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Algorithms for Radio Networks

Routing, Distance-Vector, Link-State

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Protocols of the Internet

Application	Telnet, FTP, HTTP, SMTP (E-Mail), ...
Transport	TCP (Transmission Control Protocol) UDP (User Datagram Protocol)
Network	IP **(Internet Protocol)** + ICMP **(Internet Control Message Protocol)** + IGMP **(Internet Group Management Protocol)**
Host-to-Network	LAN **(e.g. Ethernet, Token Ring etc.)**

TCP/IP Layers

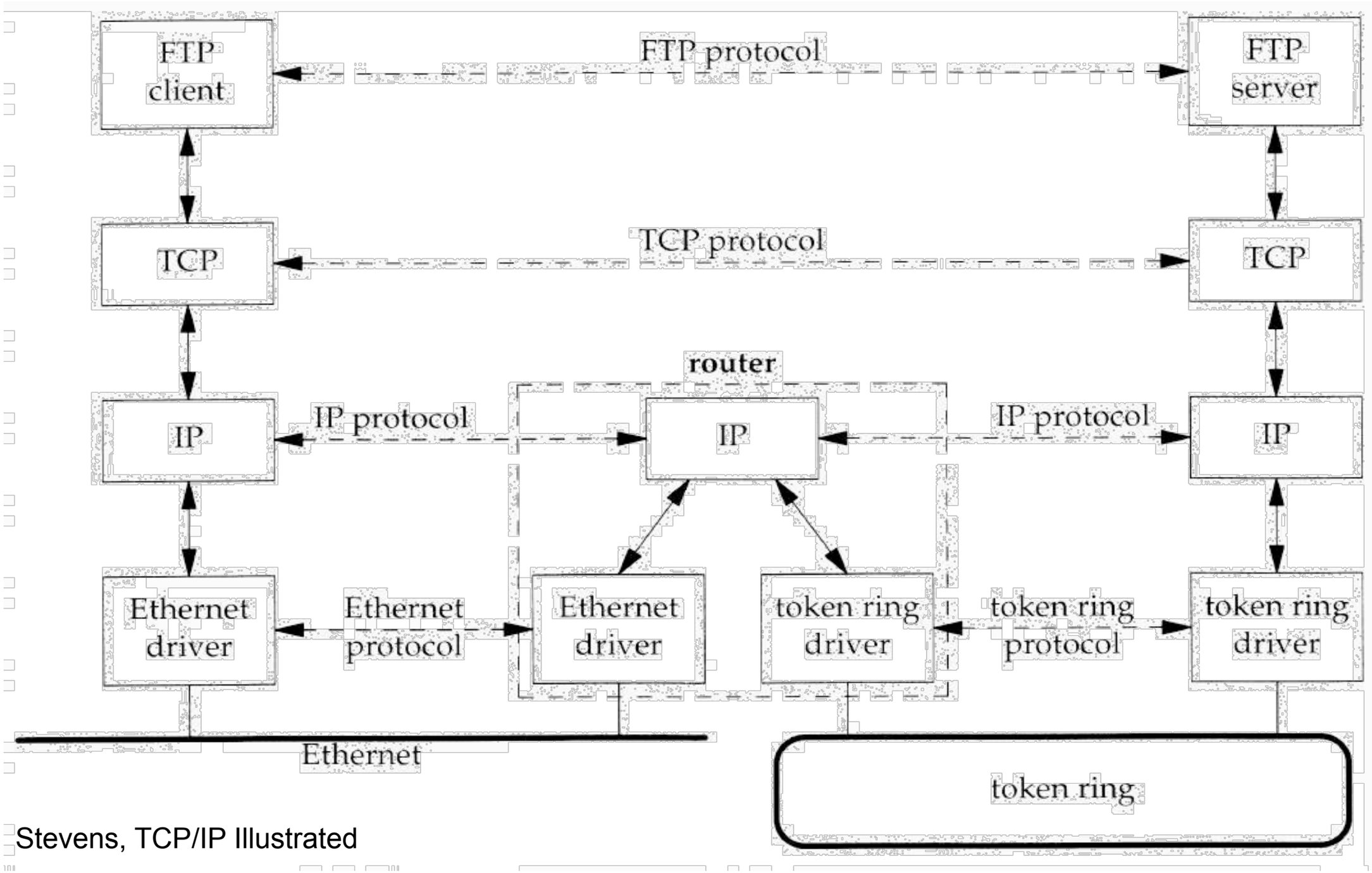
- **1. Host-to-Network**
  - Not specified, depends on the local network,k e.g. Ethernet, WLAN 802.11, PPP, DSL

- **2. Routing Layer/Network Layer (IP - Internet Protocol)**
  - Defined packet format and protocol
  - Routing
  - Forwarding

- **3. Transport Layer**
  - TCP (Transmission Control Protocol)
    - Reliable, connection-oriented transmission
    - Fragmentation, Flow Control, Multiplexing
  - UDP (User Datagram Protocol)
    - hands packets over to IP
    - unreliable, no flow control

- **4. Application Layer**
  - Services such as TELNET, FTP, SMTP, HTTP, NNTP (for DNS), ...

Example: Routing between LANs



Stevens, TCP/IP Illustrated

Routing Tables and Packet Forwarding

- **IP Routing Table**
  - contains for each destination the address of the next gateway
  - destination: host computer or sub-network
  - default gateway
- **Packet Forwarding**
  - IP packet (datagram) contains start IP address and destination IP address
  - if destination = my address then hand over to higher layer
  - if destination in routing table then forward packet to corresponding gateway
  - if destination IP subnet in routing table then forward packet to corresponding gateway
  - otherwise, use the default gateway

IP Packet Forwarding

- **IP -Packet (datagram) contains...**
  - TTL (Time-to-Live): Hop count limit
  - Start IP Address
  - Destination IP Address
- **Packet Handling**
  - Reduce TTL (Time to Live) by 1
  - If TTL ≠ 0 then forward packet according to routing table
  - If TTL = 0 or forwarding error (buffer full etc.):
    - delete packet
    - if packet is not an ICMP Packet then
      - send ICMP Packet with
        - start = current IP Address
        - destination = original start IP Address

Static and Dynamic Routing

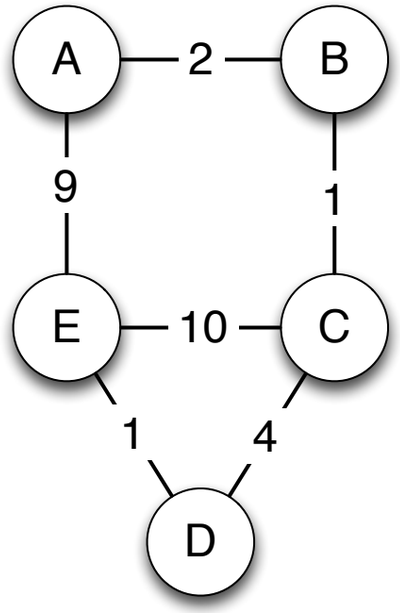
- **Static Routing**
  - Routing table created manually
  - used in small LANs
- **Dynamic Routing**
  - Routing table created by Routing Algorithm
    - Centralized, e.g. Link State
      - Router knows the complete network topology
    - Decentralized, e.g. Distance Vector
      - Router knows gateways in its local neighborhood

Intra-AS Routing

- **Routing Information Protocol (RIP)**
  - Distance Vector Algorithmus
  - Metric = hop count
  - exchange of distance vectors (by UDP)
- **Interior Gateway Routing Protocol (IGRP)**
  - successor of RIP
  - different routing metrics (delay, bandwidth)
- **Open Shortest Path First (OSPF)**
  - Link State Routing (every router knows the topology)
  - Route calculation by Dijkstra's shortest path algorithm

Distance Vector Routing Protocol

- **Distance Table data structure**
  - Each node has a
    - Line for each possible destination
    - Column for any direct neighbors
- **Distributed algorithm**
  - each node communicates only with its neighbors
- **Asynchronous operation**
  - Nodes do not need to exchange information in each round
- **Self-terminating**
  - exchange unless no update is available



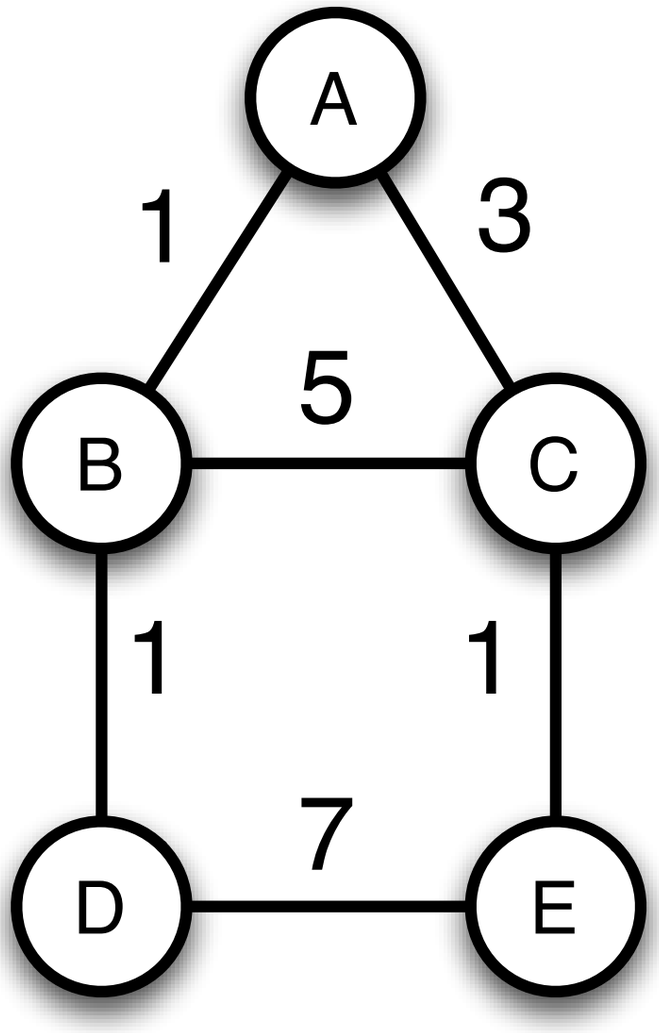
Distance Table for A

		via		Routing Table
from A		B	E	entry
to	B	**2**	15	B
	C	**3**	14	B
	D	**7**	10	B
	E	**8**	9	E

Distance Table for C

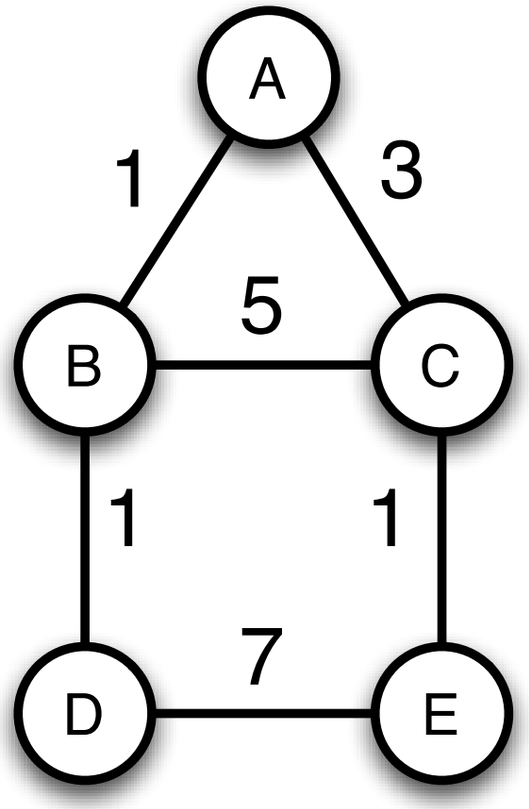
		via			Routing Table
from C		B	D	E	entry
to	A	**3**	11	18	B
	B	**1**	9	21	B
	D	6	**4**	11	D
	E	7	**5**	10	D

Distance Vector Routing Example



from A to	via		entry
	B	C	
B	**1**	8	**B**
C	6	**3**	**C**
D	**2**	9	**B**
E	7	**4**	**C**

Distance Vector Routing



from A to	via		entry
	B	C	
B	1	-	B
C	-	3	C
D	-	-	-
E	-	-	-

from B to	via			entry
	A	C	D	
A	1	-	-	A
C	-	3	-	C
D	-	-	1	C
E	-	-	8	D

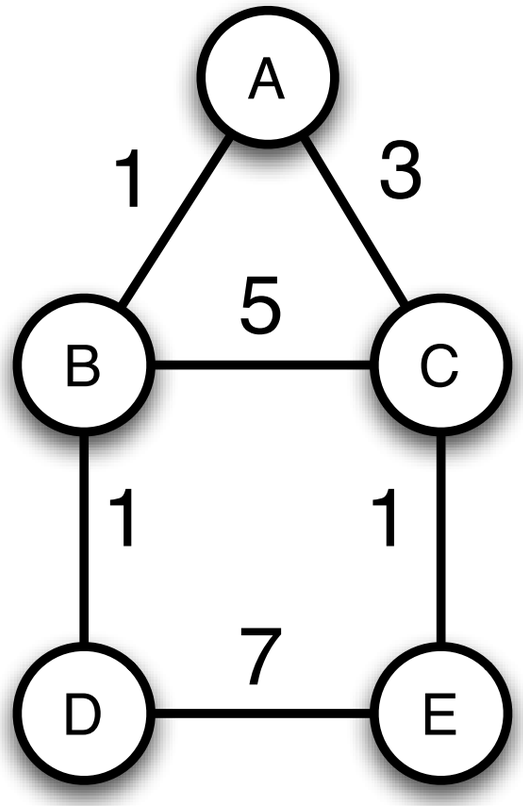
from C to	via			entry
	A	B	E	
A	3	-	-	A
B	-	5	-	B
D	-	-	8	E
E	-	-	1	E

Distance Vector Routing

from B to	via A	via C	via D	Entry
A	1	-	-	A
C	-	5	-	C
D	-	-	1	D
E	-	-	8	D

from C to	via A	via B	via E	Entry
A	3	-	-	A
B	-	5	-	B
D	-	-	8	E
E	-	-	1	E

from B to	via A	via C	via D	Entry
A	1	8	-	A
C	-	5	-	C
D	-	13	1	D
E	-	6	8	C

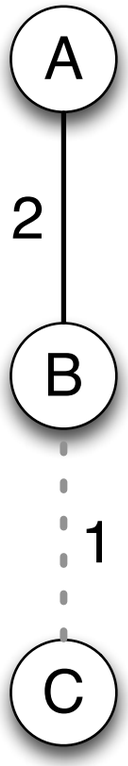


from C to	via A	via B	via E	Entry
A	3	6	-	A
B	-	5	-	B
D	-	6	8	B
E	-	13	1	E

“Count to Infinity” - Problem

- **Good news travels fast**
  - A new connection is quickly at hand
- **Bad news travels slowly**
  - Connection fails
  - Neighbors increase their distance mutally
  - "Count to Infinity" Problem

“Count to Infinity” - Problem



from A		via B	Routing Table entry
to	B	2	B
	C	3	B

from B		via A	via C	Routing Table entry
to	A	2	-	A
	C	5	-	A

from A		via B	Routing Table entry
to	B	2	B
	C	7	B

from B		via A	via C	Routing Table entry
to	A	2	-	A
	C	5	-	A

from A		via B	Routing Table entry
to	B	2	B
	C	7	B

from B		via A	via C	Routing Table entry
to	A	2	-	A
	C	9	-	A

Link-State Protocol

- **Link state routers**
  - exchange information using Link State Packets (LSP)
  - each node uses shortest path algorithm to compute the routing table
- **LSP contains**
  - ID of the node generating the packet
  - Cost of this node to any direct neighbors
  - Sequence-no. (SEQNO)
  - TTL field for that field (time to live)
- **Reliable flooding (Reliable Flooding)**
  - current LSP of each node are stored
  - Forward of LSP to all neighbors
    - except to be node where it has been received from
  - Periodically creation of new LSPs
    - with increasing SEQNO
  - Decrement TTL when LSPs are forwarded

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