

Lecture 9:

Networks to Internetworks

CSE 123: Computer Networks

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HW 1 due today



UCSDCSE



Lecture 9 Overview

- Bridging & switching (cont.)
 - ◆ Spanning Tree review
- Internetworking
 - ◆ Routing
 - ◆ Internet Protocol



Spanning Tree Algorithm

- Each bridge sends periodic configuration messages
 - ◆ (RootID, Distance to Root, BridgeID)
 - ◆ All nodes think they are root initially
- Each bridge updates route/Root upon receipt
 - ◆ Smaller root address is better
 - ◆ Select port with lowest cost to root as “root port”
 - ◆ To break ties, bridge with smaller address is better
- Rebroadcast new config to ports for which we’re “best”
 - ◆ Don’t bother sending config to LANs with better options
 - ◆ Add 1 to distance, send new configs on ports that haven’t told us about a shorter path to the root
- Only forward packets on ports for which we’re on the shortest path to root (prunes edges to form tree)

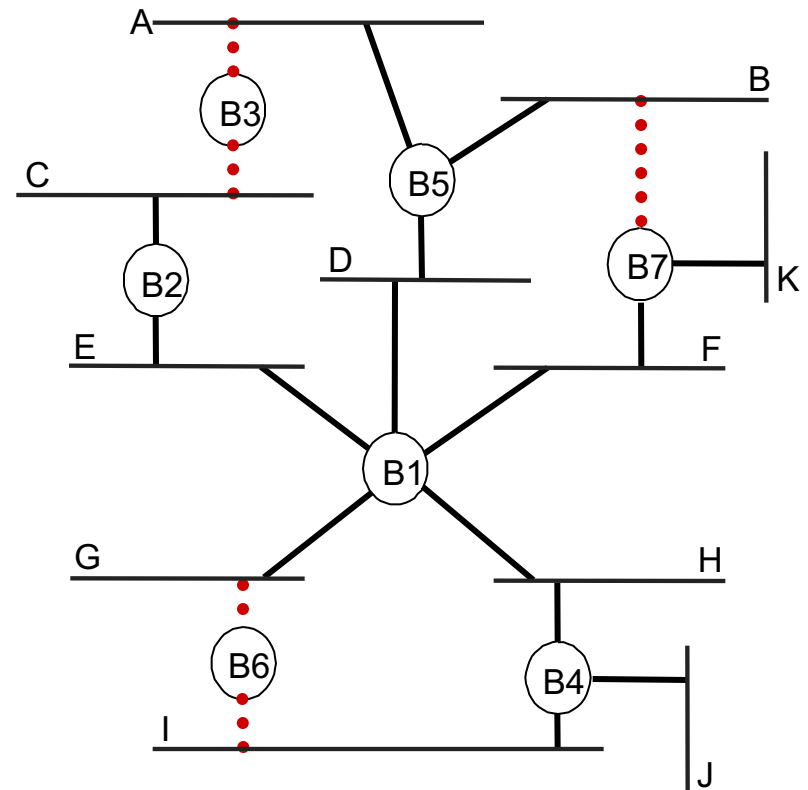
Spanning Tree Example



- Sample messages to and from B3:

1. B3 sends (B3, 0, B3) to B2 [LAN C] and B5 [LAN A]
2. B3 receives (B2, 0, B2) and (B5, 0, B5) and accepts B2 as root
3. B3 sends (B2, 1, B3) to B5
4. B3 receives (B1, 1, B2) and (B1, 1, B5) and accepts B1 as root
5. B3 wants to send (B1, 2, B3) but doesn't as its nowhere "best"
6. B3 receives (B1, 1, B2) [LAN C] and (B1, 1, B5) [LAN A] again and again...

B3 turns off forwarding to LAN A and C





Spanning tree poem

I think that I shall never see
A graph more lovely than a tree.
A tree whose crucial property Is loop-free connectivity.
A tree that must be sure to span
So packets can reach every LAN.
First, the root must be selected.
By ID, it is elected.
Least cost paths from root are traced.
In the tree, these paths are placed.
A mesh is made by folks like me,
Then bridges find a spanning tree."

— Radia Perlman *Algorhyme*



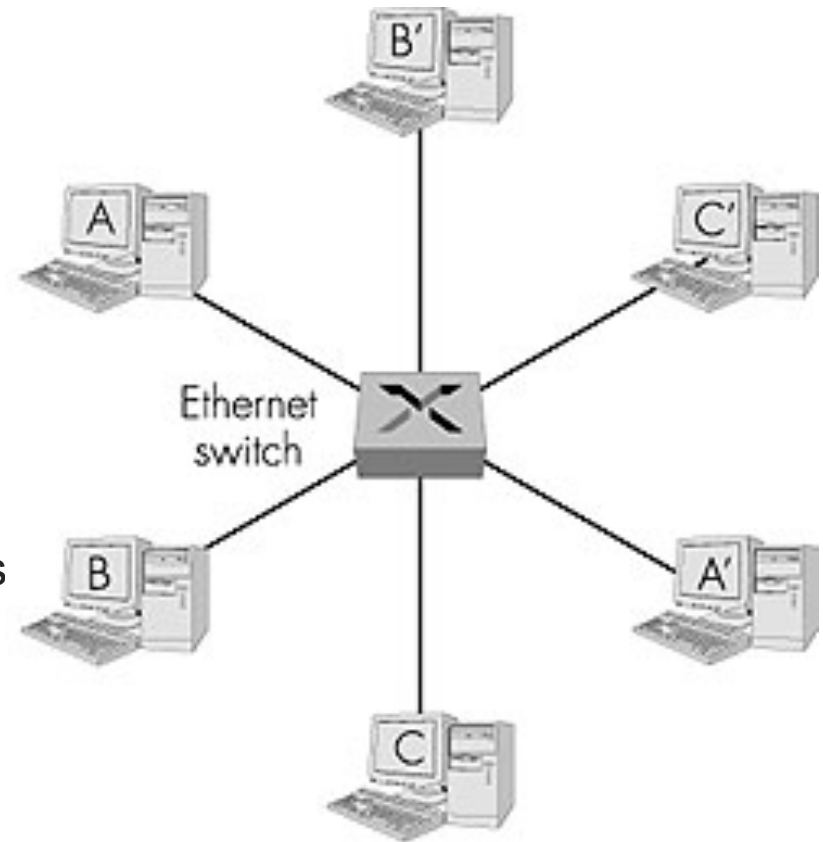
Important Details

- What if root bridge fails?
 - ◆ Age configuration info
 - » If not refreshed for MaxAge seconds then delete root and recalculate spanning tree
 - » If config message is received with a more recent age, then recalculate spanning tree
 - ◆ Applies to all bridges (not just root)
- Temporary loops
 - ◆ When topology changes, takes a bit for new configuration messages to spread through the system
 - ◆ Don't start forwarding packets immediately -> wait some time for convergence



Switched Ethernet

- Hosts directly connected to a bridge
 - ◆ learning + spanning tree protocol
- Switch supports parallel forwarding
 - ◆ A-to-B and A'-to-B' simultaneously
 - ◆ Generally full duplex as well
- **Switch** backplane capacity varies
 - ◆ Ideally, **nonblocking**
 - ◆ I.e., can run at full line rate on all ports
- No longer any shared bus
 - ◆ Each link is its own collision domain
 - ◆ Collision detection largely irrelevant

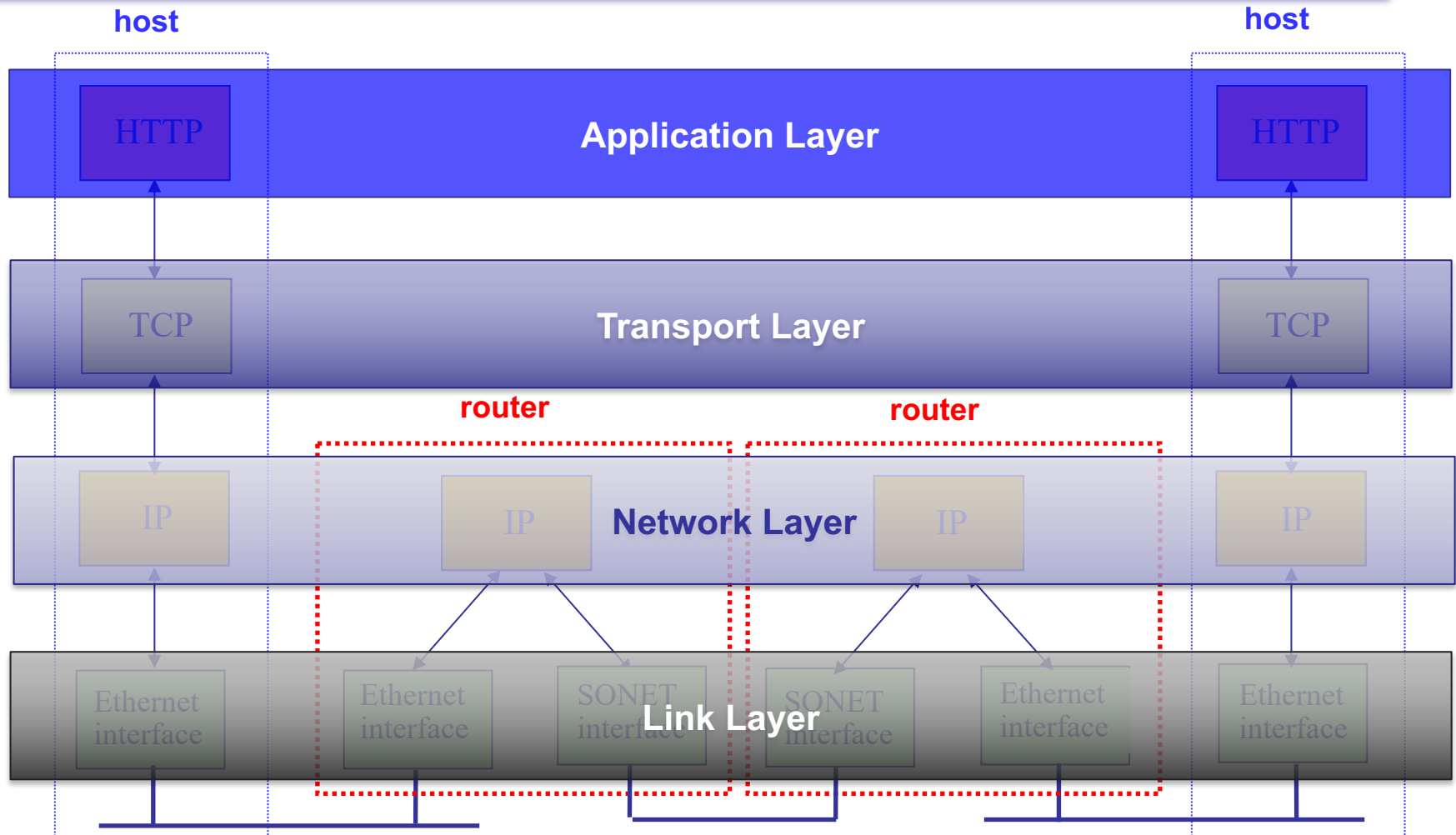




Layer-2 Forwarding

- Create spanning tree across LANs
 - ◆ Learn which ports to use to reach which addresses
- Benefits
 - ◆ Higher link bandwidth (point-to-point links)
 - ◆ Higher aggregate throughput (parallel communication)
 - ◆ Improved fault tolerance (redundant paths)
- Limitations
 - ◆ Requires homogeneous link layer (e.g. all Ethernet)
 - ◆ Harder to control forwarding topology
 - ◆ Security and performance issues (trust is assumed)
- What if we want to connect different link layers?

TCP/IP Protocol Stack





Combing Networks

- Main challenge is heterogeneity of link layers:
 - ◆ Addressing
 - » Each network media has a different addressing scheme
 - ◆ Bandwidth
 - » Dial-up modems to terabit optical networks
 - ◆ Latency
 - » Seconds to nanoseconds
 - ◆ Frame size
 - » Dozens to thousands of bytes
 - ◆ Loss rates
 - » Differ by many orders of magnitude
 - ◆ Service guarantees
 - » “Send and pray” vs reserved bandwidth



Combing Networks

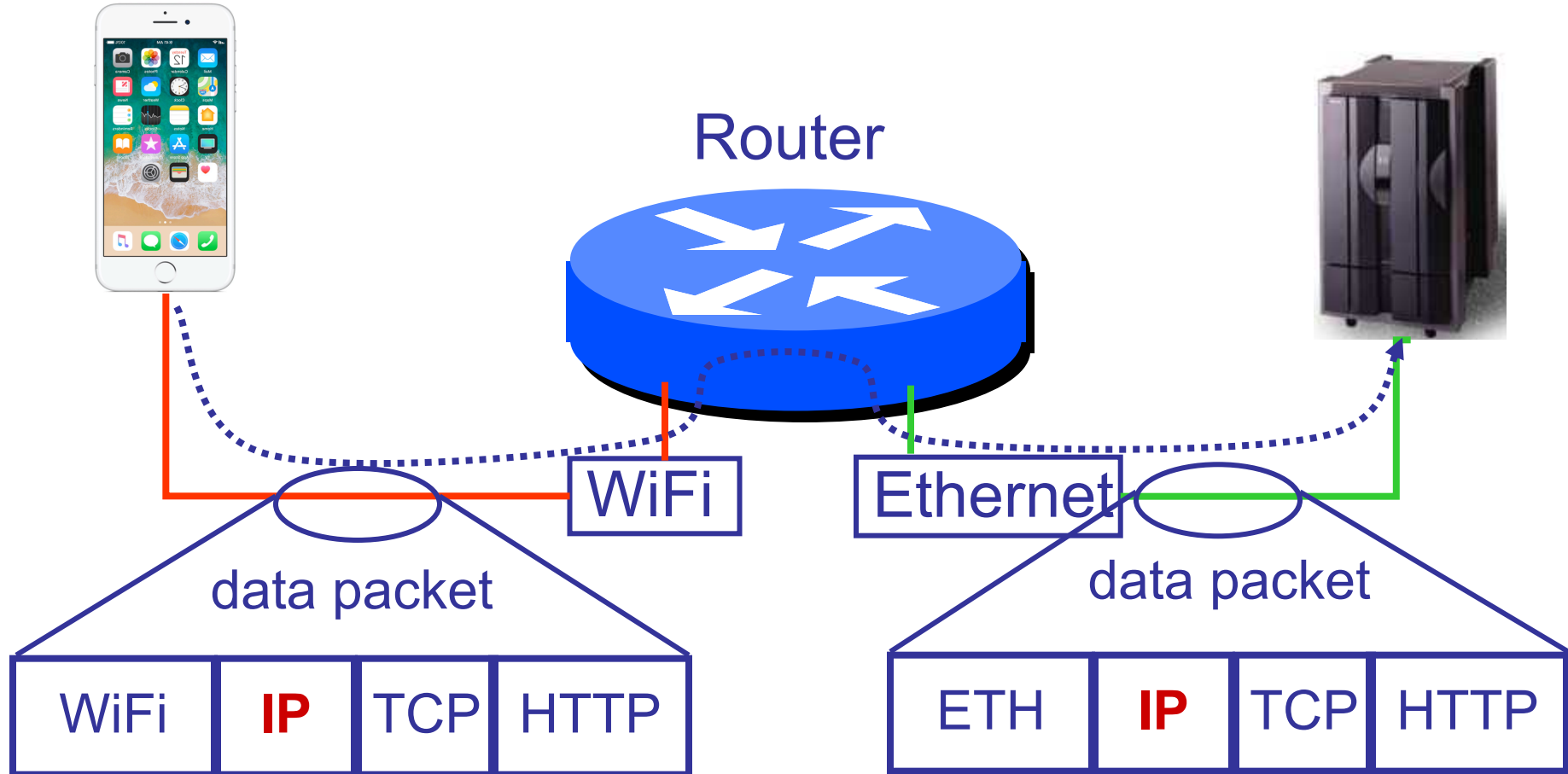
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Internetworking



- Cerf & Kahn74,
“*A Protocol for Packet Network Intercommunication*”
 - ◆ Foundation for the modern Internet
- Routers forward packets from source to destination
 - ◆ May cross many separate networks along the way
- All packets use a common Internet Protocol
 - ◆ Any underlying data link protocol
 - ◆ Any higher layer transport protocol
 - ◆ This is the “thin waist”

IP Networking



Routers



- A router is a store-and-forward device
 - ◆ Routers are connected to multiple networks
 - ◆ On each network, looks just like another host
 - ◆ A lot like a switch, but supports multiple datalink layers and makes decisions at the network layer
- Must be explicitly addressed by incoming frames (L2)
 - ◆ Not at all like a switch, which is transparent
 - ◆ Removes link-layer header, parses IP header (L3)
- Looks up next hop, forwards on appropriate network
 - ◆ Each router need only get one step closer to destination



For Next Time

- Read 3.2.5 in P&D
- Homework 1 due TODAY
- Homework 2 out on Monday
- Project 2 out today