurable ← ***Soft State***
- Multiple servers might coexist and offer IP to the same request
  - Broadcast medium
  - Client decides which one to accept

DHCP Client – Keep refreshing!

- IP address provided expires after time ***t***

- Client can release DHCP lease
  - Shutdown the laptop

- If you walk away from the building
  - Crash

- Performance trade off
  - Short time – too many broadcasts, quick recovery of addresses
  - Long time – less network traffic, longer recovery of addresses

https://samsclass.info/ipv6/exhaustion-2016.htm

Address shortage – Better solution? IPv6

- IPv6 – 128 bits

  This many addresses left:
  340,282,366,920,938,463,463,374,607,429,929,813,392

  Projected IPv6 Exhaustion Date: 9,000,000 AD

We have created and connected various networks. We can forward packets between them.

But what is the most efficient way? ← Routing

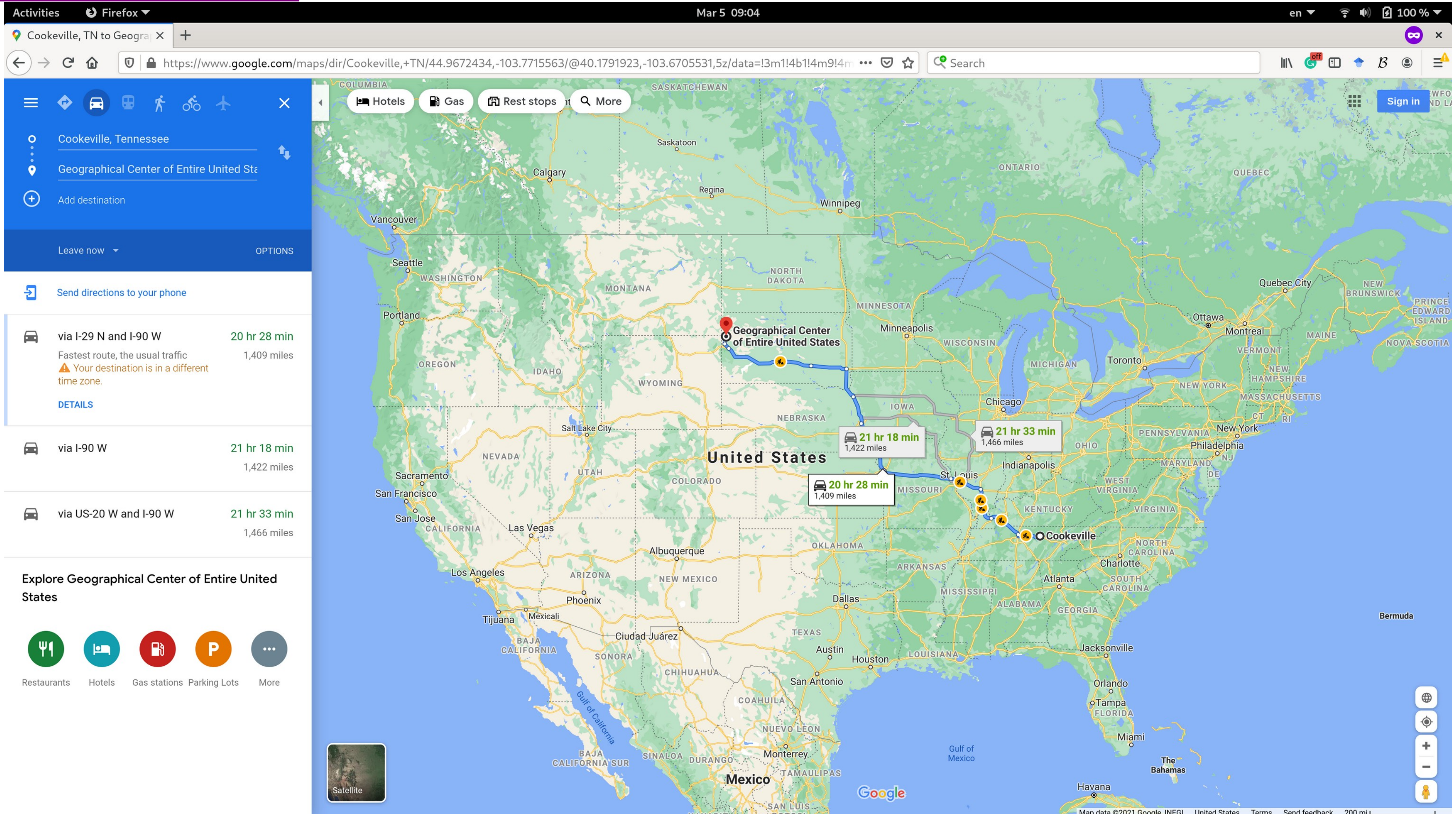
Forwarding vs Routing

- Forwarding:
  - to select an output port based on destination address and routing table
  - **Local path**

SubnetNumber	SubnetMask	NextHop
128.96.34.0	255.255.255.128	Interface 0
128.96.34.128	255.255.255.128	Interface 1
128.96.33.0	255.255.255.0	R2

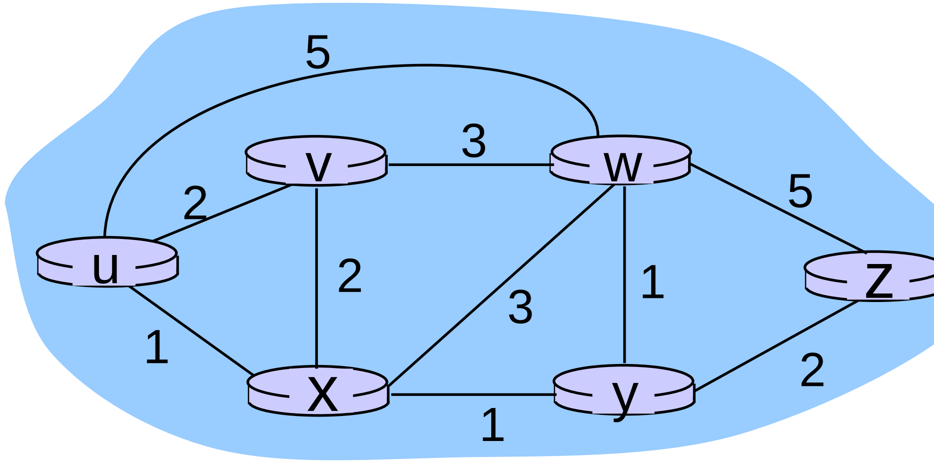
- Routing:
  - process by which routing table is built
  - **End-to-end path**

Routing = Navigation



Why bother?

- Quality of path affects performance
  - Longer path = more delay



- Balance path usage, avoid congested paths

- Deal with failures

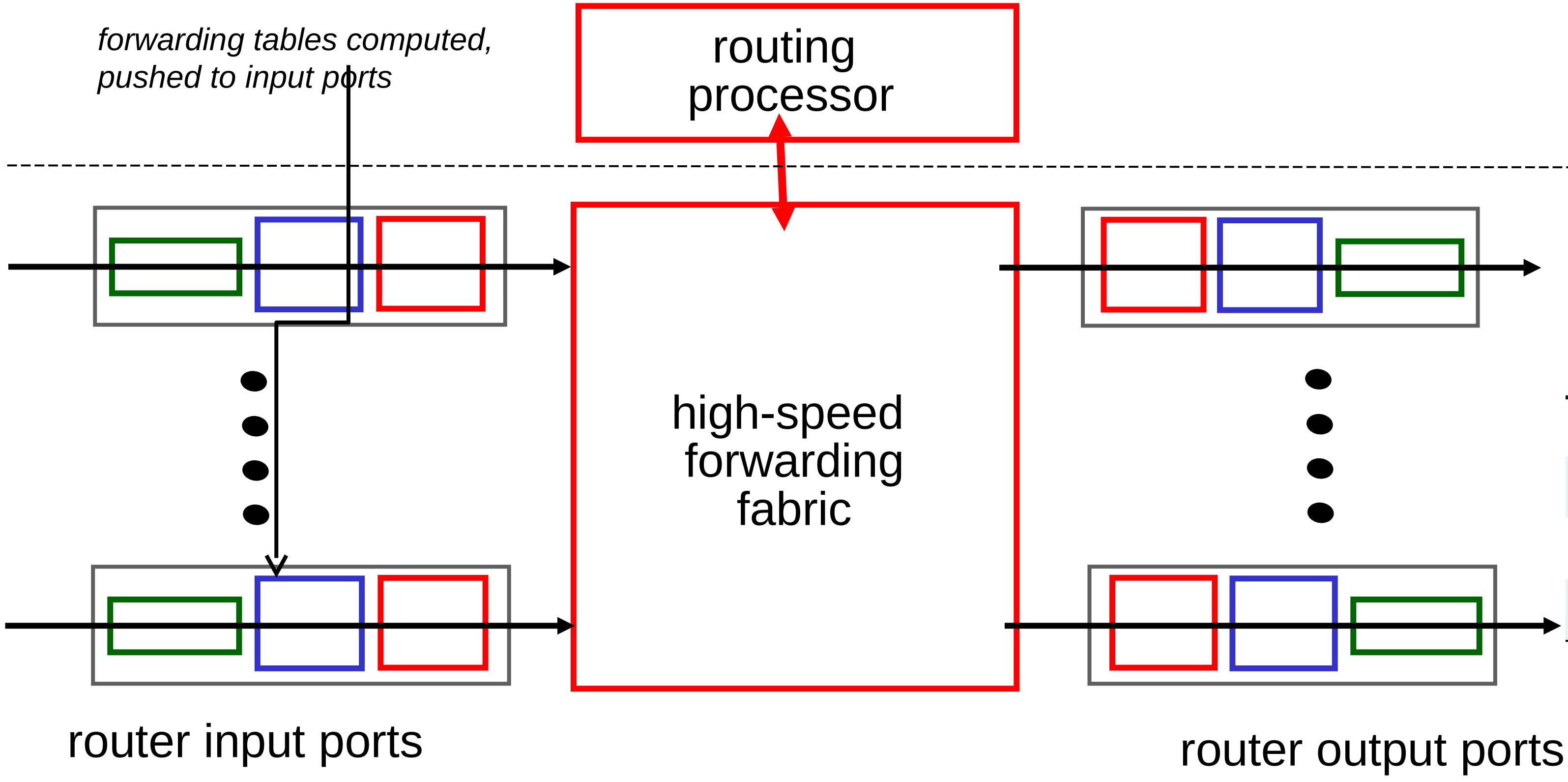
SubnetNumber	SubnetMask	NextHop
128.96.34.0	255.255.255.128	Interface 0
128.96.34.128	255.255.255.128	Interface 1
128.96.33.0	255.255.255.0	R2

Router architecture overview

Two key router functions:

- run routing algorithms/protocol (RIP, OSPF, BGP)
- *forwarding* datagrams from incoming to outgoing link

Control Plane = routing
Vs
Data Plane = forwarding

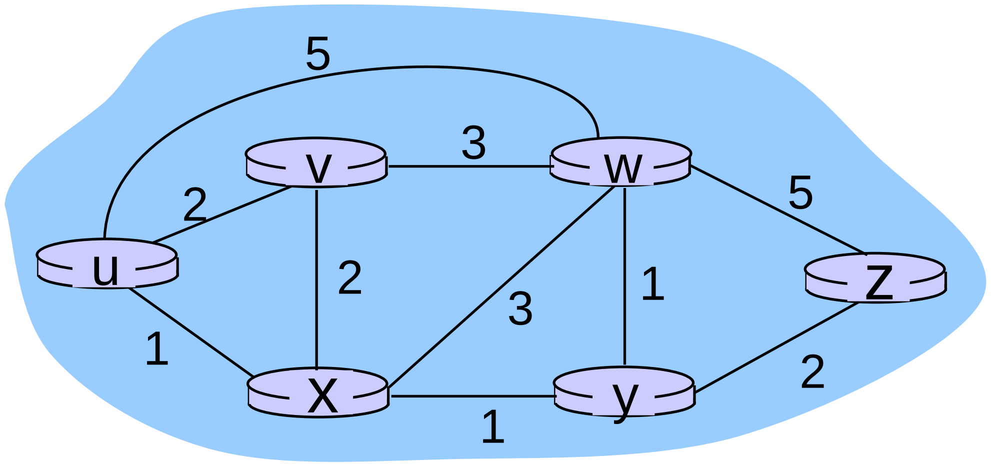


routing, management control plane (software)

forwarding data plane (hardware)

SubnetNumber	SubnetMask	NextHop
128.96.34.0	255.255.255.128	Interface 0
128.96.34.128	255.255.255.128	Interface 1
128.96.33.0	255.255.255.0	R2

Graph abstraction



graph: G = (N,E)

N = set of routers = { u, v, w, x, y, z }

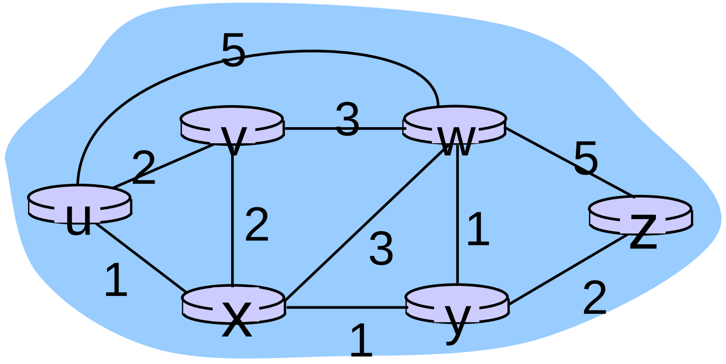
E = set of links ={ (u,v), (u,x), (v,x), (v,w), (x,w), (x,y), (w,y), (w,z), (y,z) }

X→ Z

Cost (x,v,w,z) = cost(x,v) + cost (v, w) + cost(w,z) = 10
Cost (x,w,z) = cost(x,w) + cost(w,z) = 8
Cost(x, y, z) = ?
Objective → find the lowest cost path between all nodes

Dijkstra’s Shortest-Path Algorithm

- Given a graph (network) with link costs
- Find the lowest cost paths to all nodes



- Iterative
  - After n iterations, you will find least cost path to *n nodes*

- *S = Least cost paths already known, initially source node {U}*
- *D(v): current cost of path from source(U) to node V*
  - *Initially, D(v) = c(u,v) for all nodes v adjacent to u*
  - *D(v) = ∞ for all other nodes*
  - *Update D(v) as we go*

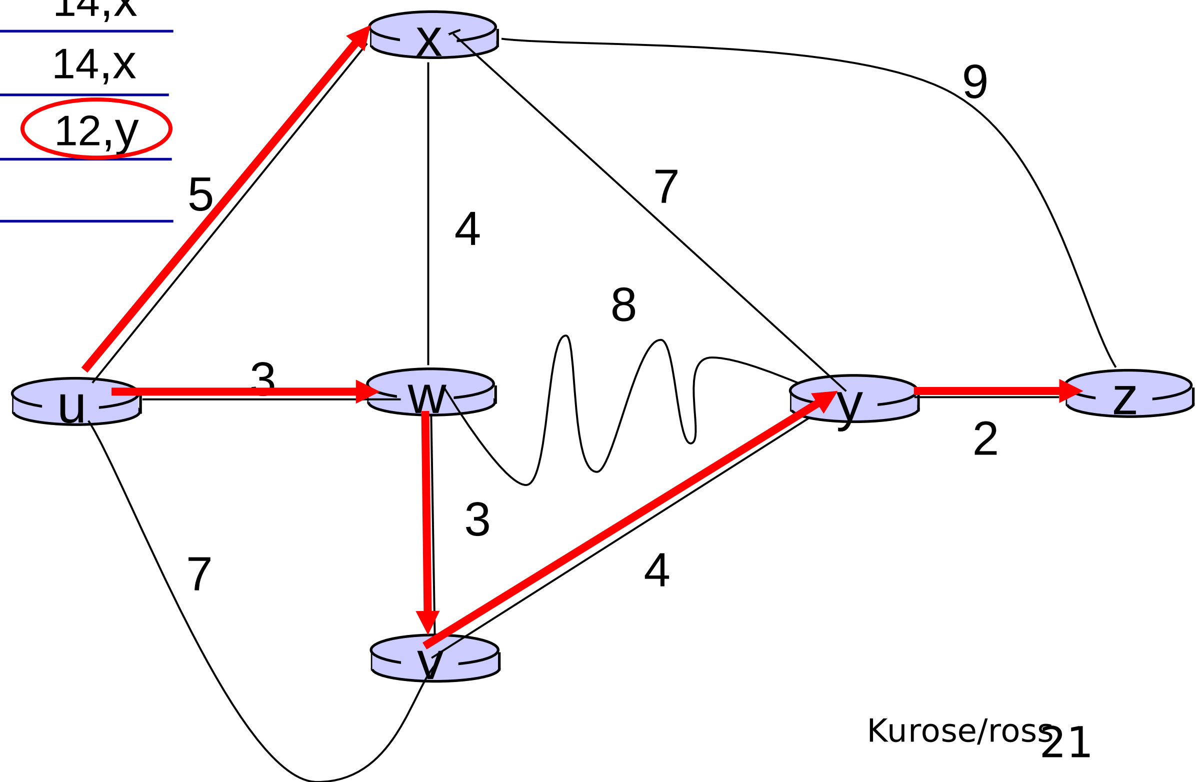
Dijsktra’s Algorithm

```
Initialization:
  N' = {u}
  for all nodes v
    if v adjacent to u
        then D(v) = c(u,v)
    else D(v) = ∞

Loop
  find w not in N' such that D(w) is a minimum
  add w to N'
  update D(v) for all v adjacent to w and not in N' :
     D(v) = min( D(v), D(w) + c(w,v) )
  /* new cost to v is either old cost to v or known
   shortest path cost to w plus cost from w to v */
until all nodes in N'
```

Dijkstra's algorithm: example

Step	N'	D(v) p(v)	D(w) p(w)	D(x) p(x)	D(y) p(y)	D(z) p(z)
0	u	7,u	3,u	5,u	∞	∞
1	uw	6,w		5,u	11,w	∞
2	uwx	6,w			11,w	14,x
3	uwxv				10,v	14,x
4	uwxvy					12,y
5	uwxvyz					

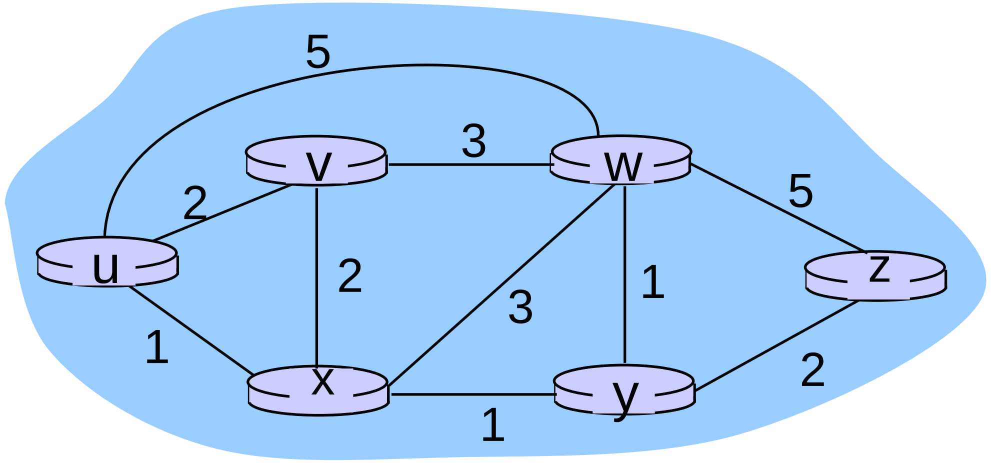


notes:

- construct shortest path tree by tracing predecessor nodes
- ties can exist (can be broken arbitrarily)

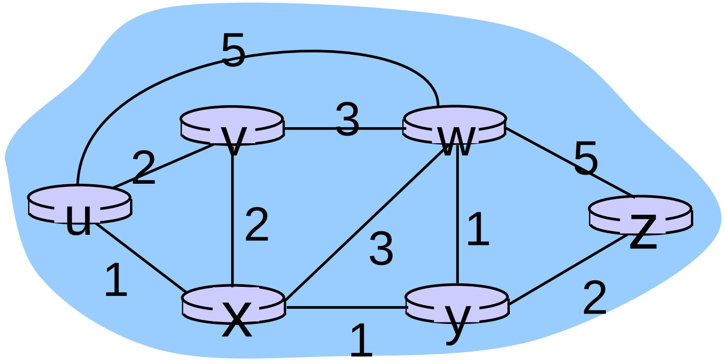
Dijkstra's algorithm: another example

Step	N'	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
0	u	2,u	5,u	1,u	∞	∞
1	ux	2,u	4,x		2,x	∞
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					



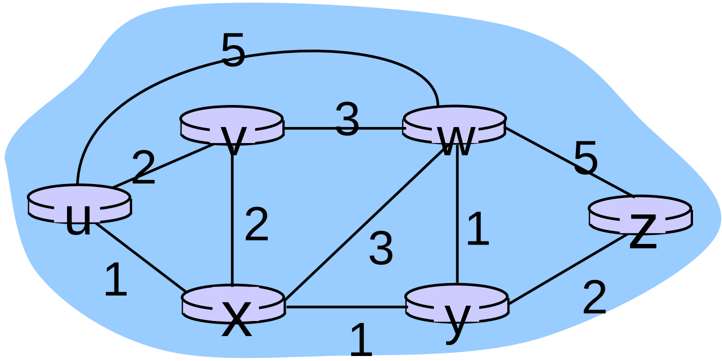
Dijsktra's → Link State Routing

- Each node keeps track of adjacent links
- Each router broadcasts it's state
- Each router runs Dijkstra's algorithm
- Each router has complete picture of the network
- Example: Open Shortest Path First (OSPF)

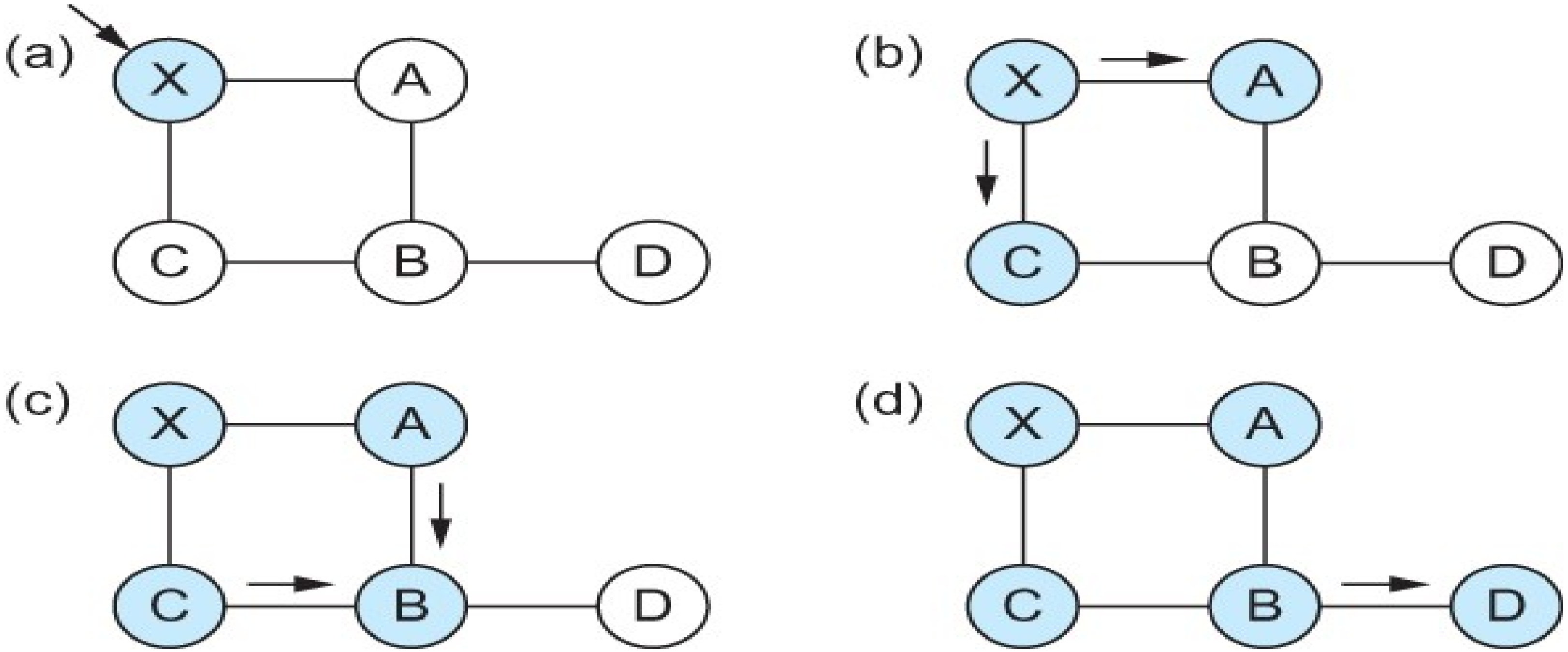


OSPF – Open Shortest Path First

- SPF – another name for Link State Routing
- Each node creates an update packet - link-state packet (LSP)
  - The ID of the node that created the LSP (U)
  - A list of directly connected neighbors and the cost of the link ((V, 2), (X, 1), **(W, 5)**)
- A sequence number (1122)
- A time to live for this packet (16)
- LSP → ({U}, {(V, 2), (X, 1), (W, 5)}, {1122}, {16})



Link State Routing – controlled flooding



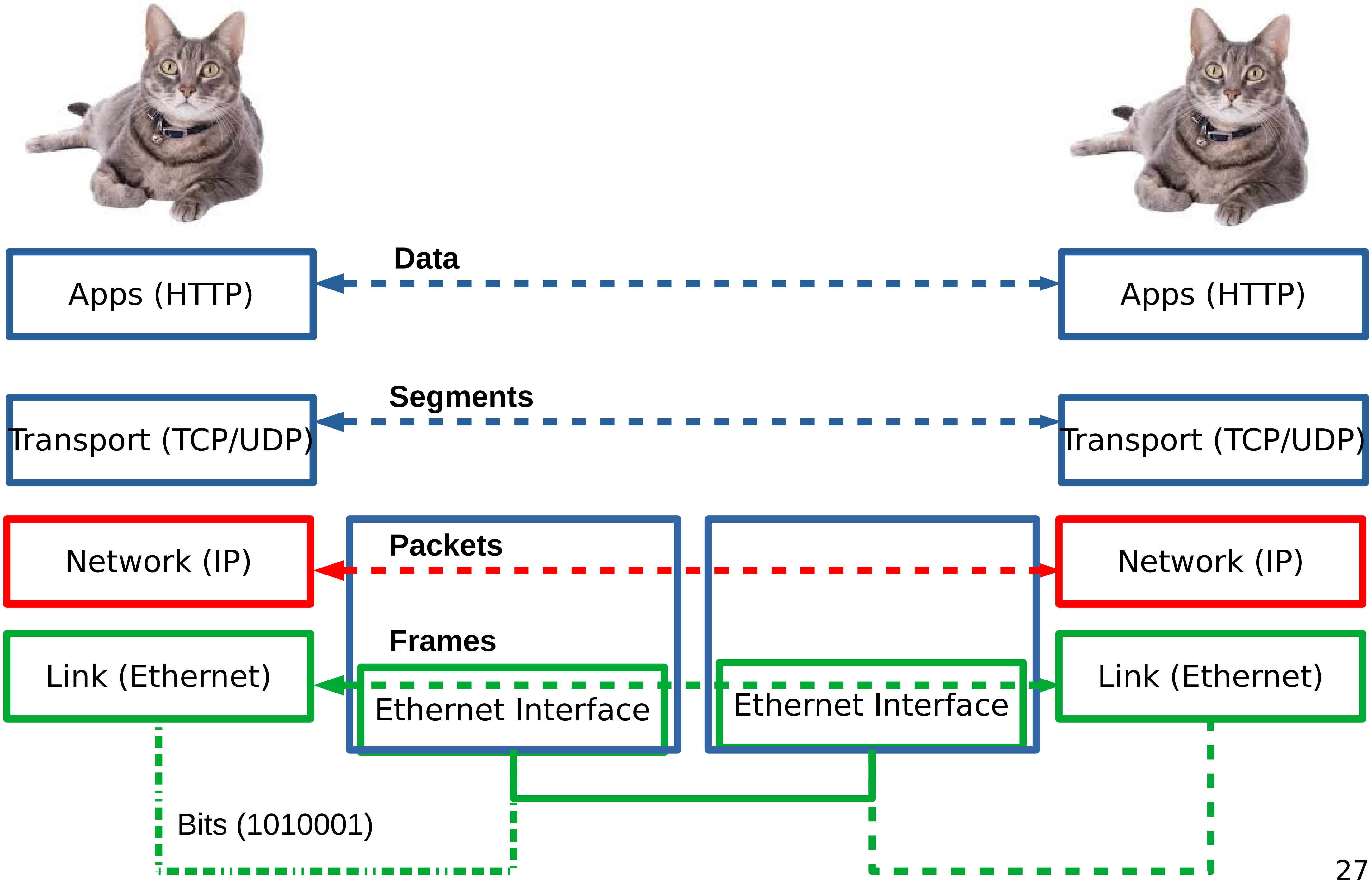
Flooding of link-state packets. (a) LSP arrives at node X; (b) X floods LSP to A and C; (c) A and C flood LSP to B (but not X); (d) flooding is complete

Link State Routing – controlled flooding

- Flood when topology changes or link goes down
  - Detected by periodic hello messages
  - If message missed → link down

- Refresh and flood periodically

- Problems?
  - High computational cost
  - Reliable flooding may not be reliable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Ethernet Interface
Ethernet Interface
Link (Ethernet)
Bits (1010001)

Reading Assignment

- ARP
  - https://book.systemsapproach.org/internetworking/basic-ip.html#address-translation-arp
  - About 10 minutes

- DHCP
  - https://book.systemsapproach.org/internetworking/basic-ip.html#host-configuration-dhcp
  - About 10 minutes

- Reading Assignment:
  - https://book.systemsapproach.org/internetworking/basic-ip.html#error-reporting-icmp
  - About 10 minutes