CSC4200/5200 – COMPUTER NETWORKING

Instructor: Susmit Shannigrahi

NAT, ROUTING

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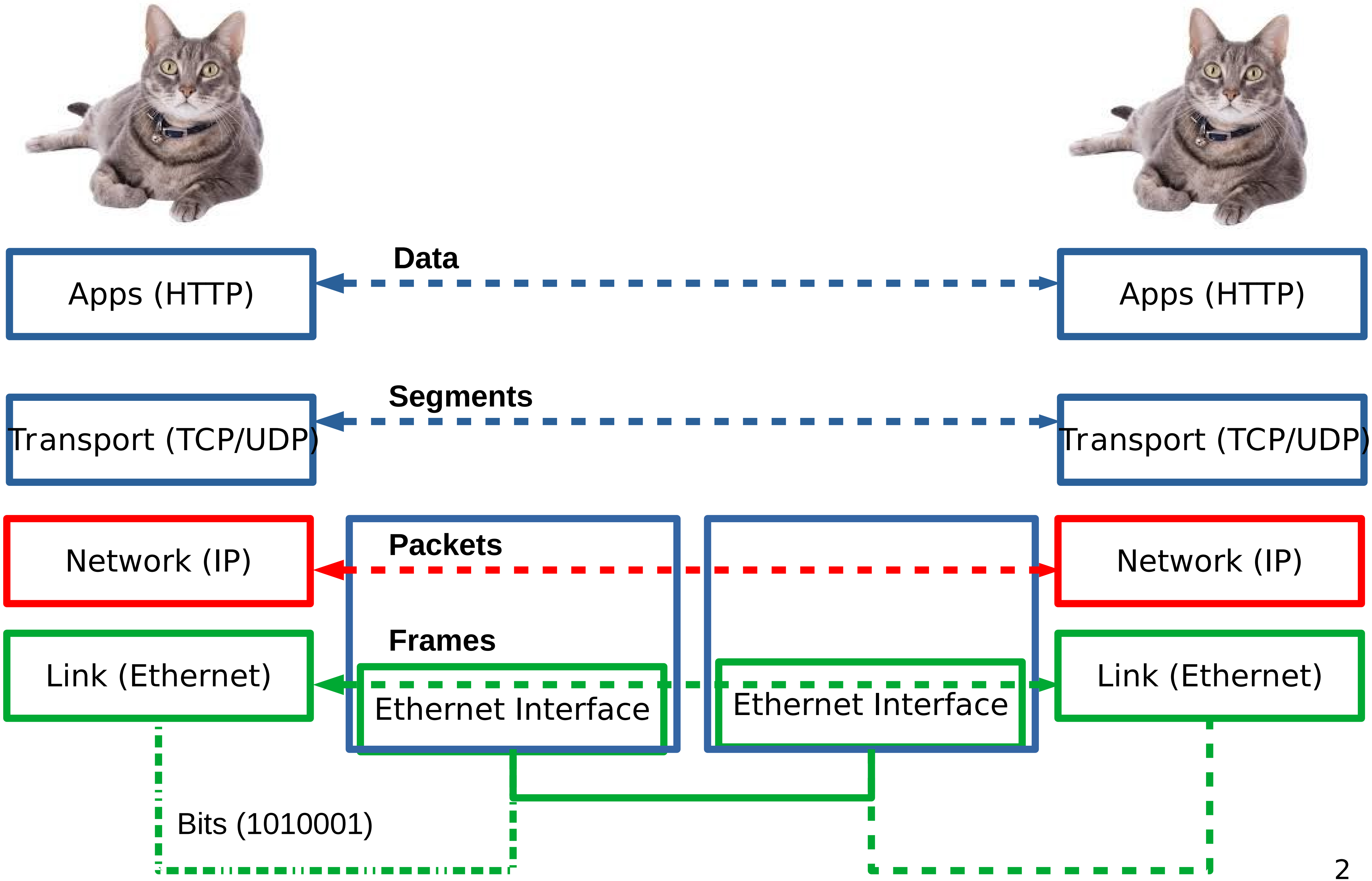
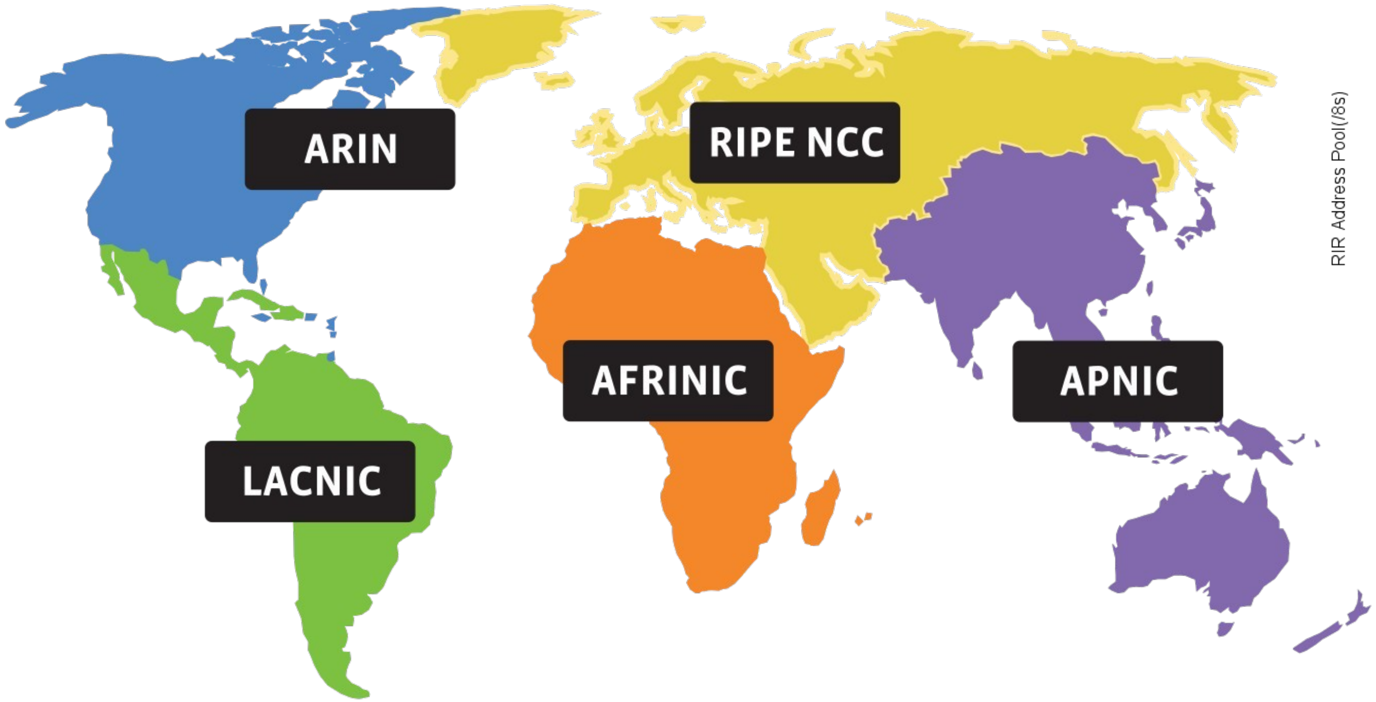
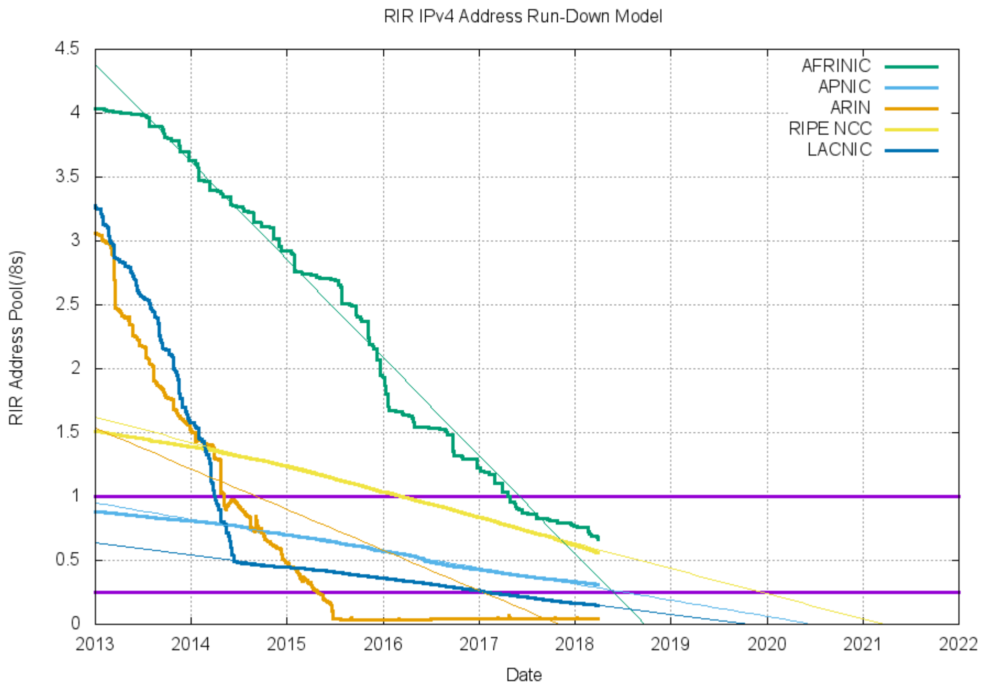
Tennessee TECH


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)

Address shortage

• IPv4 – 32 bits – Around 4 billion





Solution?

Home > WAN > Internet

BUZZBLOG

By Paul McNamara, News Editor, Network World | APR 21, 2017 8:29 AM PDT

About |
In addition to my editing duties, I have written Buzzblog since January, 2006. Feel free to e-mail me at buzz@nww.com.

MIT selling 8 million coveted IPv4 addresses; Amazon a buyer

Thinkstock

MIT is selling half of its 16 million valuable IPv4 addresses – an increasingly scarce stash it has held since the birth of the Internet. While details of the sale have not been made public, at least some of those addresses have already been transferred to Amazon.

sell ipv4 addresses

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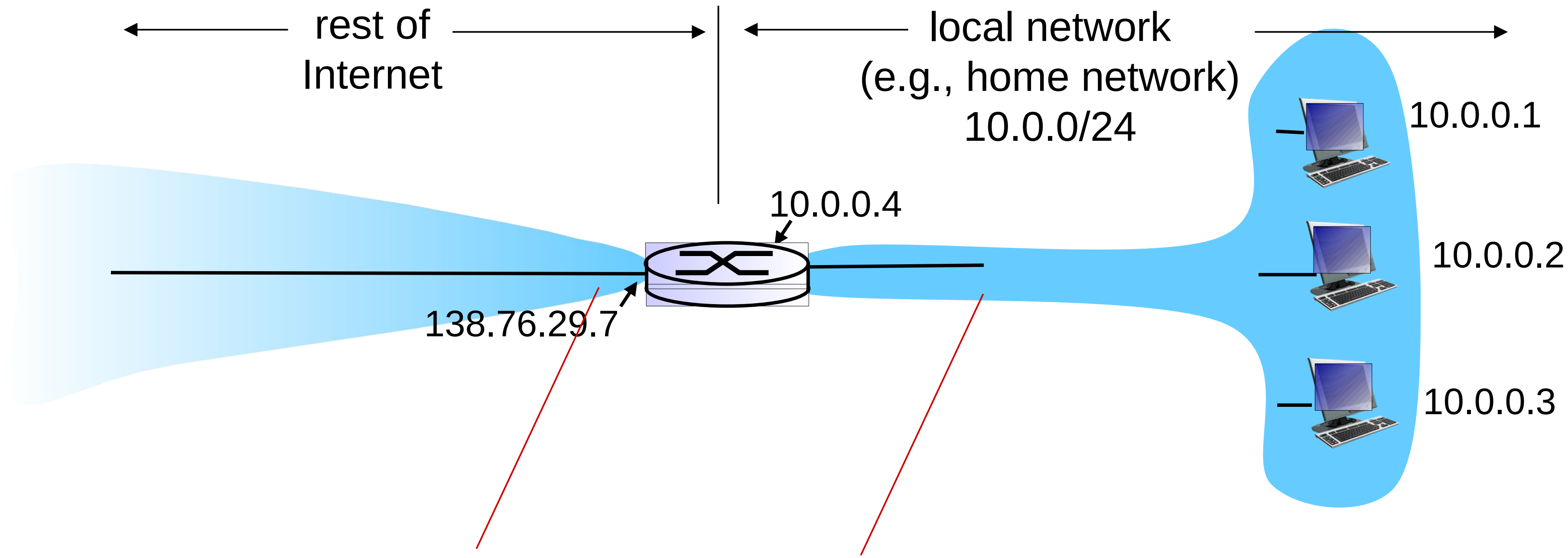
www.cfo.com › it-value › 2017/07 › got-extra-ip-addre...
Got Extra IP Addresses? You Can Sell Them - CFO
Jul 19, 2017 — Whatever you call it, any company that possesses unused internet **addresses** — that is, internet protocol version 4 (**IPv4**) **addresses** — can very likely **sell** them at a high profit margin. That's because **IPv4** numbers were distributed for free by the Internet Assigned Numbers Authority and its five regional registries.

ipv4marketgroup.com › Broker Services
IPv4 Address Space for Sale | IPv4 Market Group
Sell IP Addresses with IPv4 Market Group. Now is a great time to **sell IPv4 address** blocks because they're in high demand due to their limited availability and the ...

ipv4marketgroup.com › sell-ipv4-addresses-ipv4-group
Sell Your IPv4 Addresses with IPv4 Group - IPv4 Market Group
Oct 5, 2017 — The IPv4 Transfer Market is an after-market IPv4 transfer mechanism. It creates financial incentive for entities to **sell** their unused **IPv4 addresses**, ...

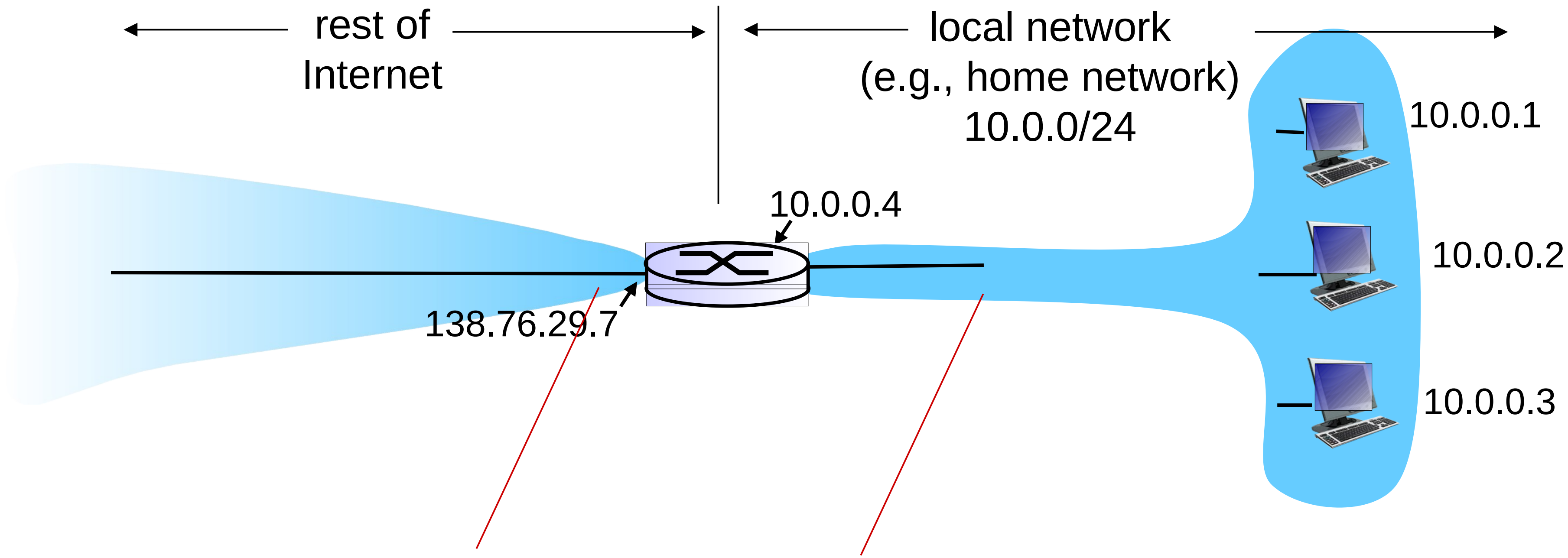
ipv4connect.com › sell-ipv4
Sell IP Address | IPv4 Space | IPv4 Connect
Safely & quickly **Sell IPv4 address** space to pre qualified buyers around the world.

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



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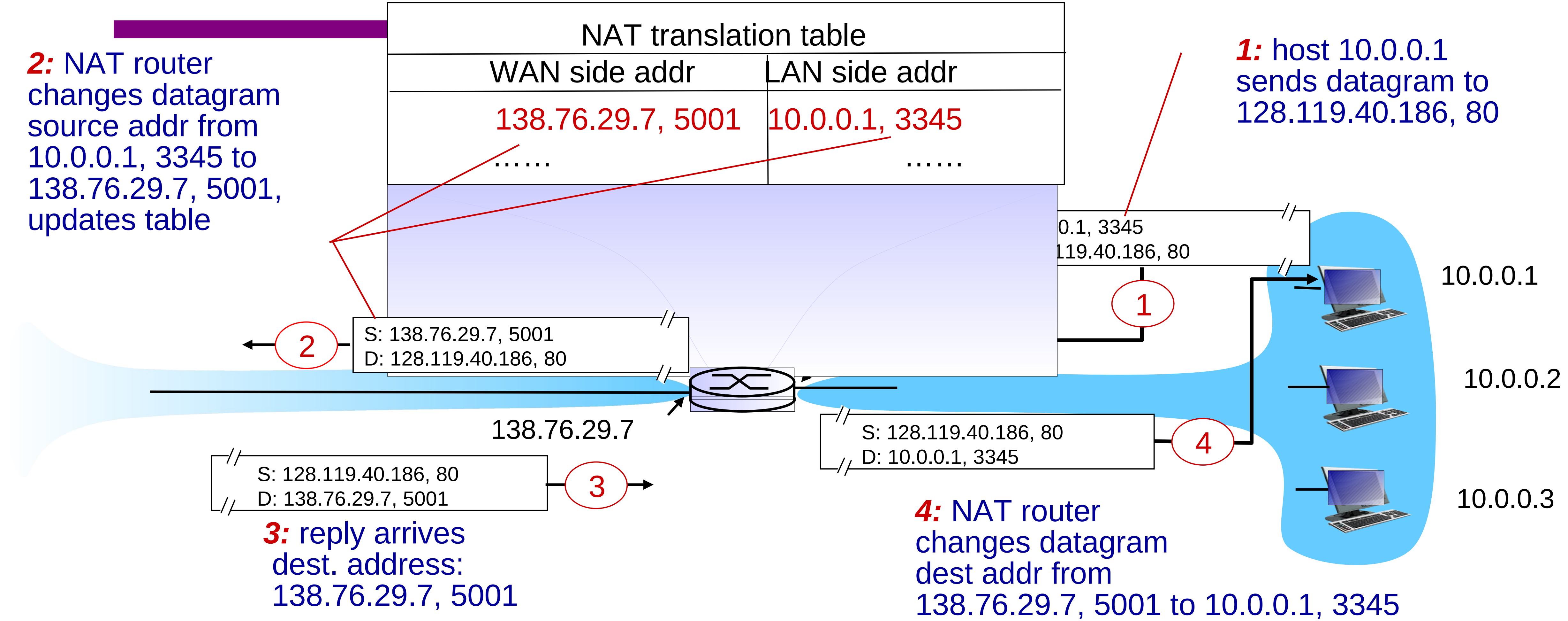
NAT: network address translation

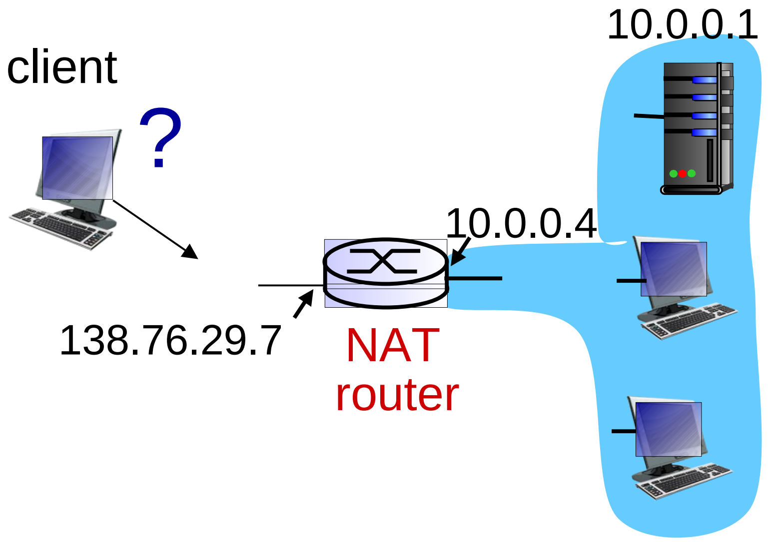


NAT

- 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?



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

Address shortage – Better solution? IPv6

- IPv6 – 128 bits

There are only this many IPv6 addresses left:

340,282,366,920,938,463,463,374,607,430,530,552,200

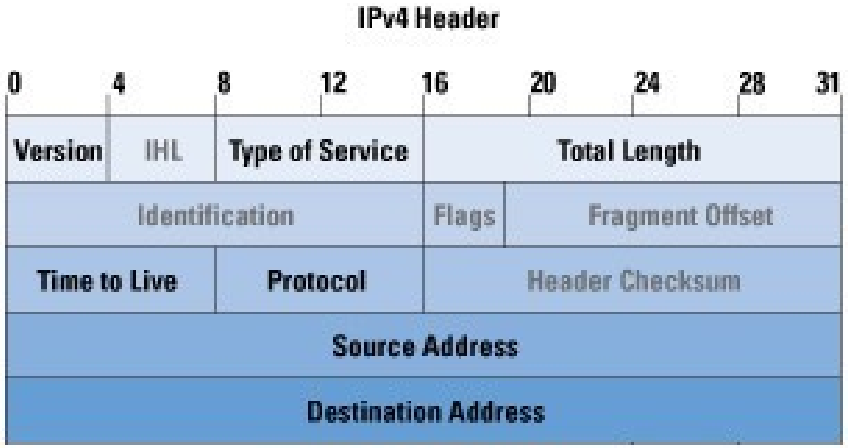
Projected IPv6 Exhaustion Date

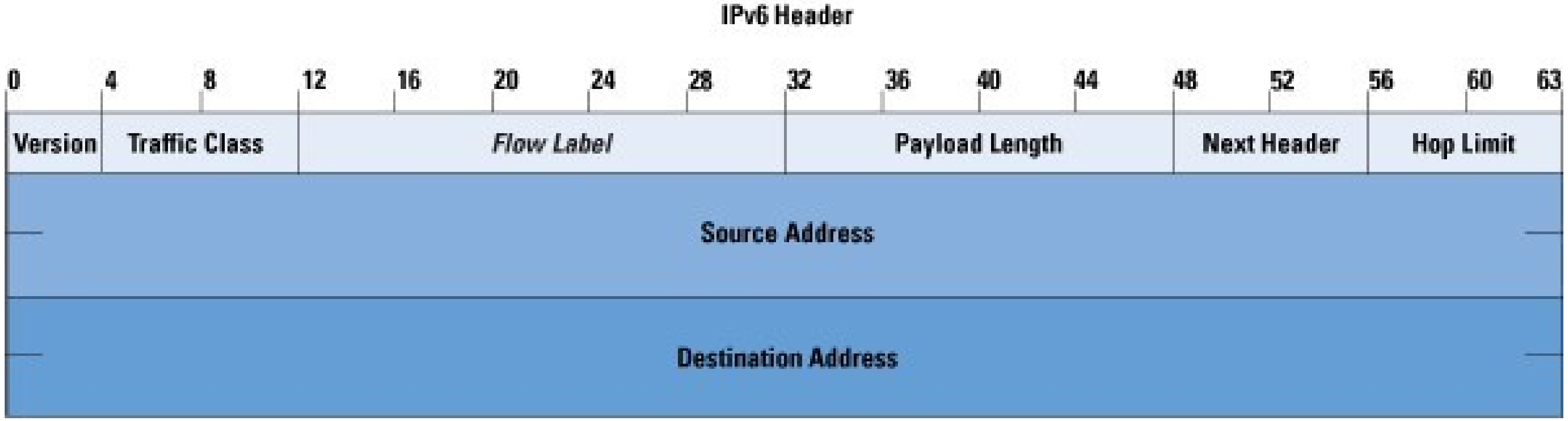
9,000,000 AD

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

Address shortage – Better solution? IPv6

- IPv4 – 128 bits



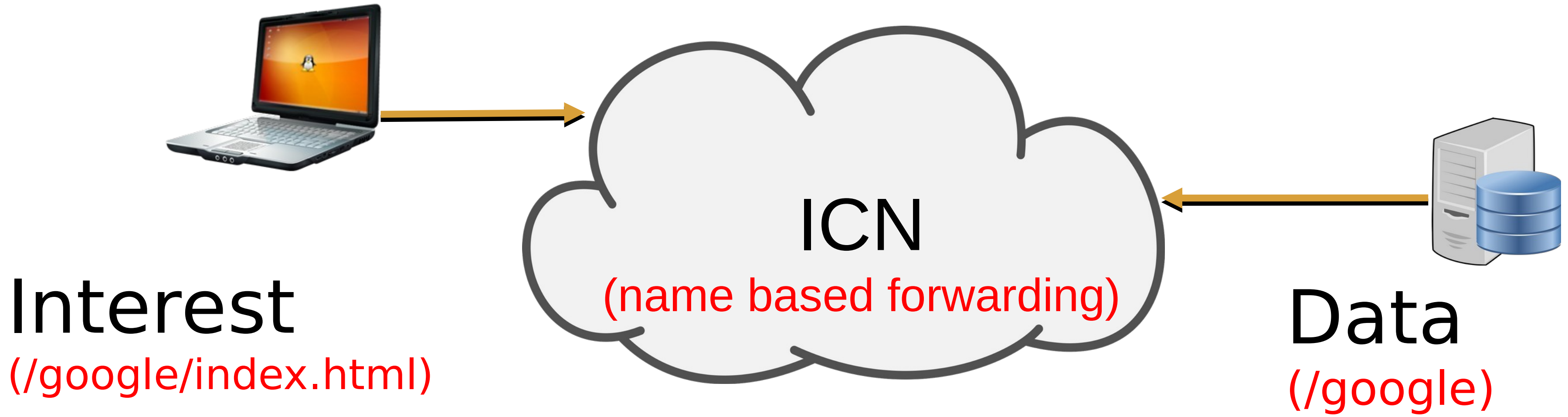


Address shortage – Better solution? Get rid of the Addresses!

- Next generation of the Internet

- You don’t care about the hosts anyway
  - For most part

- Why not ask for content directly?
  - Information Centric Networking (ICN)



ICMP: Internet Control Message Protocol

- Errors in network:
  - Router does not know how to forward a packet
  - Packet is broken

- IP is best effort
  - Can silently drop packets

- How would be ever know something is wrong?
  - Feedback about the problem
  - ICMP

ICMP: Internet Control Message Protocol

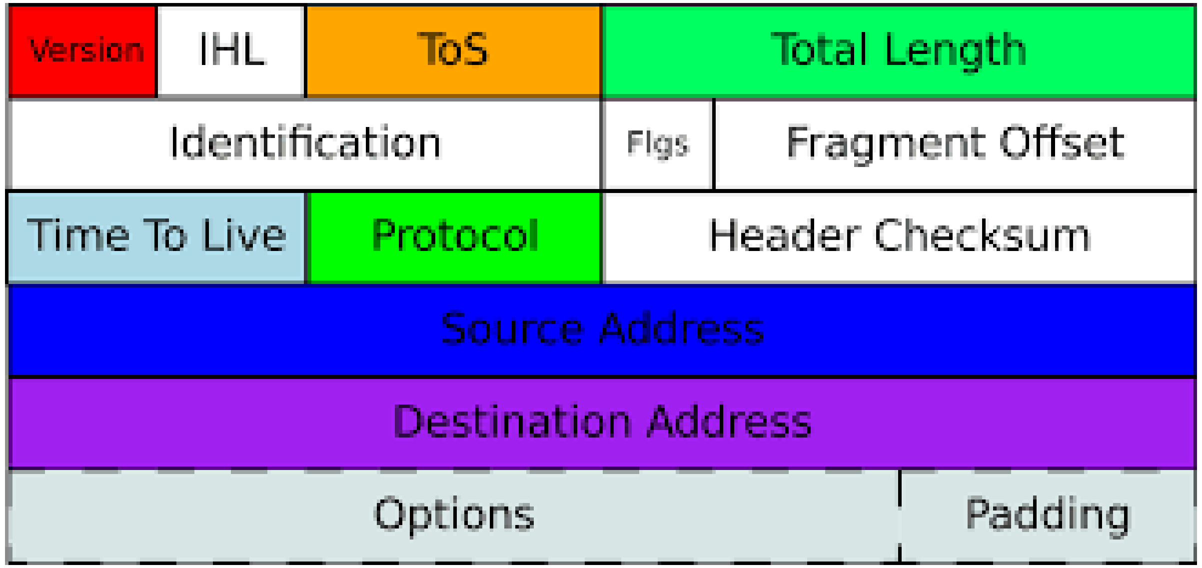
- Used for
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)

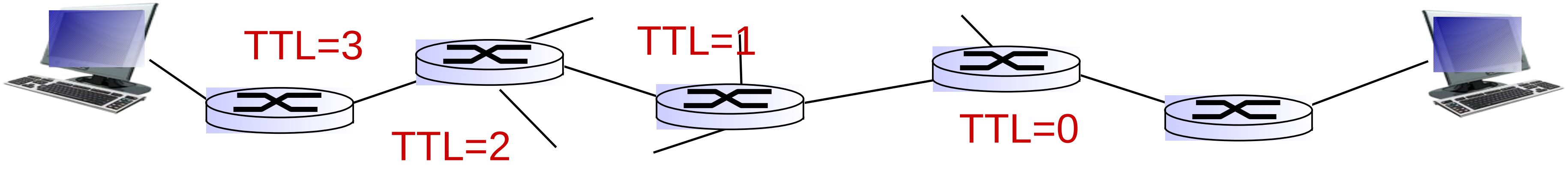
- Application at network-layer
  - ICMP msgs carried in IP datagrams
  - Essentially at application layer
  - Considered part of IP

Type	Code	description
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

ICMP and Time to Live

- Each time a host sends a packet it sets the TTL field
- Each router that forwards it decrements the number
- When TTL reaches 0, send a time exceeded message



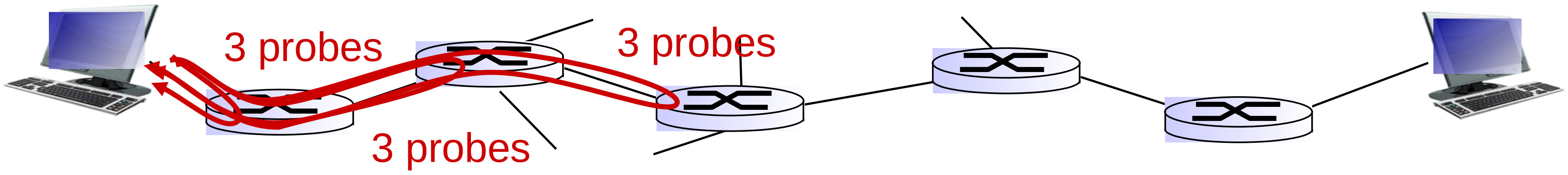


Traceroute and ICMP

- source sends series of UDP segments to dest
  - first set has TTL =1
  - second set has TTL=2, etc.
  - unlikely port number
- when *n*th set of datagrams arrives to nth router:
  - router discards datagrams
  - and sends source ICMP messages (type 11, code 0)
  - ICMP messages includes name of router & IP address
- when ICMP messages arrives, source records RTTs

stopping criteria:

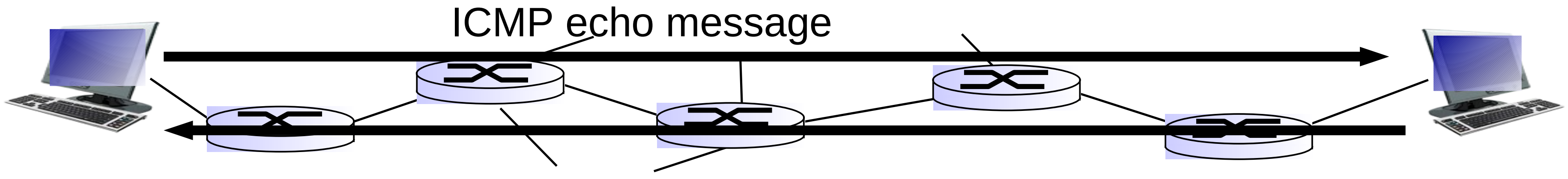
- UDP segment eventually arrives at destination host
- destination returns ICMP "port unreachable" message (type 3, code 3)
- source stops



Ping and ICMP

- source sends an ICMP echo message

- Destination sends an ICMP echo reply



Forwarding vs Routing

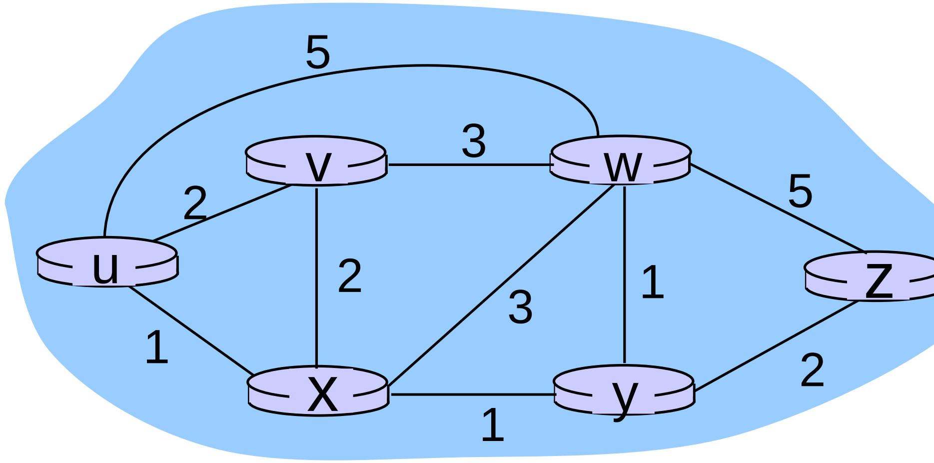
- Forwarding:
  - to select an output port based on destination address and routing table
  - **Local path**

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**

Why bother?

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



- Balance path usage, avoid congested paths

- Deal with failures

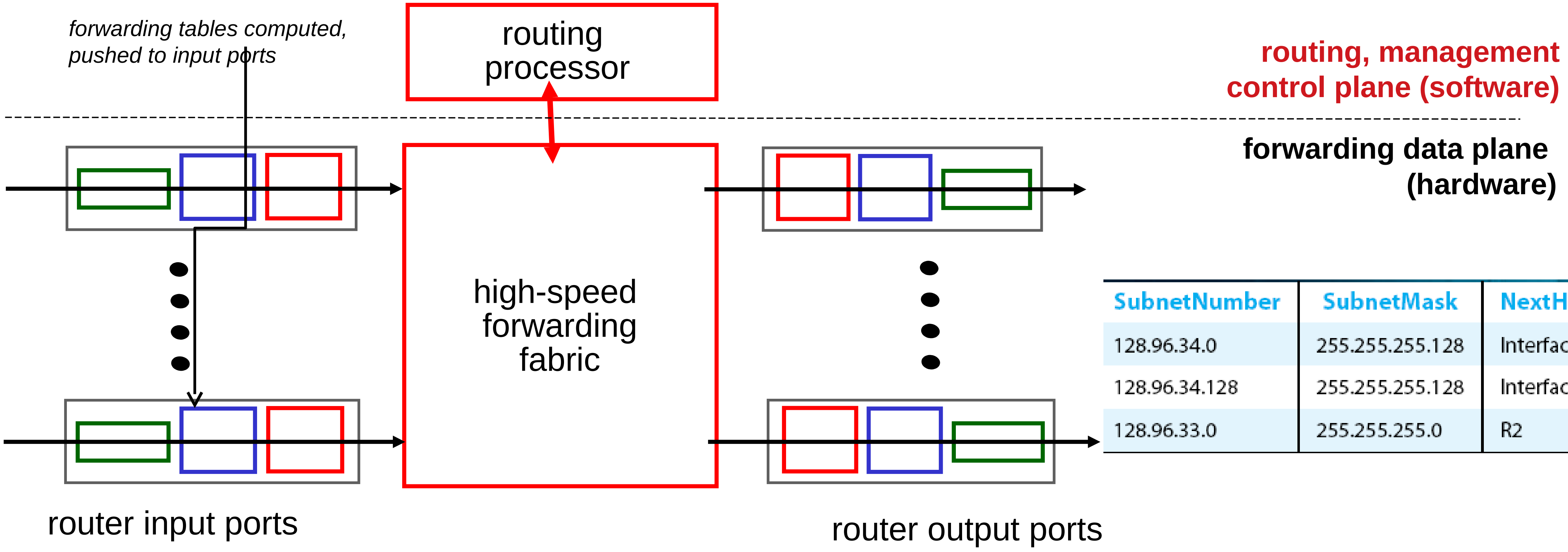
SubnetNumber	SubnetMask	NextHop
128.96.34.0	255.255.255.128	Interface 0
128.96.34.128	255.255.255.128	Interface 1
128.96.33.0	255.255.255.0	R2

Router architecture overview

Two key router functions:

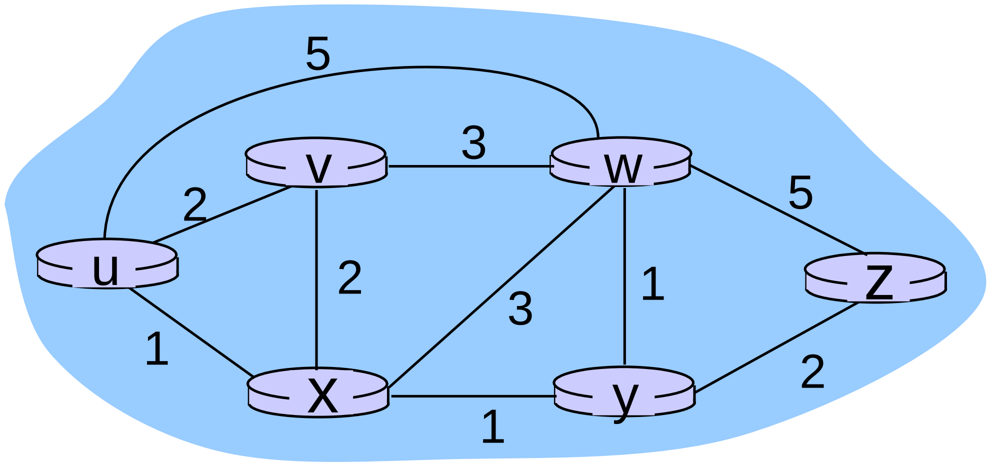
- run routing algorithms/protocol (RIP, OSPF, BGP)
- *forwarding* datagrams from incoming to outgoing link

Control Plane = routing
Vs
Data Plane = forwarding



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

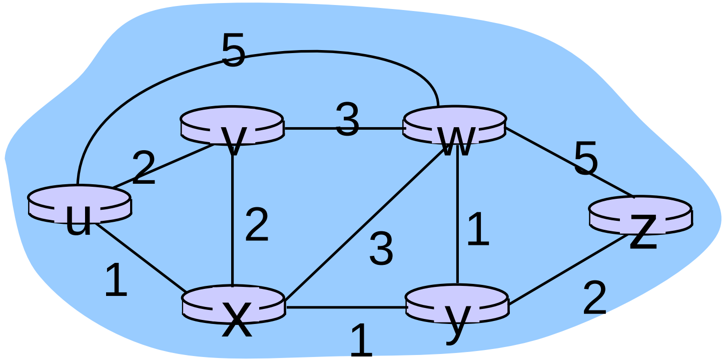
Cost (x,v,w,z) = cost(x,v) + cost (v, w) + cost(w,z) = 10

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*

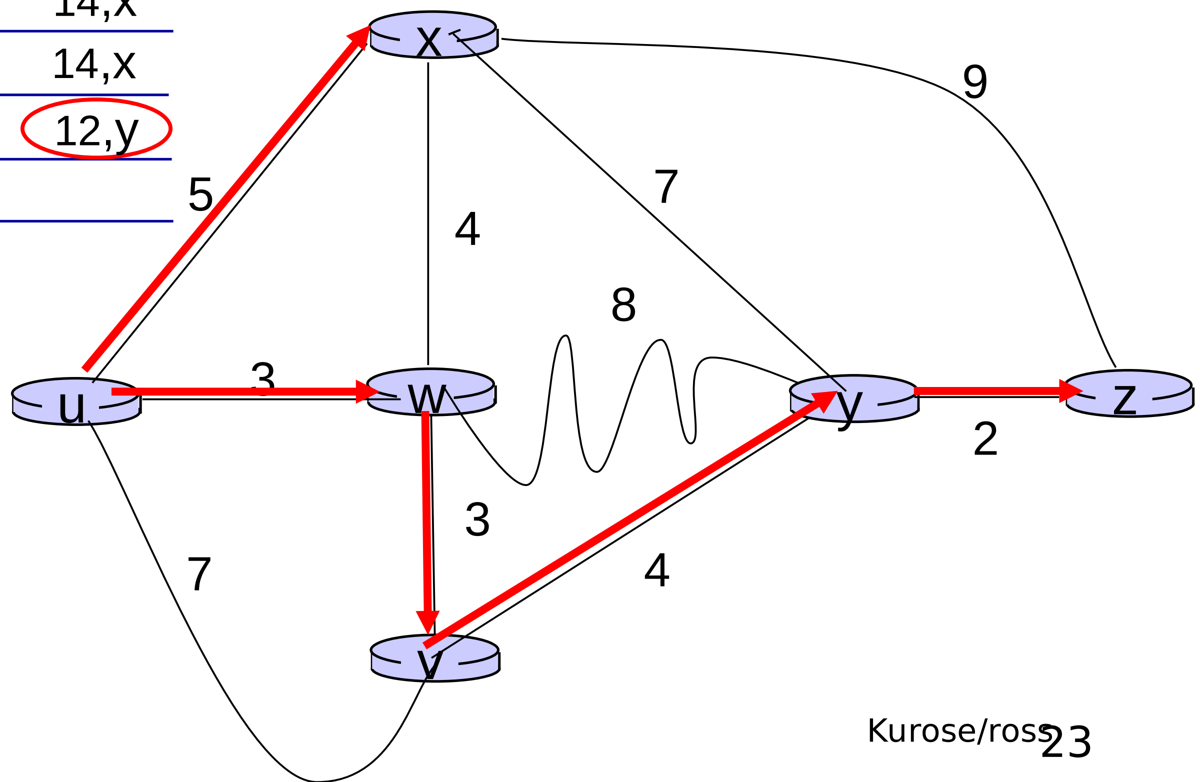
Dijsktra’s Algorithm

```
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					

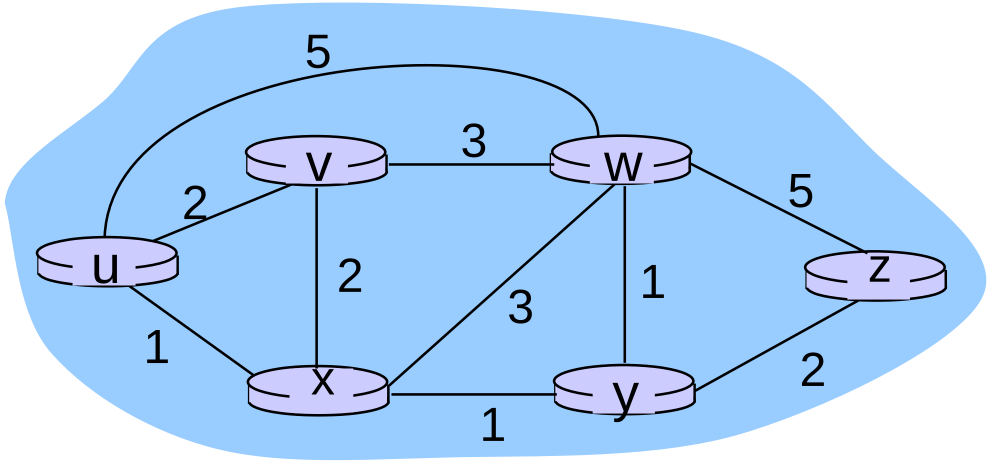


notes:

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

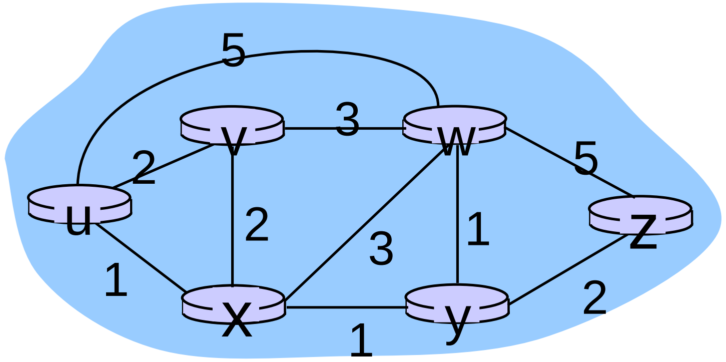
Dijkstra's algorithm: another example

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					

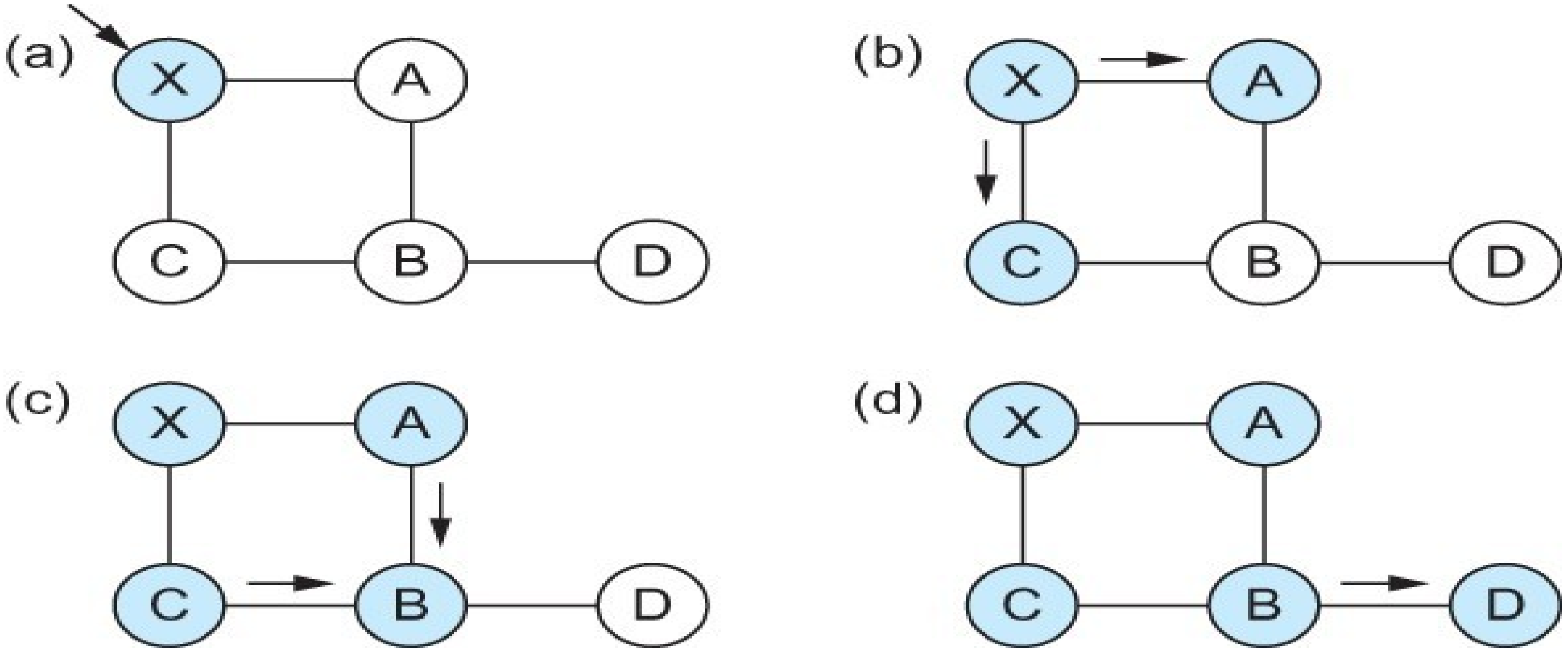


Dijsktra’s → Link State Routing

- 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)



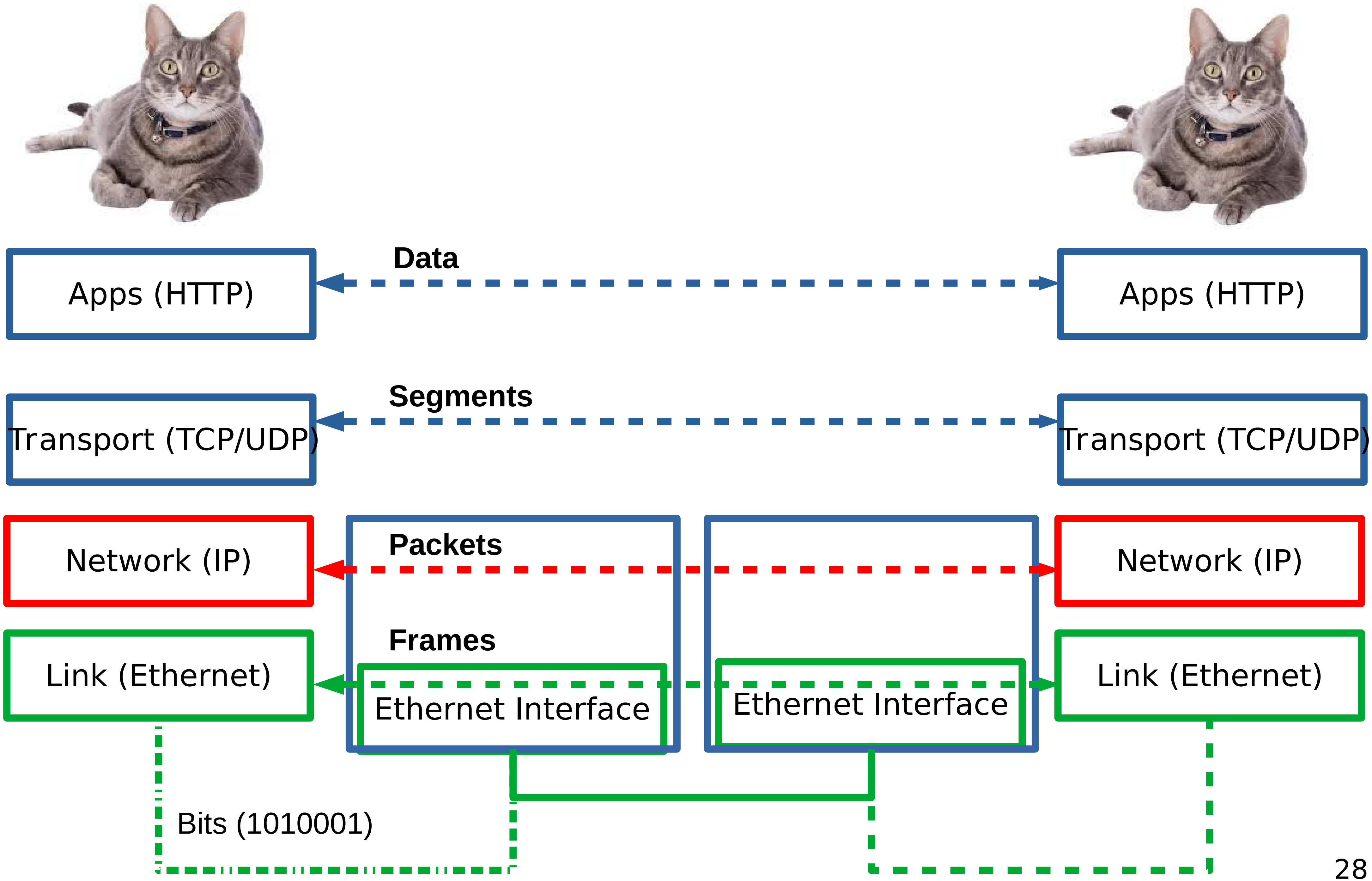
Link State Routing – controlled flooding



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
Link (Ethernet)
Bits (1010001)

Next Steps

Reading Assignment:

https://book.systemsapproach.org/internetworking/basic-ip.html#error-reporting-icmp

About 10 minutes