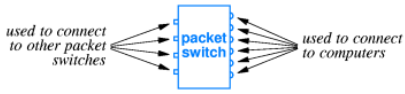
COMP476
Networked Computer Systems

Routing

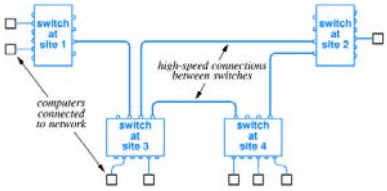
WAN – Wide Area Networks

- WANs are made of store and forward switches.



** 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.*

Packet Switches



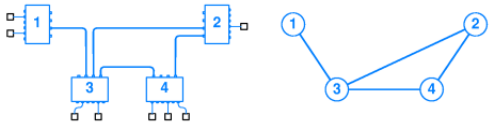
** A small WAN formed by interconnecting packet switches. Connections between packet switches usually operate at a higher speed than connections to individual computers.*

Packet Switch Operation

```
forall input lines {
  do forever {
     read a packet;
     if (valid) {
          output_line = table[destination_addr]
          if (queue[output_line] not full)
               put packet on queue[output_line]
     }
  }
}
```

Routing - Network Model

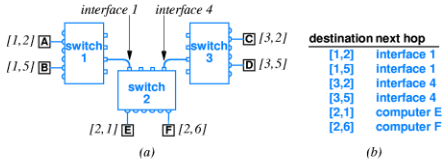
- The graph below models a network. Each node corresponds to a packet switch in the network.



** Each node corresponds to a packet switch, and each edge represents a connection between the corresponding packet switches.*

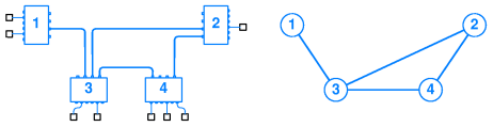
Next-Hop Forwarding

- A given switch has information about the next place (hop) to send a packet so the packet will eventually reach its destination.



The table is the next-hop forwarding information found in switch 2. Each switch has different next-hop information.

Next Hop Routing Tables

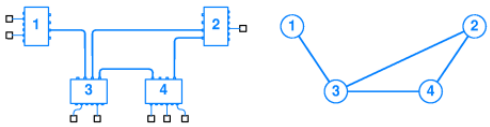


node 1		node 2		node 3		node 4	
dest	next	dest	next	dest	next	dest	next
1	-	1	3	1	1	1	3
2	3	2	-	2	2	2	2
3	3	3	3	3	-	3	3
4	3	4	4	4	4	4	-

Routing Tables with Alternatives

- Routing tables can also contain a second choice route
- In the event the first route is unavailable or congested, packets can be sent on the alternate interface.

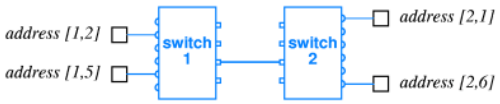
Next Hop Routing Tables with Alternatives



node 1			node 2			node 3			node 4		
dest	next	alt	dest	next	alt	dest	next	alt	dest	next	alt
1	-	-	1	3	4	1	1	-	1	3	2
2	3	-	2	-	-	2	2	4	2	2	3
3	3	-	3	3	4	3	-	-	3	3	2
4	3	-	4	4	3	4	4	2	4	-	-

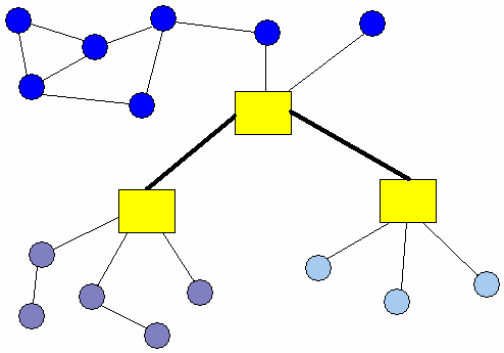
Hierarchical Addressing

- Hierarchical addresses can be used to simplify routing.



- *Example of hierarchical addresses in a WAN.*
- *Each address consists of two parts:*
  1. *Identifies a packet switch*
  2. *Identifies a computer connected to the switch.*

Hierarchical Routing



Route Generation

- Global routing is done by local decisions.
- Routing table can be created:
  - By a central system and distributed to nodes
  - By sending node for each packet
  - "Learned" by each node from neighbors

Optimal Routes

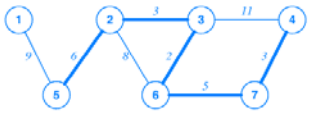
- There are several algorithms for computing the optimal path.

  - •Dijkstra's algorithm
  - •Floyd's algorithm
  - •distributed algorithm

Dijkstra's Algorithm

(One of the more popular methods for computation of the optimal path)

- Solves the problem of finding the shortest path from a point in a graph (the *source*) to a destination.
- Dijkstra's algorithm computes shortest paths in a graph by using weights on edges as a measure of distance. A path with the fewest number of edges may not be the path with least weight.



** A graph with weights assigned to edges. The shortest path between nodes 4 and 5 is shown darkened. The distance along the path is 19, the sum of the weights on the edges.*

Floyd's Algorithm

Start with a table giving the distance from each source to each destination. Immediate neighbors use the link distance. Other nodes have an infinite distance.

		Destination			
		1	**2**	**3**	**4**
source	**1**	0	∞	4	∞
	2	∞	0	5	1
	3	4	5	0	7
	4	∞	1	7	0

Floyd's Algorithm

For each non-infinite link, see if that is a shorter way to other destinations. If shorter, replace the current distance with the sum of the distance to an intermediate plus the distance from the intermediate to the destination.

		Destination			
		1	**2**	**3**	**4**
source	**1**	0	∞	4	∞
	2	∞	0	5	1
	3	4	5	0	7
	4	∞	1	7	0

Floyd's Algorithm

Node 1 can get to node 3 in 4 time units. Node 3 can get to node 2 in 5 time units. The time to get from node 1 to 3 to 2 is 4+5=9.

		Destination			
		1	**2**	**3**	**4**
source	**1**	0	9	4	∞
	2	∞	0	5	1
	3	4	5	0	7
	4	∞	1	7	0

Floyd's Algorithm

Repeat for each source node, for each intermediate and for each destination.

		Destination			
		1	**2**	**3**	**4**
source	**1**	0	9	4	11
	2	9	0	5	1
	3	4	5	0	7
	4	11	1	7	0

Floyd's Algorithm

Iterate until no more changes are made.

		Destination			
		1	**2**	**3**	**4**
source	**1**	0	9	4	10
	2	9	0	5	1
	3	4	5	0	6
	4	10	1	6	0

Distributed Routing

- Each node computes the time to send a packet to its neighbors.
- Periodically, each node shares its routing table with its neighbors.
- Use the minimum(current path,
  (time to neighbor + neighbor to destination))

Connection oriented and connectionless systems

Issue	**Connection oriented**	**Connectionless**
Initial setup	required	not necessary
Destination address	only needed during initial setup	needed every packet
Packet sequencing	guaranteed	not guaranteed
Option negotiation	possible at setup	not available
Overhead	moderate	low

Connectionless Examples

- Ethernet
- Token Ring
- FDDI
- Internet Protocol
- User Datagram Protocol

Connection Oriented Examples

- ATM
- Transmission Control Protocol (TCP)