CSC4200/5200 – COMPUTER NETWORKING

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ROUTING

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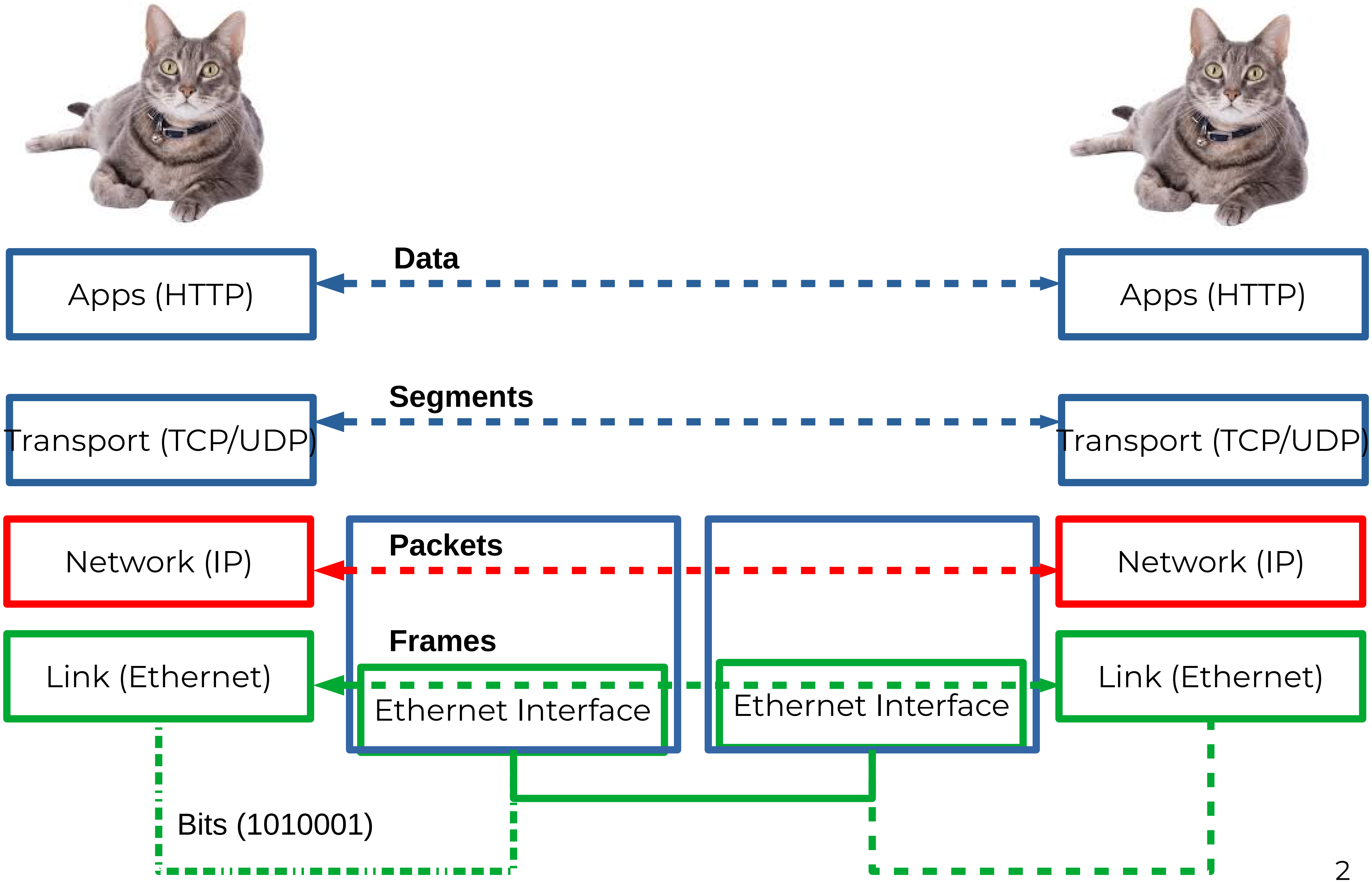
Tennessee TECH


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

So far…

- We now know how communication works
- How does routing work?

Forwarding vs Routing

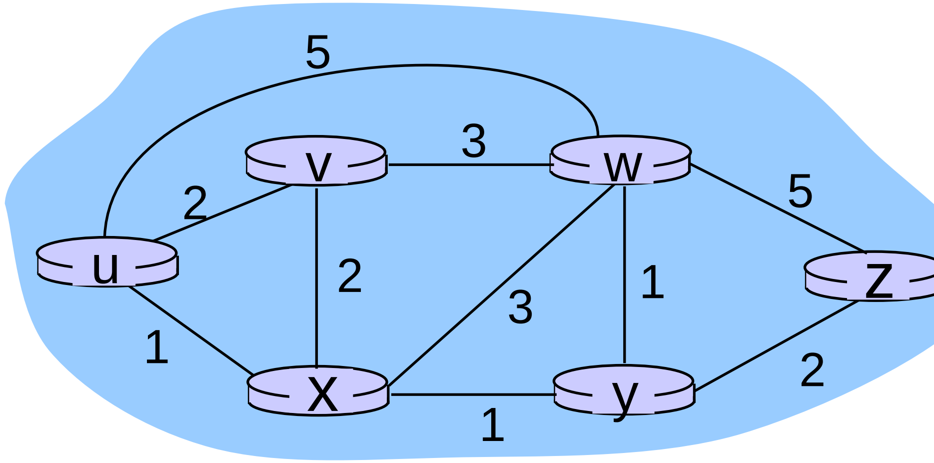
- Forwarding:
  - to select an output port based on destination address and routing table
  - **Local path**

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

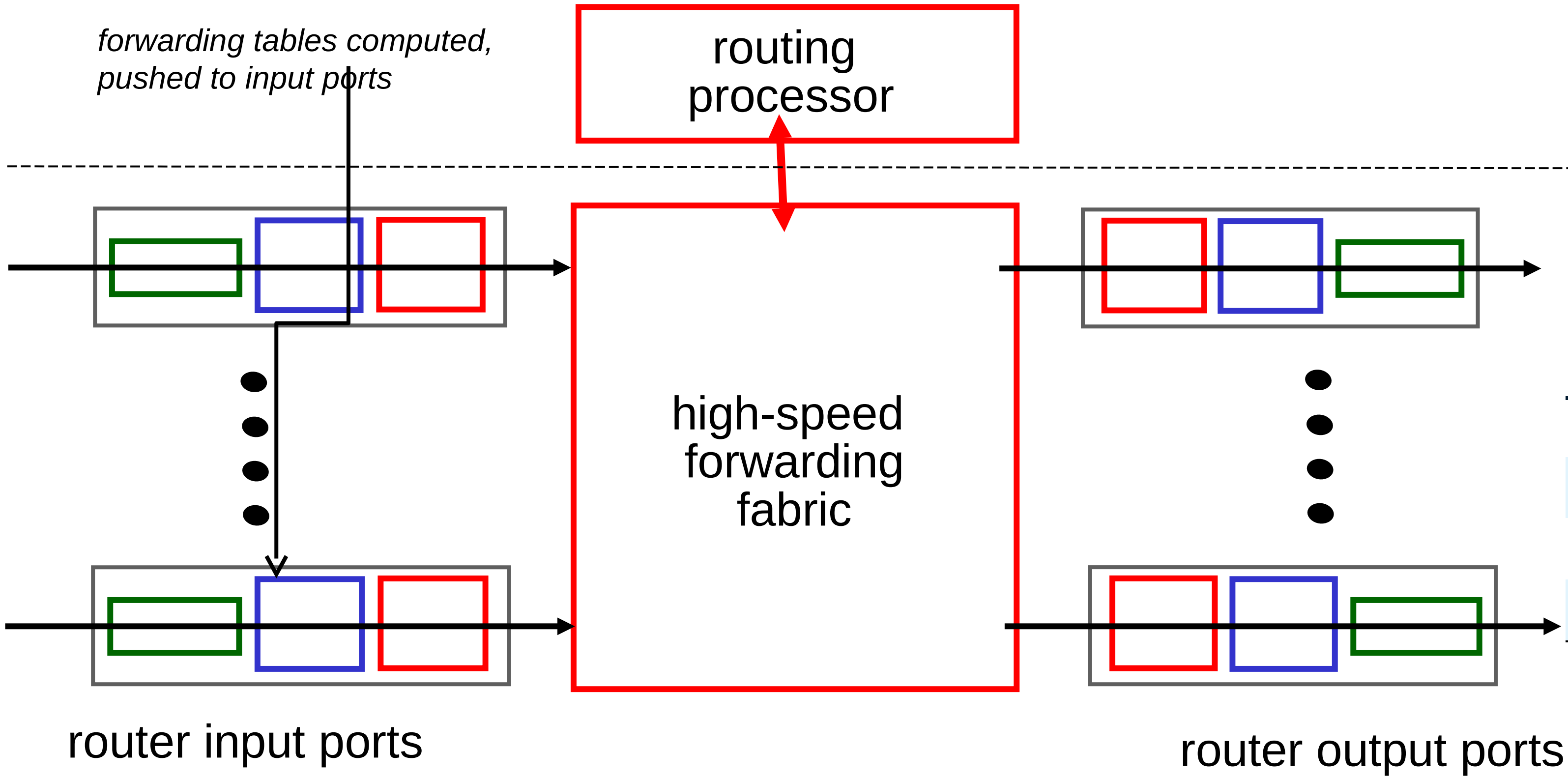
- Deal with failures

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

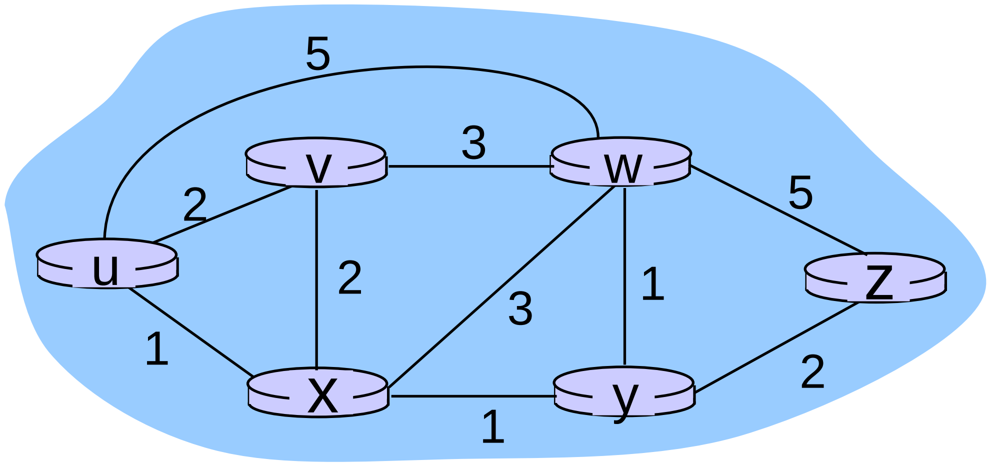


routing, management control plane (software)

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

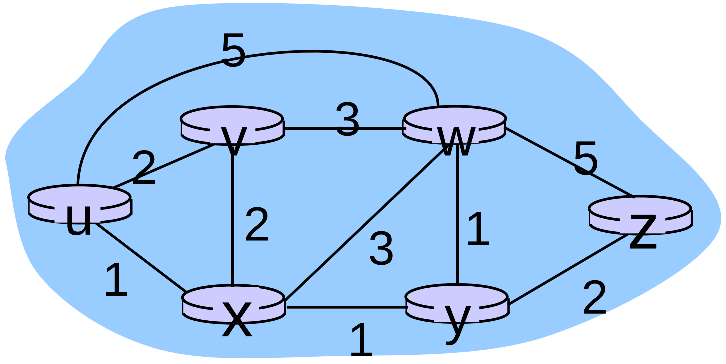
Cost (x,v,w,z) = cost(x,v) + cost (v, w) + cost(w,z) = 10

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*

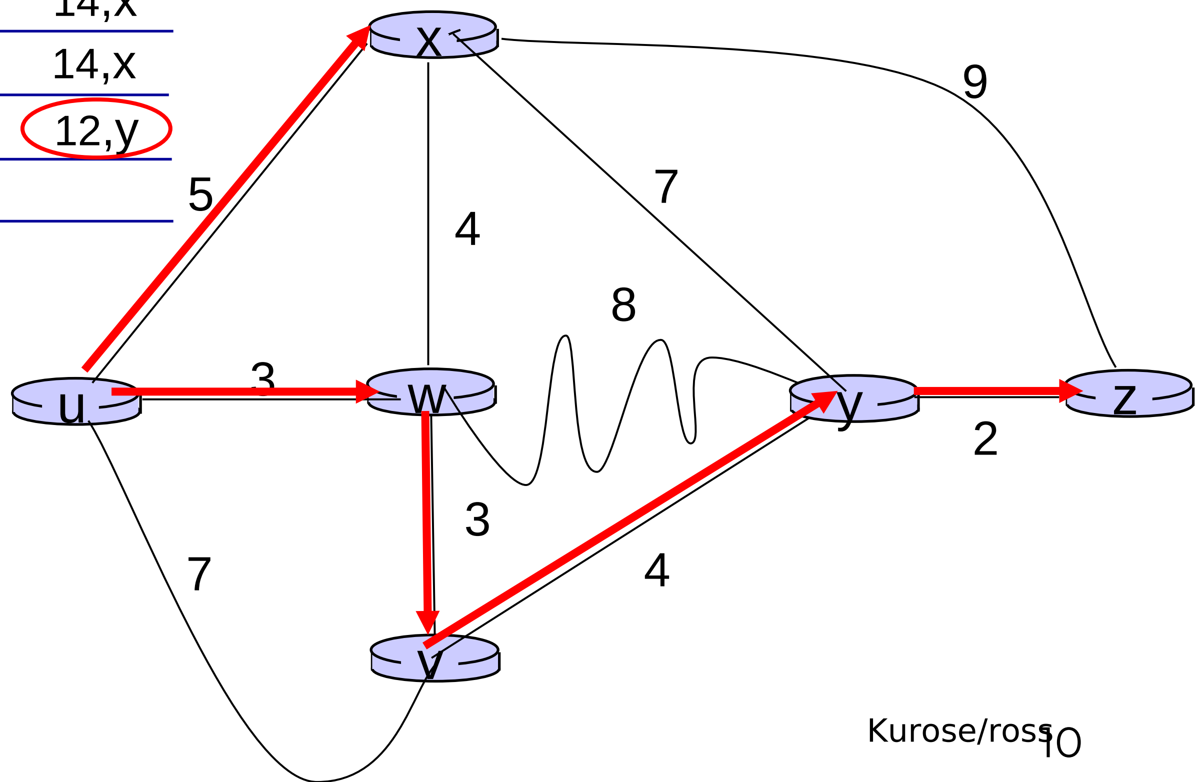
Dijsktra’s Algorithm

```
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					



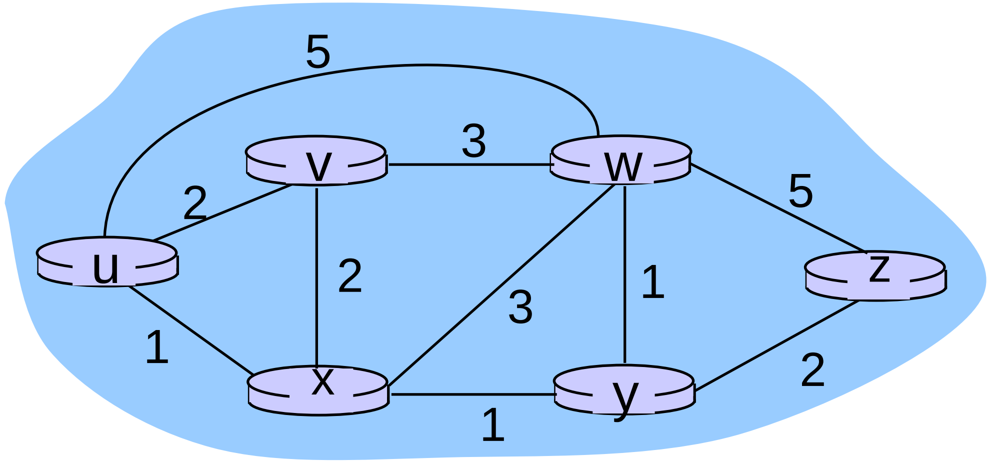
notes:

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

Kurose/ross

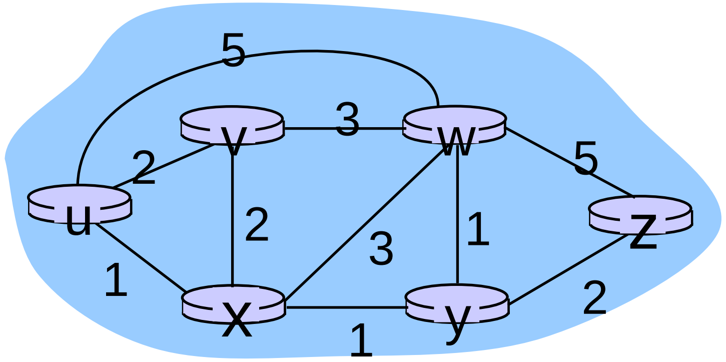
Dijkstra’s algorithm: another example

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					

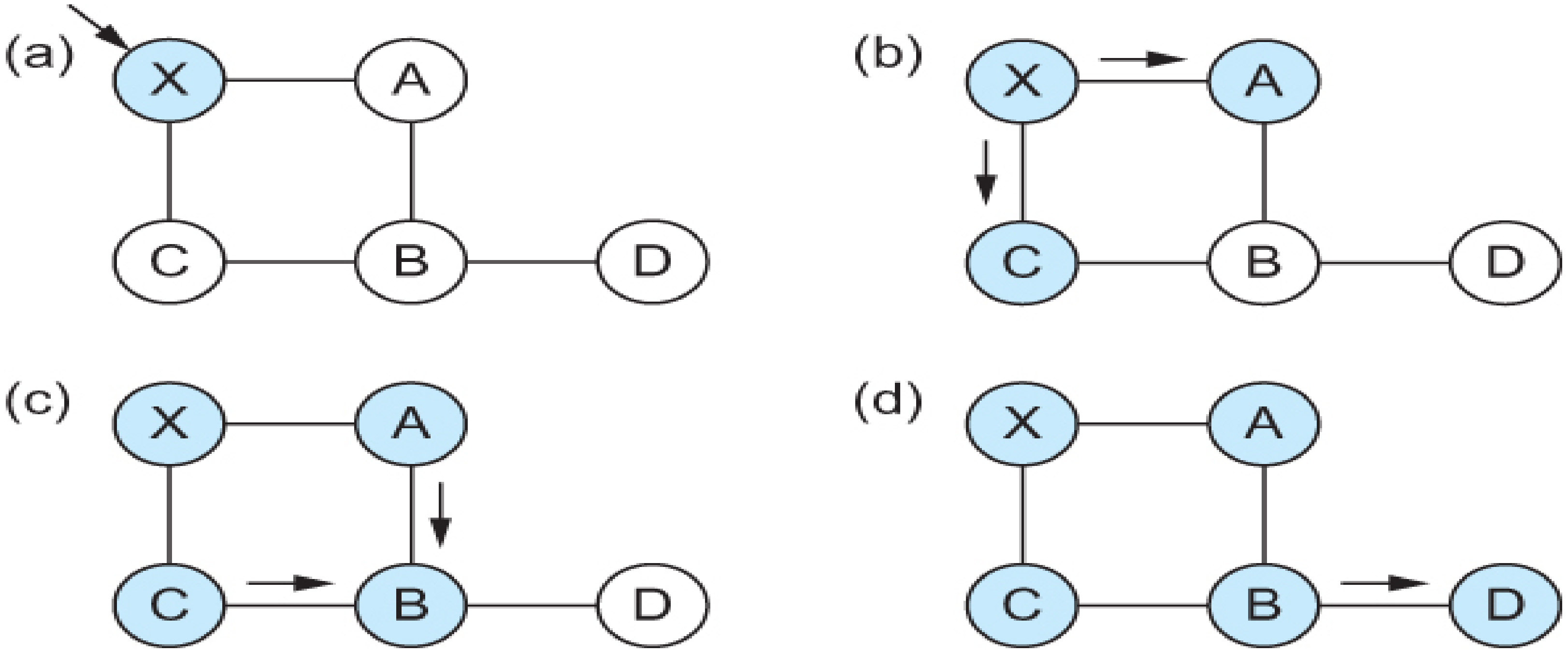


Dijsktra's → Link State Routing

- 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



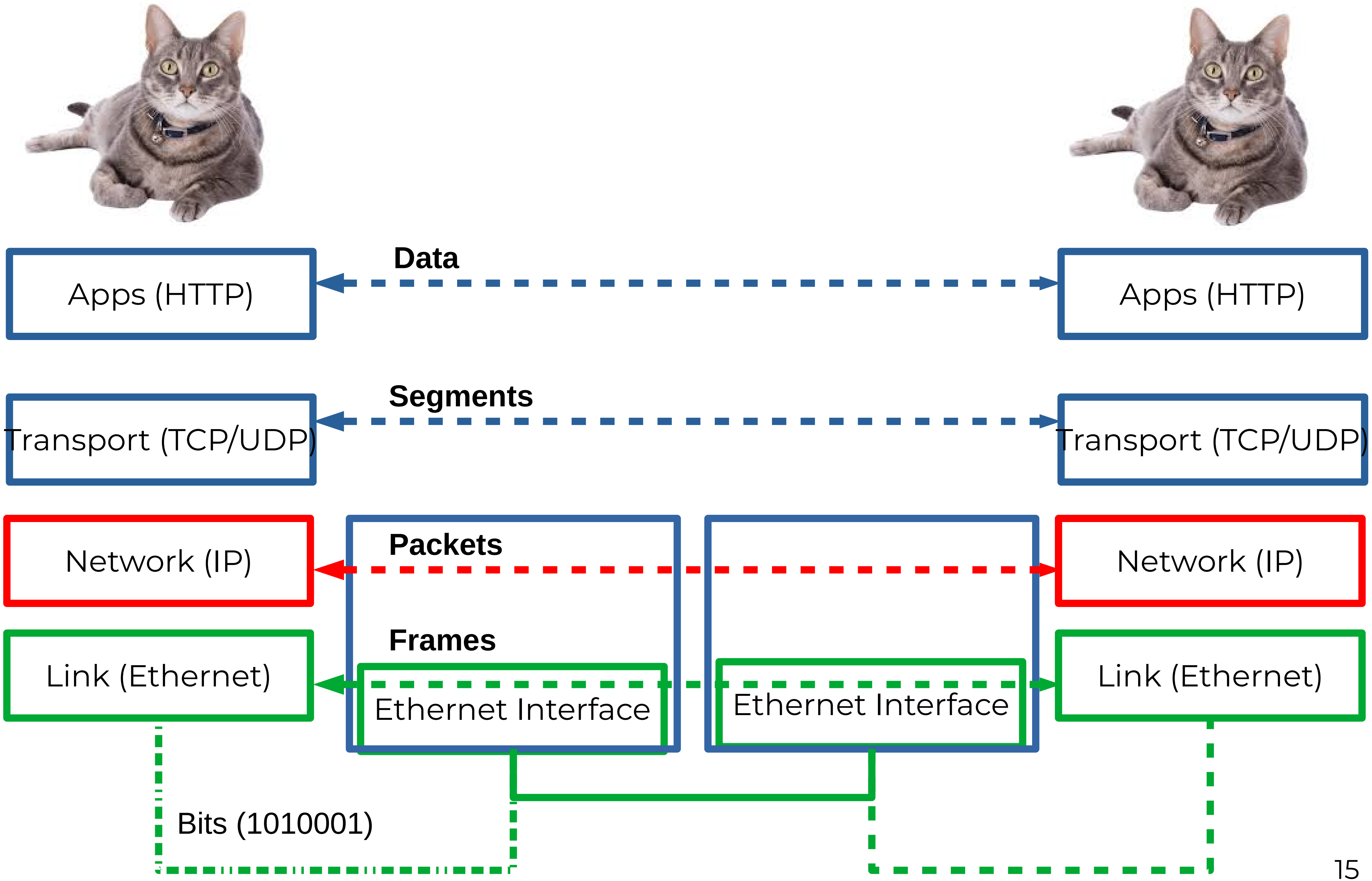
Flooding of link-state packets. (a) LSP arrives at node X; (b) X floods LSP to A and C; (c) A and C flood LSP to B (but not X); (d) flooding is complete

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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Next Steps

Distance Vector routing
Midterm review