AHRAM CANADIAN UNIVERSITY

Lecture (08)
Routing in Switched Networks (I)

Dr. Ahmed ElShafee

Agenda

- Routing protocols
  - Fixed
  - Flooding
  - Random
  - Adaptive
- ARPANET Routing Strategies
- Least cost algorithms
  - Dijkstra's algorithm
  - Bellman-Ford algorithm

Routing protocols

- A key design issue in switched networks, including packet-switching, frame relay, and ATM networks, and with internets, is that of routing.
- generally, more than one route is possible.
- Thus, a routing function must be performed to find the best possible route.

characteristics required:

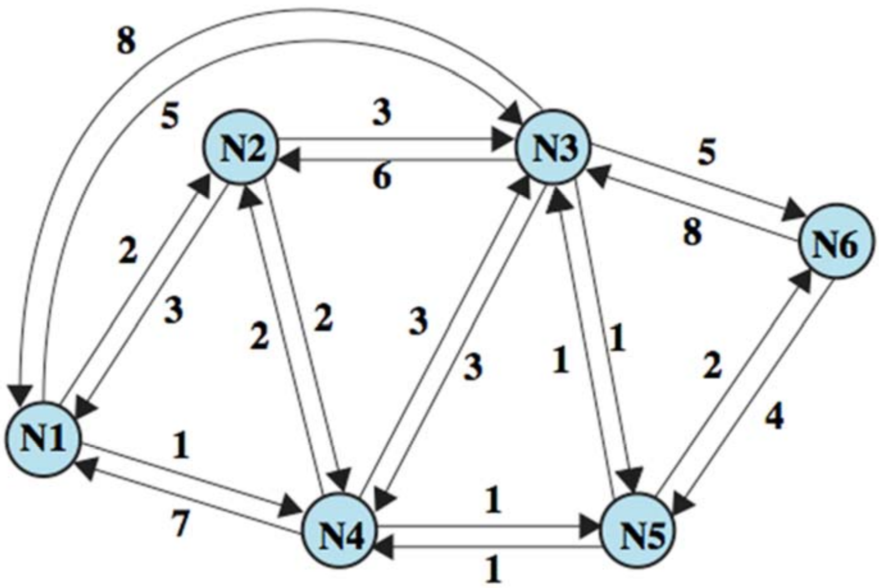
- correctness
- simplicity
- Robustness: ability of the network to deliver packets via localized failures and overloads.
- Stability
- Fairness x
- efficiency
- optimality

Some performance criteria may give higher priority to the exchange of packets between nearby stations compared to an exchange between distant stations.

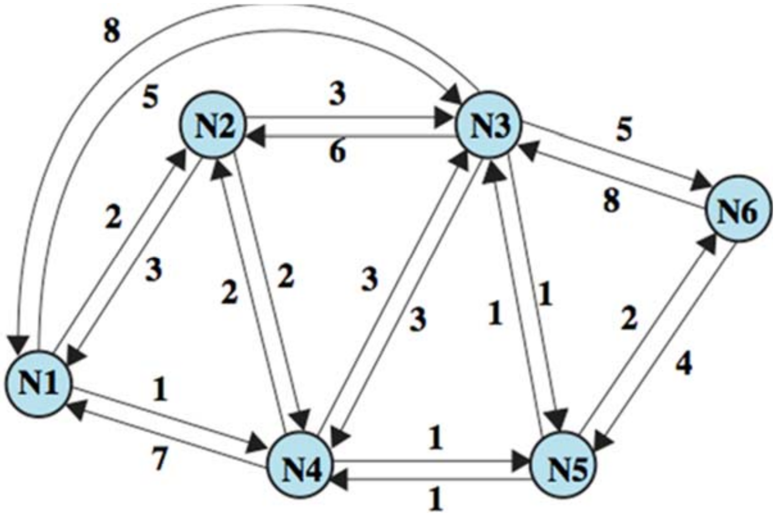
This policy may maximize average throughput but will appear unfair to the station that primarily needs to communicate with distant stations

- A cost is associated with each link, and, for any pair of attached stations, the route through the network that accumulates the least cost is sought.
- In either the minimum-hop or least-cost approach, the algorithm for determining the optimum route for any pair of stations is relatively straightforward, and the processing time would be about the same for either computation.
- Because the least-cost criterion is more flexible, this is more common than the minimum-hop criterion.
- Several least-cost routing algorithms are in common use.

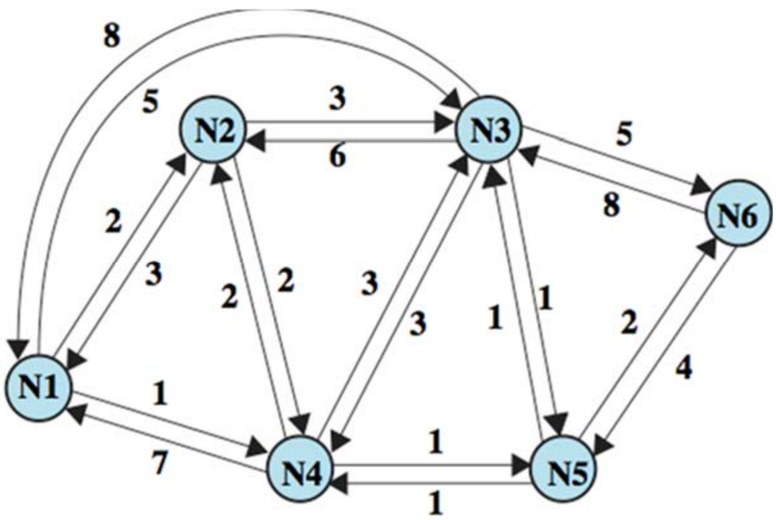
Link cost concept:



- Figure illustrates a network in which the two arrowed lines between a pair of nodes represent a link between these nodes, and the corresponding numbers represent the current link cost in each direction.
- The shortest path (fewest hops) from node 1 to node 6 is 1-3-6 (cost = 5 + 5 = 10),



- but the least-cost path is 1-4-5-6 (cost = 1 + 1 + 2 = 4).
- Costs are assigned to links to support one or more design objectives.



What is cost?

- cost could be inversely related to the data rate (i.e., the higher the data rate on a link, the lower the assigned cost of the link)
- the current queuing delay on the link.

- In the first case, the least-cost route should provide the highest throughput.
- In the second case, the least-cost route should minimize delay.

The Decision

- Routing decisions are made on the basis of some performance criterion.
- Two key characteristics of the decision are the
  - **time**
  - **Place**

Decision time?

- time is determined by whether the routing decision is made on a packet or virtual circuit basis.
- For datagram, a routing decision is made individually for each packet
- virtual circuit operation, a routing decision is made at the time the virtual circuit is established, so all subsequent packets using that virtual circuit follow the same route

Decision place

- *refers to which node or nodes in the* network are responsible for the routing decision.

1. distributed routing (most common is), in which each node has the responsibility of selecting an output link for routing packets as they arrive

   <u>Dis/advantage: (more complex but is also more robust.).</u>

2. centralized routing, the decision is made by some designated node, such as a network control center.

   <u>Dis/advantage(the loss of the network control center may block operation of the network.)</u>

3. source routing, decision made by the source station then communicated to the network. This allows the user to dictate a route through the network that meets criteria local to that user

Network information source and updating time

Now we can understand that, Routing decision based on

- knowledge of the topology of the network,
- traffic load,
- link cost.

- Information update timing, is a function of both the information source and the routing strategy
- the more information available, and the more frequently it is updated, the more likely the network is to make good routing decisions.
- On the other hand, the transmission of that information consumes network resources.

- For distributed routing:
  – the individual uses of only local information, such as the cost of each outgoing link.
  – Each node might also collect information from adjacent (directly connected) nodes, such as the amount of congestion experienced at that node.
  – A common algorithm is used to allow the node to gain information from all nodes on any potential route of interest.

- For central routing
  – the central node typically makes use of information obtained from all nodes.

Routing strategies

- Fixed routing
- Flooding
- Random
- Adaptive

1. Fixed routing (least cost)

- permanent route is configured for each source-destination pair of nodes in the network, using least-cost routing algorithms
- The routes are fixed, or at least only change when there is a change in the topology of the network.

Concerns

- The link costs used in designing routes cannot be based on any dynamic variable such as traffic.
- So route is based on the expected traffic or capacity.

- no difference between routing for datagrams and virtual circuits, all packets from a given source to a given destination follow the same route.

Advantage

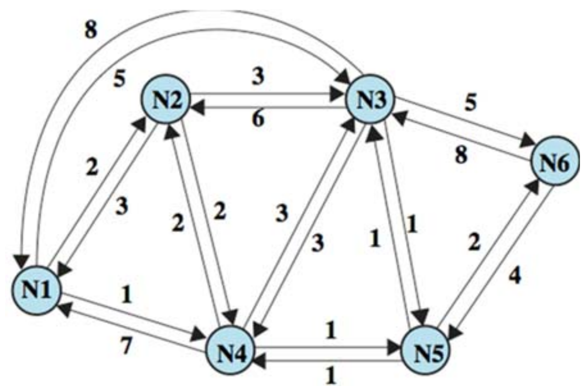
- simplicity,
- reliable network with a stable load.

disadvantage

- lack of flexibility.
- It does not react to network congestion or failures.

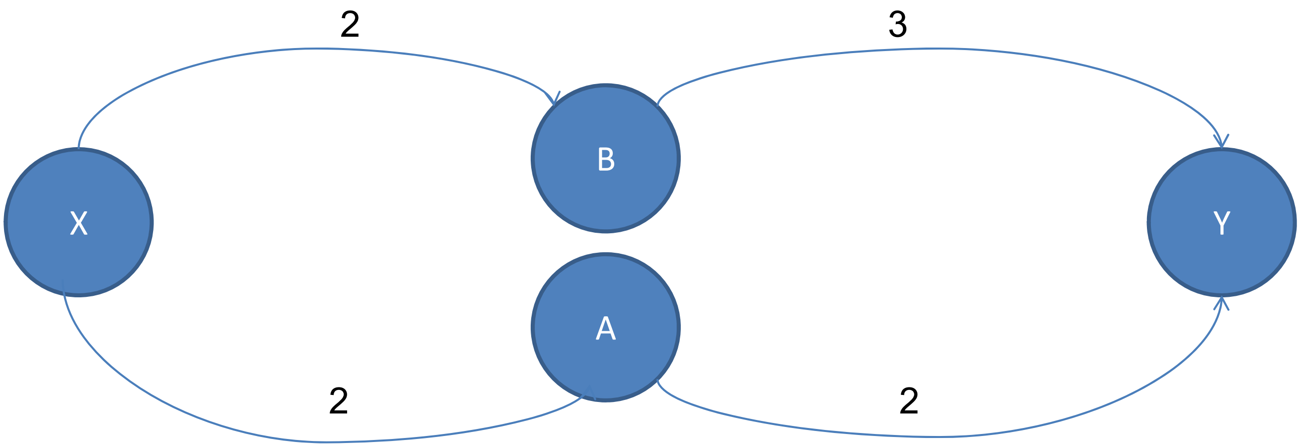
Build Fixed Routing Tables

- A central routing matrix is created, to be stored perhaps at a network control center.
- The matrix shows, for each source-destination pair of nodes, the next node on the route.
- Note that it is not necessary to store the complete route for each possible pair of nodes.
- Rather, it is sufficient to know, for each pair of nodes, the identity of the first node on the route.

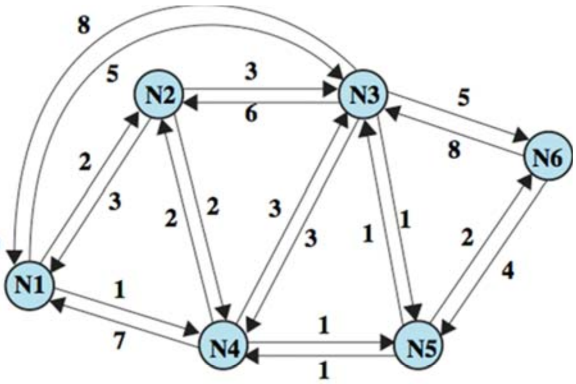


algorithm

- suppose that the least-cost route from *X to Y begins with the X-A link or A-B*
- *To decide the next hub for the route X-Y calculate the wait for the whole route, the next hub of the least cost route is selected*



- it is only necessary to know the identity of the next node, not the entire



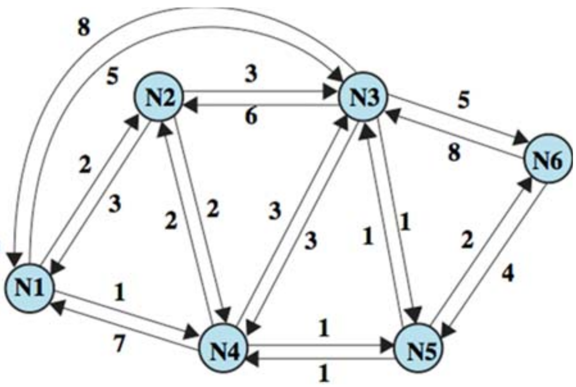
- In our example, the route from node 1 to node 6 begins by going through node 4.
- Again consulting the matrix, the route from node 4 to node 6 goes
- through node 5.
- Finally, the route from node 5 to node 6 is a direct link to node 6.
- Thus, the complete route from node 1 to node 6 is 1-4-5-6.
- From this overall matrix, routing tables can be developed and stored at each node.

Node 1 Directory

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Directory

Destination	Next Node
1	1
3	3
4	4
5	4
6	4



- From the reasoning in the preceding paragraph, it follows that each node need only store a single column of the routing directory.
- The node's directory shows the next node to take for each destination.

Node 3 Directory

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Directory

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

Node 5 Directory

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

Node 6 Directory

Destination	Next Node
1	5
2	5
3	5
4	5
5	5

CENTRAL ROUTING DIRECTORY

To Node \ From Node	1	2	3	4	5	6
1	—	1	5	2	4	5
2	2	—	5	2	4	5
3	4	3	—	5	3	5
4	4	4	5	—	4	5
5	4	4	5	5	—	5
6	4	4	5	5	6	—

Node 1 Directory

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Directory

Destination	Next Node
1	1
3	3
4	4
5	4
6	4

Node 3 Directory

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Directory

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

Node 5 Directory

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

Node 6 Directory

Destination	Next Node
1	5
2	5
3	5
4	5
5	5

2. **Flooding (number of hubs)**

- This technique requires no network information whatsoever and works as follows.
- A packet is sent by a source node to every one of its neighbors.
- At each node, an incoming packet is retransmitted on all outgoing links except for the link on which it arrived.
- Eventually, a number of copies of the packet will arrive at the destination.
- The packet must have some unique identifier (e.g., source node and sequence number, or virtual circuit number and sequence number) so that the destination knows to discard all but the first copy.

Problem:

retransmission of packets, the number of packets in circulation just from a single source packet grows without bound.

Solution

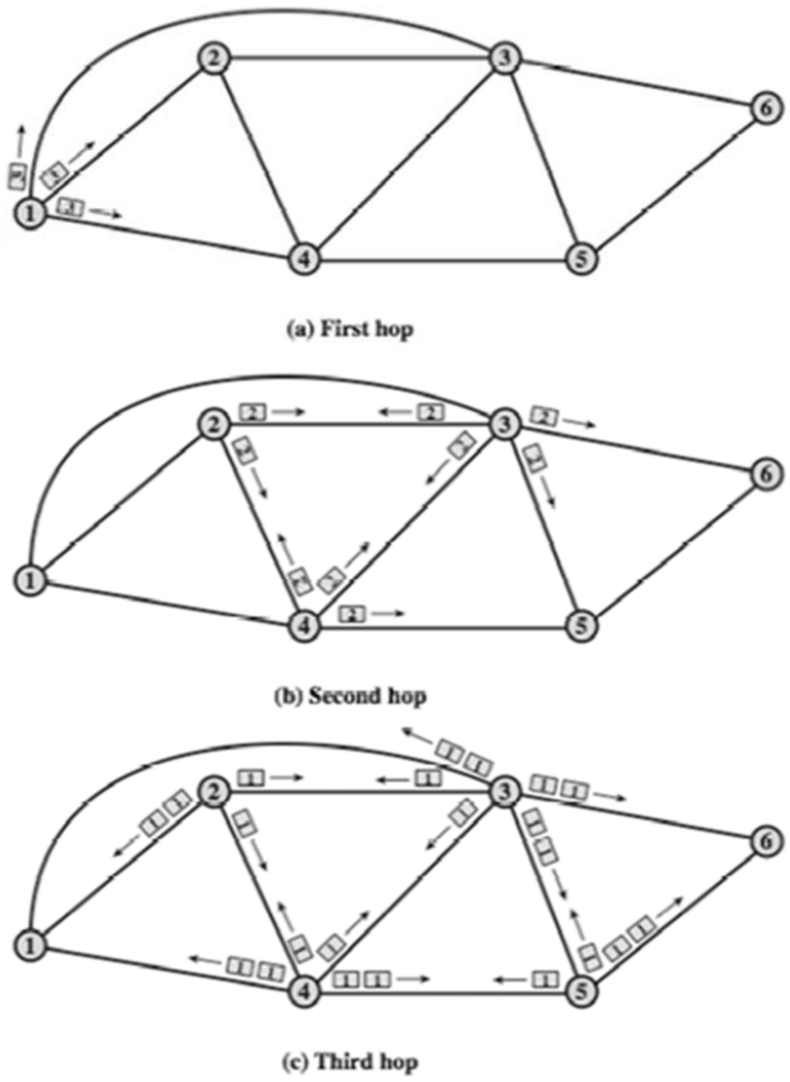
1. To prevent this each node remembers the identity of those packets it has already retransmitted.

   When duplicate copies of the packet arrive, they are discarded.

2. Is to include a hop count field with each packet.

   The count can originally be set to some maximum value, such as the diameter, (length of the longest minimum-hop path through the network) of the network.

- The label on each packet in the figure indicates the current value of the hop count field in that packet.
- A packet is to be sent from node 1 to node 6 and is assigned a hop count of (3) longest minimum-hop path.
- On the first hop, three copies of the packet are created, and the hop count is decrement to 2.

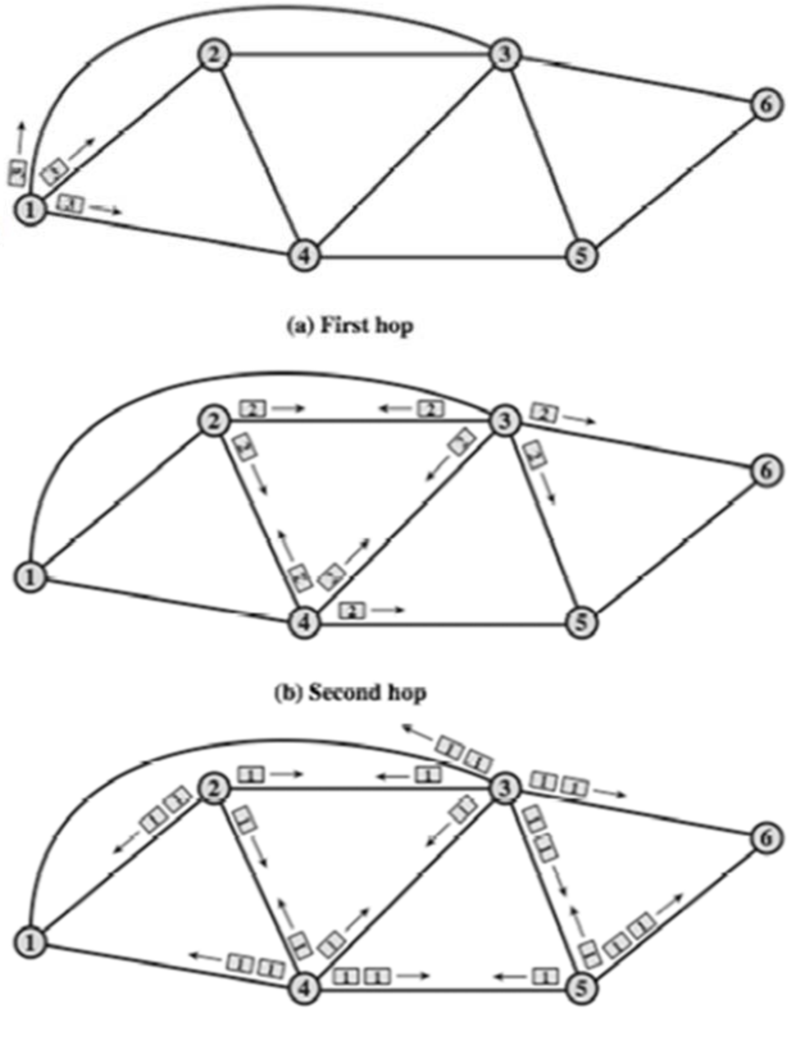


(a) First hop

(b) Second hop

(c) Third hop

- For the second hop of all these copies, a total of nine copies are created.
- One of these copies reaches node 6, which recognizes that it is the intended destination and does not retransmit.

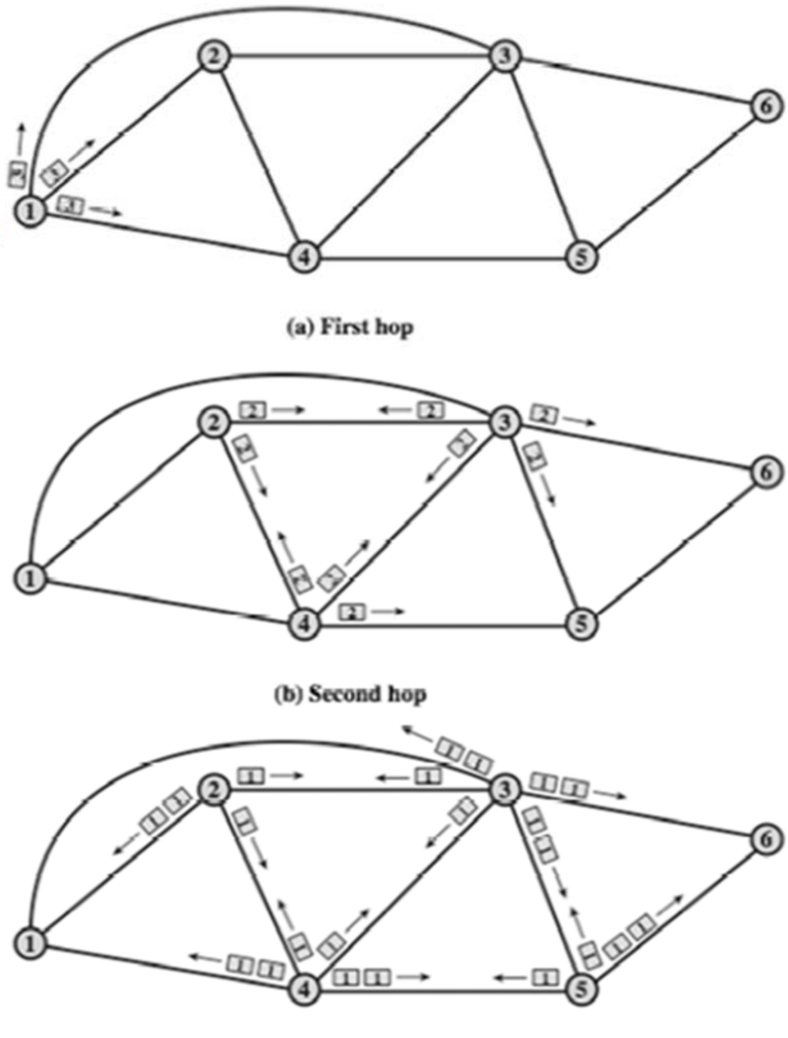


(a) First hop

(b) Second hop

(c) Third hop

- However, the other nodes generate a total of 22 new copies for their third and final hop.
- Each packet now has a hope count of 1.
- Note that if a node is not keeping track of packet identifier, it may generate multiple copies at this third stage.



(a) First hop

(b) Second hop

(c) Third hop

The flooding technique properties:

- All possible routes between source and destination are tried. Thus, no matter what link or node outages have occurred, a packet will always get through if at least one path between source and destination exists
- Because all routes are tried, at least one copy of the packet to arrive at the destination will have used a minimum-hop route.
- All nodes that are directly or indirectly connected to the source node are visited.

Flooding technique advantages & applications

highly robust and could be used to send emergency messages.

1. Example is a military network that is subject to extensive damage.
2. flooding might be used initially to set up the route for a virtual circuit.
3. flooding can be useful for the dissemination of important information to all nodes; used in some schemes to disseminate routing information.

Flooding technique disadvantages

- high traffic load that it generates, which is directly proportional to the connectivity of the network.

Thanks,…