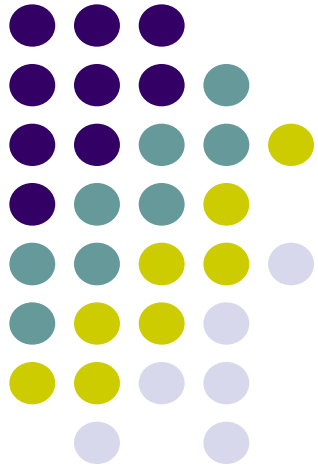
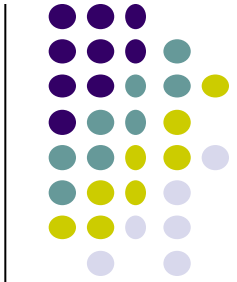
WAN Technologies and Routing

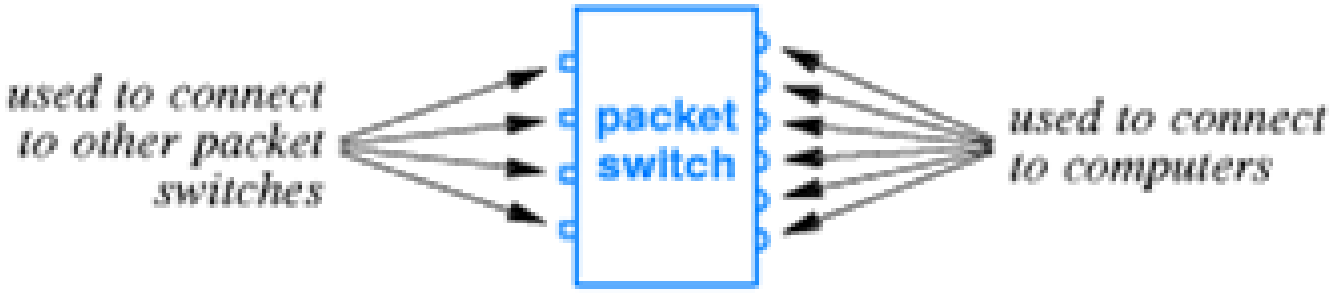




- Network Technology is classified into three broad categories, depending on the size of networks that can be created:
  - LAN can span a single building or campus
  - MAN can span a single city
  - WAN (also called long-haul networks) can span sites in multiple cities, countries, continents.

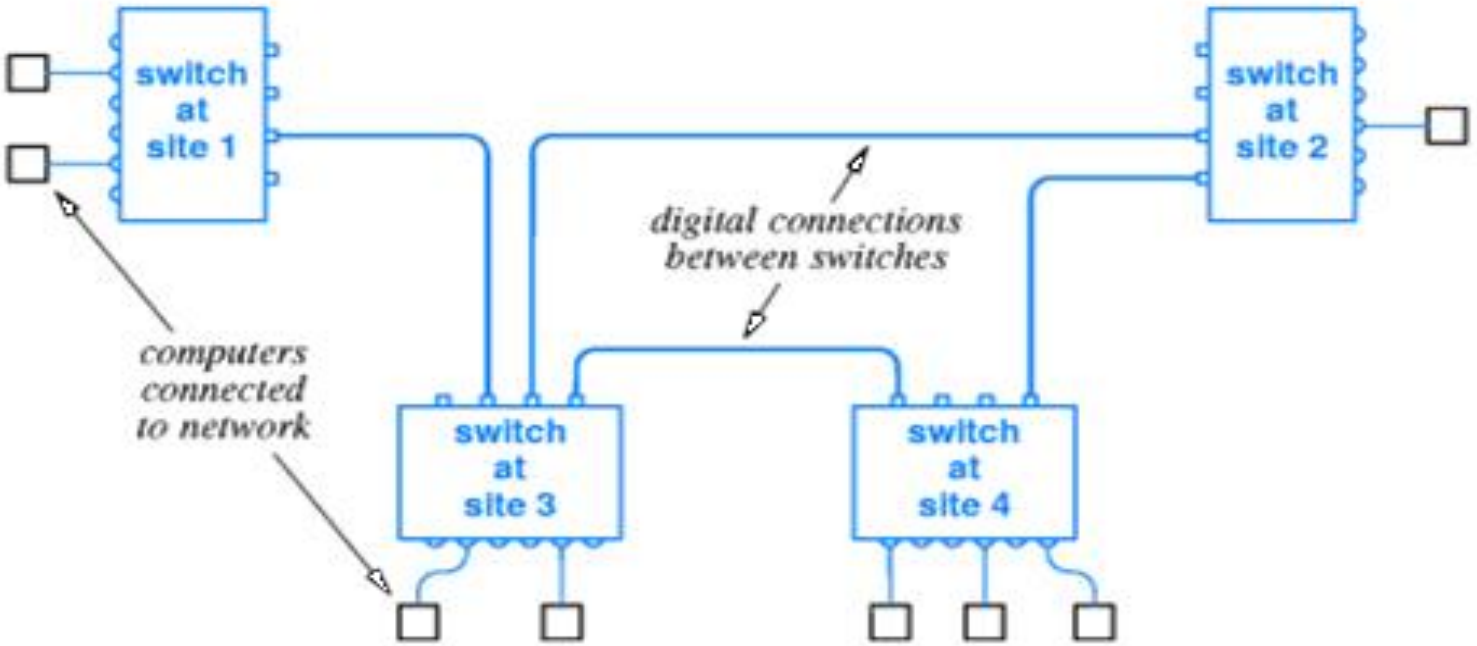
Packet Switch

- Basic electronic switch used in a WAN is called packet switch, because it moves complete packets from one computer to another.
- Each packet switch is a small computer that has a processor and memory as well as I/O devices used to send/receive packets.



A packet switch with two types of I/O connectors: one type is used to connect to other packet switches, and the other is used to connect to computers.

Sample WAN



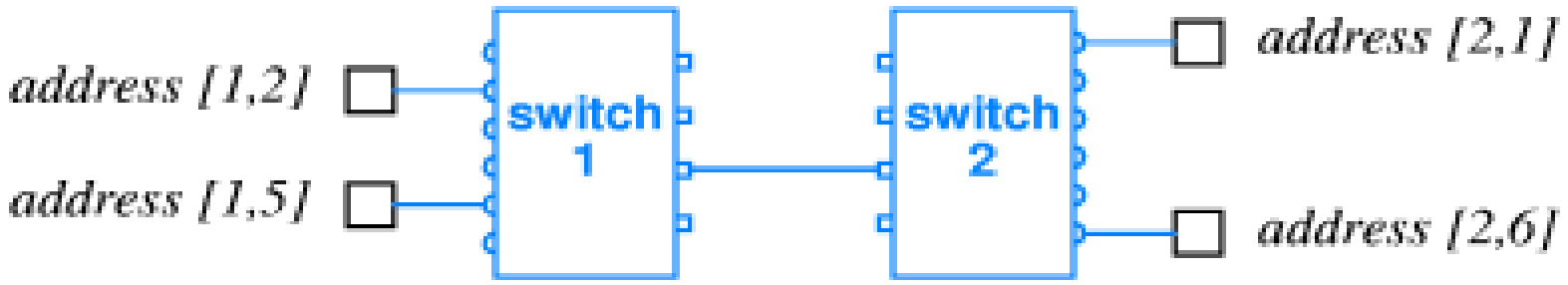
A small WAN formed by interconnecting packet switches. Connections between packet switches usually operate at a higher speed than connections to individual computers.

Store & Forward

- Buffer incoming packets (Store at a queue)
- Send the packet to a suitable I/O interface.

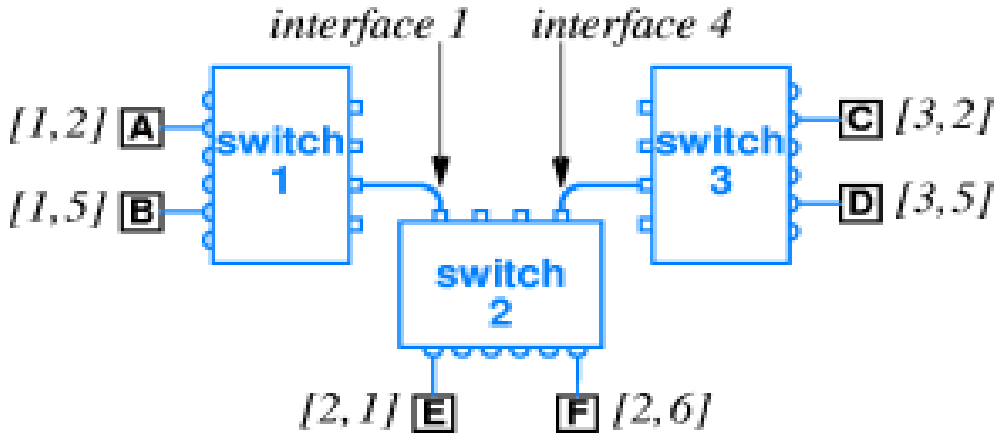
Physical Addressing

- Hierarchical Addressing Scheme makes forwarding more efficient.
- Divides an address into multiple parts.



Next-Hop Forwarding

- A packet switch must choose an outgoing path over which to forward each packet.
- Example Routing



(a)

destination	next hop
[1,2]	interface 1
[1,5]	interface 1
[3,2]	interface 4
[3,5]	interface 4
[2,1]	computer E
[2,6]	computer F

(b)

Routing Table on Switch 2

Route Summarization

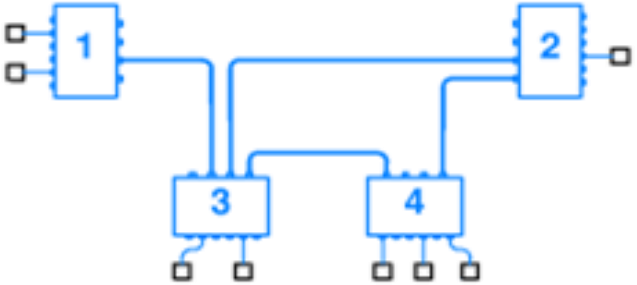
- Source Independence

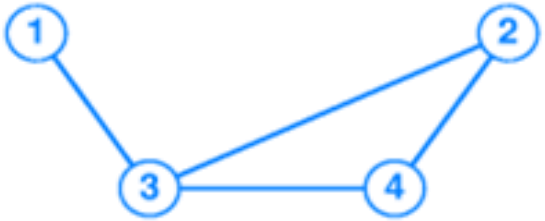
- Summarized Routing Table:

Destination	Next Hop
(1, anything)	Interface 1
(3, anything)	Interface 4
(2, anything)	local computer

Routing in a WAN

- Interior Switches / Exterior Switches
- Values in the routing table must guarantee; Universal Routing and Optimal Routes.
- Graph representation: node, edge (or link).





destin-ation	next hop
1	-
2	(1,3)
3	(1,3)
4	(1,3)

node 1

destin-ation	next hop
1	(2,3)
2	-
3	(2,3)
4	(2,4)

node 2

destin-ation	next hop
1	(3,1)
2	(3,2)
3	-
4	(3,4)

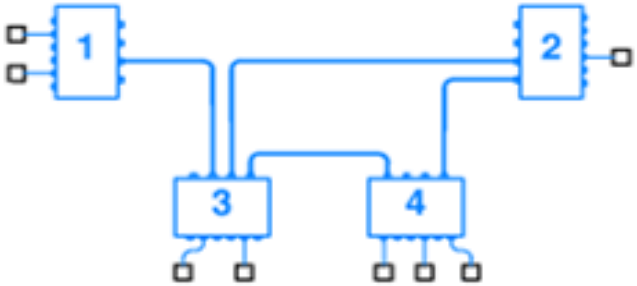
node 3

destin-ation	next hop
1	(4,3)
2	(4,2)
3	(4,3)
4	-

node 4

Use of Default Routes

- Although hierarchical addressing reduces the size of the routing table by removing duplicate routes for individual computers, the abbreviated routing table still contains many entries with the same next hop.
- **Default role (default routing table entry)**, is a mechanism that can be used to eliminate common case of duplication routing, which most WAN systems include.



destin-ation	next hop
1	-
*	(1,3)

node 1

destin-ation	next hop
2	-
4	(2,4)
*	(2,3)

node 2

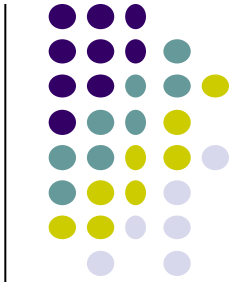
destin-ation	next hop
1	(3,1)
2	(3,2)
3	-
4	(3,4)

node 3

destin-ation	next hop
2	(4,2)
4	-
*	(4,3)

node 4

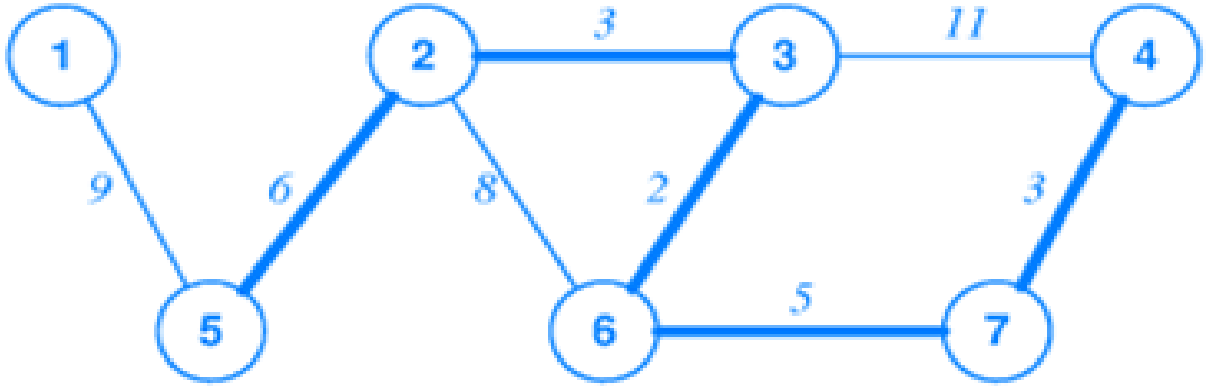
Routing Table Computation



- Two basic approaches:
  - Static Routing: A program computes and installs routes when a packet switch boots; the routes do not change.
    - Advantages: Simplicity and low network overhead.
    - Disadvantages: Inflexibility.
  - Dynamic Routing: A program builds an initial routing table when a packet switch boots; the program then alters the table as conditions in the network change.
    - Advantages: Flexibility, automatically problem handling.
    - Disadvantages: High network overhead.

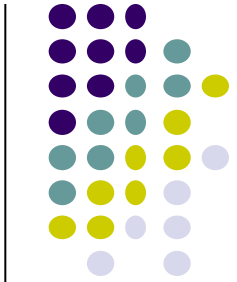
Shortest Path Computation

- Represent network as a graph
- Dijkstra's Algorithm
  - Computes shortest path in a graph by using weights on edges as a measure of distance.
  - Three data structures to store the current distance to each node, the next hop for the shortest path, information about the remaining set of nodes.



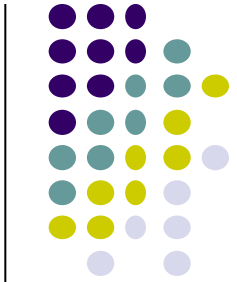
- Different measures of distance

Distributed Route Computation



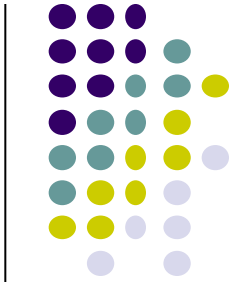
- Each packet switch computes its routing table locally.
- It sends messages across the network to neighboring packet switches to inform them of the result.
- Some distributed route computation algorithms:
  - Distance Vector Routing
  - Link-State Routing

Distance Vector Routing



- Distance-Vector Algorithm
- Each link in the network has a **weight** and **distance** to the destination is defined to be the sum of weights along the path to the destination.
- An additional field “next hop” is included.
- Each packet switch sends routing information across the network.
- Each packet includes (destination, distance) pairs.

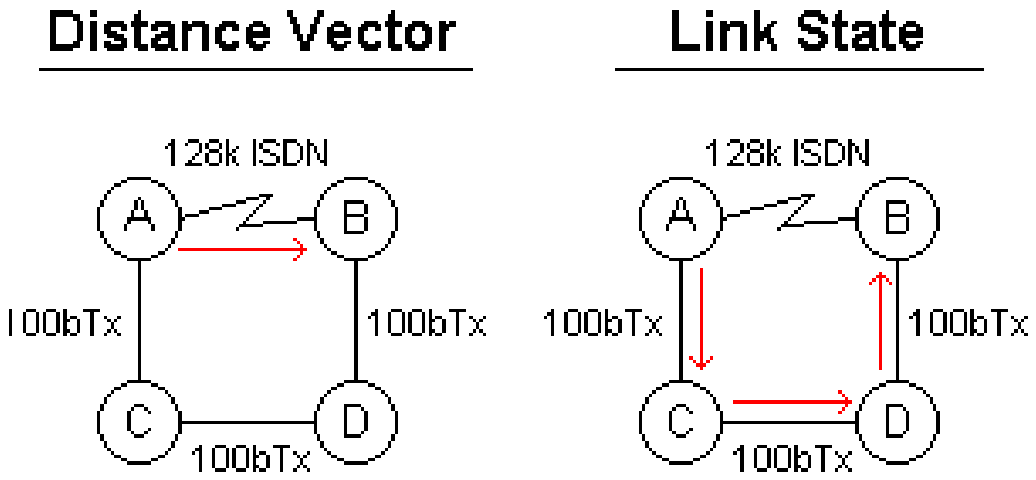
Link-State Routing (SPF Routing)



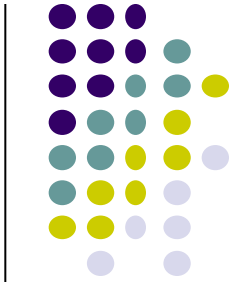
- Each message sent by packet switches includes status of the link between two packet switches.
- Each message is broadcast to all switches.
- Each switch collects incoming status messages and build a graph of the network.
- The switch uses Shortest Path Algorithm to build the routing table.

Distance Vector vs. Link State Routing

- If all routers were running a Distance Vector protocol, the path or 'route' chosen would be from A B directly over the ISDN serial link, even though that link is about 10 times slower than the indirect route from A C D B.

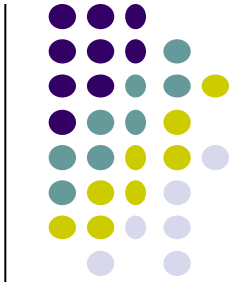


- A Link State protocol would choose the A C D B path because it's using a faster medium (100 Mb ethernet). In this example, it would be better to run a Link State routing protocol.
- But if all the links in the network are the same speed, then a Distance Vector protocol is better.



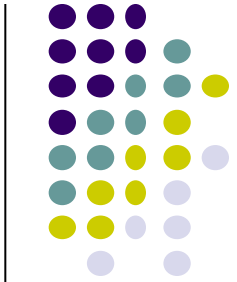
- Because of their awareness of media types and other factors, link state protocols require more processing power (more circuit logic in the case of ASICs) and memory. Distance vector algorithms being simpler require simpler hardware.
- Link state routing can adapt to hardware failures, like distance-vector algorithm.
- In Link State Routing algorithm, all computations can be carried out simultaneously, after the status of a link changes, all packet switches receive a status message, and each begins computing its routing table. A Distance –Vector algorithm requires a packet switch to update its routing table before sending a message to another packet switch.

Distance Vector Protocols



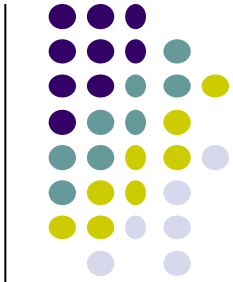
- IP Routing Information Protocol (RIP) Version 1 and 2
- IP Interior Gateway Routing Protocol (IGRP)
- Novell NetWare Internetwork Packet Exchange Routing Information Protocol (IPX RIP)
- Apple Talk Routing Table Maintenance Protocol (RTMP)
- Apple Talk Update-Based Routing Protocol (AURP)
- IP enhanced IGRP (an advanced distance-vector protocol)
- IP Border Gateway Protocol (BGP) (a path-vector routing protocol)

Link-State Routing Protocols



- IP Open Shortest Path First (OSPF)
- IP Intermediate System-to-Intermediate System (IS-IS)
- NetWare Link Services Protocol (NLSP)

Example WAN Technologies



- ARPANet
- X.25
- Frame Relay (F/R)
- Switched Multi-megabit Data Service (SMDS)
- ATM