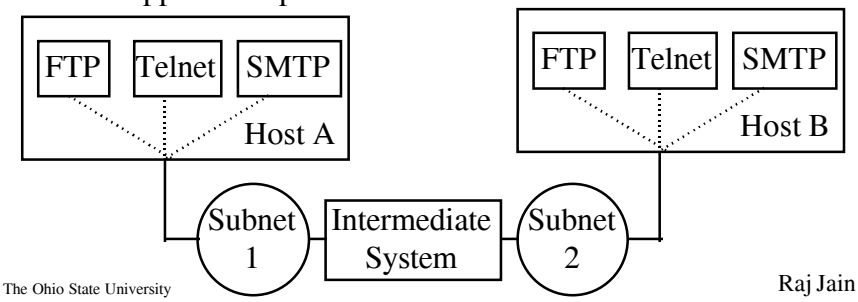
Internetworking

Raj Jain
Professor of CIS
The Ohio State University
Columbus, OH 43210
Jain@ACM.Org
http://www.cis.ohio-state.edu/~jain/

- Internetworking terms and services
- Bridges vs routers
- How bridges work?
- Spanning Tree and source routing
- Internet Protocol (IP): Services, Header, Address format
- Other Router-level protocols: ARP, ICMP, EGP, OSPF

Internetworking Terms

- End-system: Host
- Network: Provides data transfer between end-systems
- Internet: A collection of networks
- Subnetwork: Each component of an internet
- Intermediate System: Connects two subnetworks
- Port: Application processes in the host

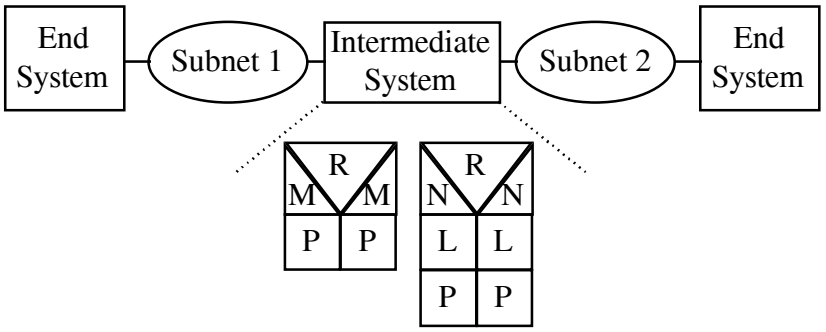


Internetworking Services

- Connects two or more subnets
- May provide accounting and status information
- Accomodate subnets with
  - Different addressing schemes
  - Different maximum packet sizes
  - Different network access mechanisms
  - Different timeouts
  - May provide error recovery
  - Different routing techniques
  - Different user access control
  - Connectionless and connection-oriented subnets

Bridge vs Router

- Bridge: Connects or more identical LANs. Operates at layer 2 of the OSI modeml.
- Router: Connects two or more LANs that may or may not be identical. Operates at layer 3 of the OSI model



Bridge: Functions

- Monitor all frames on LAN A
- Pickup those frames that are for stations on the other side
- Retransmit the frames on the other side
- Knows or learns about which stations are on various sides
- Makes no modification to content of the frames
  May change headers.
- Provides storage for frames to be forwarded
- Improves reliability (less nodes per LAN)
- Improves performance (more bandwidth per node)
- Security (Can keeps different traffic from entering a LAN)
- May provide flow and congestion control

Data Encaptulation by Bridges

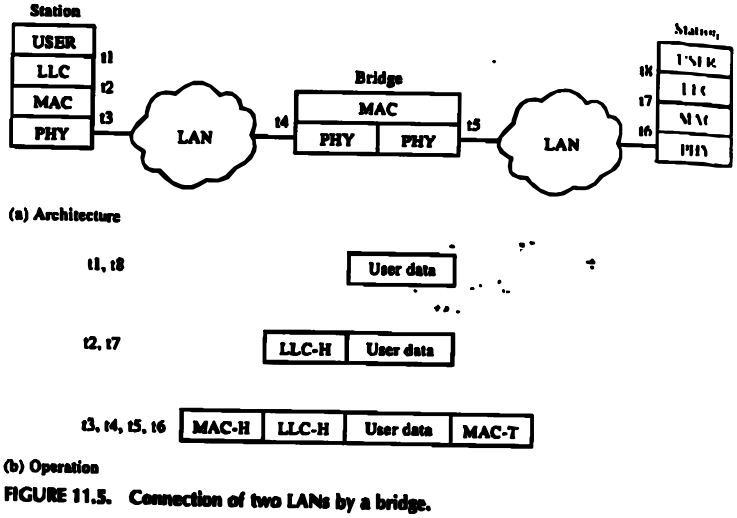
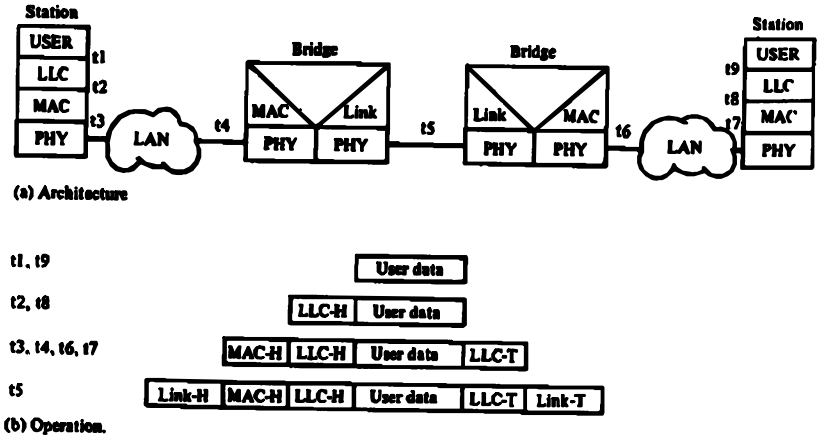
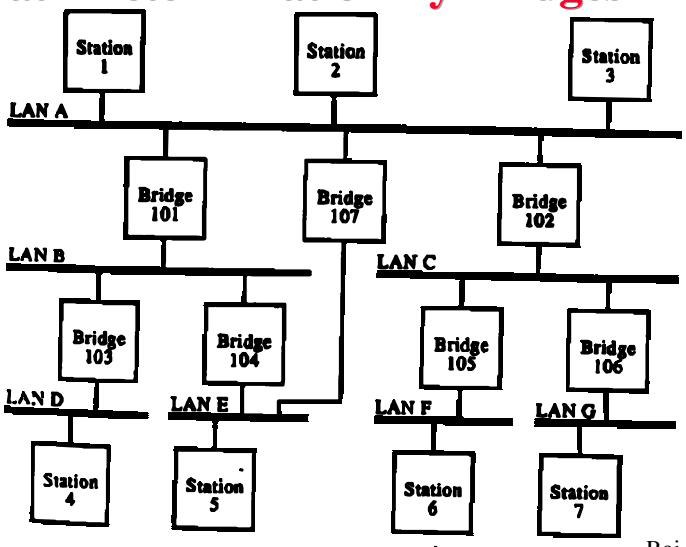


FIGURE 11.5. Connection of two LANs by a bridge.

Half-Bridges for Point-to-point links



Path Determination By Bridges



1. Fixed Routing

Central Routing Matrix

Source LAN \ Destination LAN	A	B	C	D	E	F	G
A	–	101	102	101	107	102	102
B	101	–	101	103	104	101	101
C	102	102	–	102	102	105	106
D	103	103	103	–	103	103	103
E	107	104	107	104	–	107	107
F	105	105	105	105	105	–	105
G	106	106	106	106	106	106	–

Bridge 101 table

from LAN A Dest	from LAN A Next	from LAN B Dest	from LAN B Next
B	B	A	A
C	–	C	–
D	B	D	A
E	–	E	–
F	–	F	A
G	–	G	A

Bridge 102 table

from LAN A Dest	from LAN A Next	from LAN C Dest	from LAN C Next
B	–	A	A
C	C	B	A
D	–	D	A
E	C	E	A
F	C	F	–
G	C	G	–

Bridge 103 table

from LAN B Dest	from LAN B Next	from LAN D Dest	from LAN D Next
A	–	A	B
C	D	B	B
D	–	C	B
E	–	E	B
F	–	F	B
G	–	G	B

Bridge 104 table

from LAN B Dest	from LAN B Next	from LAN E Dest	from LAN E Next
A	–	A	B
C	–	B	B
D	E	C	B
E	–	D	B
F	–	F	–
G	–	G	–

Bridge 105 table

from LAN C Dest	from LAN C Next	from LAN F Dest	from LAN F Next
A	–	A	C
B	–	B	C
D	–	C	C
E	–	D	C
F	F	E	C
G	–	G	C

Bridge 106 table

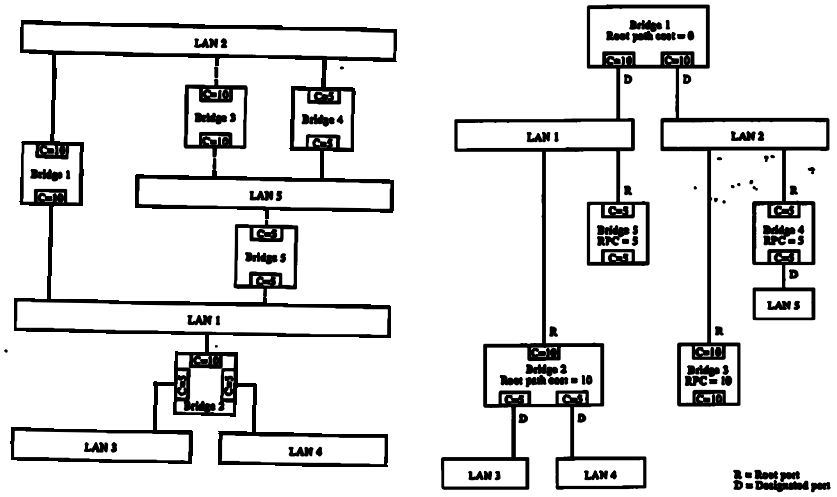
from LAN C Dest	from LAN C Next	from LAN G Dest	from LAN G Next
A	–	A	C
B	–	B	C
D	–	C	C
E	–	D	C
F	–	E	C
G	G	F	C

Bridge 107 table

from LAN A Dest	from LAN A Next	from LAN E Dest	from LAN E Next
B	–	A	A
C	–	B	–
D	E	C	A
E	–	D	–
F	E	E	A
G	E	F	A

Fig 11.10

2. Spanning Tree



Spanning Tree: Terminology

- Bridge Identifier: MAC address plus a priority level
- Port identifier: For each port of a bridge
- Path cost: Cost transmitting through a port
- Root Bridge: The bridge with the lowest identifier
- Root port: The port with the minimum cost to the root bridge
- Root path cost: Cost of the path to the root bridge
- Designated bridge: One per LAN. The bridge that provides minimum cost path from the LAN to the root bridge.
- Designated Port: The port of the designated bridge that connects the bridge to the LAN

Spanning Tree Algorithm

- All bridges multicast to "All bridges"
  - My ID
  - Root ID
  - My cost to root
- The bridges use the information received to update their info using Dijkstra's algorithm and rebroadcast
- Initially all bridges consider themselves to be the root but eventually converge to one root as they find out the lowest Bridge ID.
- On each LAN, the bridge with minimum cost to the root becomes the Designated bridge
- All ports of all non-designated bridges are blocked.

3. Source Routing

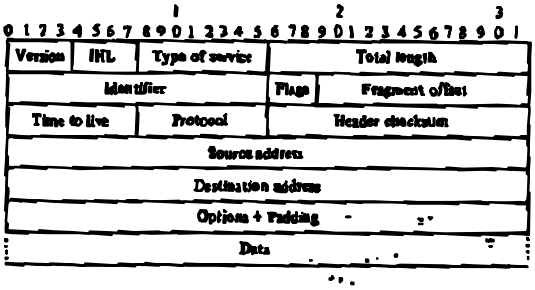
- The frame header contains the complete route:
  LAN 1 - Bridge B1 - LAN 3 - Bridge B3 - LAN 2 - Dest
- Bridges are simple, end systems do the routing
- Four types of destination addressing:
  - Null: Destination on the same LAN
  - Nonbroadcast: Includes a route to destination
  - All-route Broadcast: Flooded.
    Bridges record route in the frame.
  - Single-route Broadcast: Once and only once on each LAN.
    Spanning tree used for broadcast

Route Discovery

- Manually on small internets
- Route server
- Dynamic route discovery
  - Transmit "All-route request frame" to destination
    The destination sends back "nonbroadcast response" on each frame. Source knows all routes to the destination. Selects one.
  - Transmit "single-route request frame" to destination
    The destination responds with one "All-routes response." The source receives many responses and discovers all routes.

Internet Protocol (IP)

- IP deals with only with host addresses
- Services:
  - Send: User to IP
  - Deliver: IP to User
  - Error (optional): IP to User
- IP Header



IP Header

- Version (4 bits)
- Internet header length (4 bits): in 32-bit words.
  Min header is 5 words or 20 bytes.
- Type of service (8 bits): Reliability, precedence, delay, and throughput
- Total length (16 bits): header+data in bytes
- Identifier (16 bits): Helps uniquely identify the datagram during its life for a given source, destination address
- Flags (3 bits): More flag - used for fragmentation
  No-fragmentation
  Reserved

IP Header

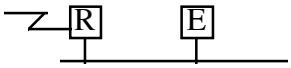
- Fragment offset (13 bits): In units of 8 bytes
- Time to live (8 bits): Specified in router hops
- Protocol (8 bits): Next level protocol to receive the data
- Header checksum (16 bits): 1's complement sum of all 16-bit words in the header
- Source Address (32 bits)
- Destination Address (32 bits)
- Options (variable): Security, source route, record route, stream id (used for voice) for reserved resources, timestamp recording
- Padding (variable): Makes header length a multiple of 4
- Data (variable): Data + header $\leq$ 65,535 bytes

IP vs ISO CLNP (Continued)

Function	IP	ISO CLNP
❑ Options	Security	Security
	Precedence bits in TOS	Priority
	Stricter source route	Complete source route
	Loose source route	Partial source route
	Record route	Record route
	Padding	Padding
	Timestamp	Not present

Ref: Piscitello and Chapin, p 384.

Address Resolution Protocol (ARP)



- Problem: Given an IP address find the MAC address
- Solution: Address resolution protocol
- The host broadcasts a request:
  "What is the MAC address of 127.123.115.08?"
- The host whose IP address is 127.123.115.08 replies back:
  "The MAC address for 127.123.115.08 is
  $8A\text{-}5F\text{-}3C\text{-}23\text{-}45\text{-}56_{16}$"
- A router may act as a proxy for many IP addresses

Internet Control Message Protocol (ICMP)

- Required companion to IP.
  Provides feedback from the network.
  - Destination unreachable
  - Time exceeded
  - Parameter problem
  - Source quench
  - Redirect
  - Echo
  - Echo reply
  - Timestamp
  - Timestamp reply
  - Information Request
  - Information reply

Autonomous Systems

- An internet connected by homogeneous routers under the administrative control of a single entity

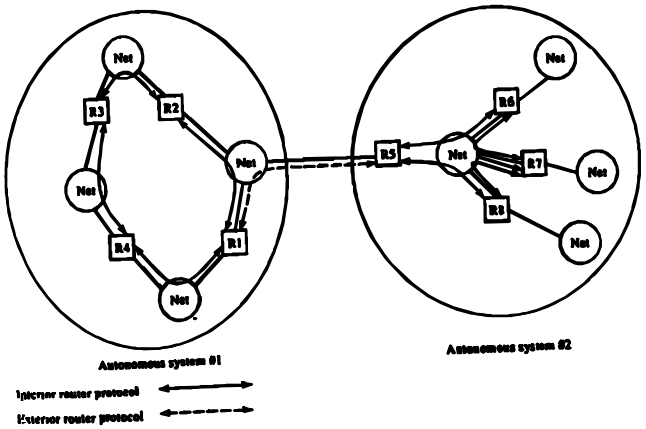


Fig 11.21

Other Router-level Protocols

- Interior Router Protocol (IRP): Used for passing routing information among routers internal to an autonomous system
- Exterior Router Protocol (ERP): Used for passing routing information among routers between autonomous systems
- Routing Information Protocol (RIP): First generation ARPAnet IRP protocol. Entire routing table sent to neighbors. Distance vector routing.
- Open Shortest Path First (OSPF): Interior routing protocol. Provides least-cost path routes using a fully user configurable routing metric (any fn of delay, data rate, dollar cost, etc.) Link costs flooded (Link-state routing)
- Exterior Gateway Protocol (EGP): Periodic hellos and responses with cost to other networks

Summary

- Subnetwork, IS, ES
- Bridges and routers
- Spanning tree, source routing, route discovery
- IP: Address, header
- ARP, ICMP, EGP, OSPF