Switching techniques

Traditionally the telephonic system is based on circuit switching; is the main infrastructure for communications (computer) networks => the switching term remains.

Switching techniques used in information transfer are:

-circuit switching

-message switching

-packet switching

Circuit switching

Physical path between communicating parts, achieved using circuit switching –switches (relays)-in the networks nodes.

Three phase communication:

-circuit establishment (setup), establish a (optimum) path between parts; both parts agree communication

-effective data transmission (signal transfer), on this route

-circuit release (disconnection); initiative of one part.

Drawbacks:

-not efficient due to existence of the first phase (it will exist even if there's no data transfer)

-need for covering bandwidth allocation

-important amount of cabling

-no buffers in switches for transmission equalization

Today use of digital **PBX** (Private Branch Exchange)

First circuit-switching: space-division switching (separated signal paths – divided in space): crossbar matrix of I/O full duplex lines
An improvement: multiple-stage switches
Today all telephony: digital time-division techniques (synchronous TDM)
Signaling in digital telephony:
-inchannel
    -in-band: signals using the same band as the voice channel (as payload)
    -out-band: (voice signals do not use whole 4kHz bandwidth)
-common channel – a common signal channel for a number of voice channels
Signaling may use the same (or not) path as the payload (associated/nonassociated modes)
What's signaling? **Signal = control** Examples:
    -connection setup request = off-hook signal from telephone to switch
    -connection setup acknowledge = dial tone
    -destination address = pulse or tone dialing
    -destination busy = busy tone
    -destination available = ringing tone
Other signaling functions: transmission of: dialed number between switches, information about a call not completed, about billing, diagnose and failure isolation

Message switching

Data transfer using **messages** (independent data units, with diff. lengths but similar structures). Types: control and data (embedding control)

Need for addressing (source & destination of message)

Communications nodes are not physical switches, but computing systems (with memory and processing units).

Philosophy is: message *store & forward* .

Not more dedicated communications path; established in an optimum way (cost, network status) by nodes (using routing tables).

Advantages:

-improvement in efficiency (path multiplexing)

-introduces message priority

-equilibrated transmissions.

Drawbacks:

-messages are too long, memory waste and difficult error recovery

Packet switching

Combines the advantages of previous methods. The **packet** has similar message structure but a lower length, up to 1000octets.

Two methods:

-use of **datagrams** (close to message switching)-more speedy and flexible method

-use or not of transmission acknowledgments (ACK)

-use of **virtual circuits** (close to circuit switching)-use of the three phases (connection request, data transfer, disconnect) for a logical connection activation; use of special control packets for that. Also embedding of control information (piggybacking).

A logical connection may be implemented with more different physical connections.

Routing in packet-switching networks

Circuit switching vs. Packet switching

Most of WANs based on circuit or packet switching

Circuit switching designed for voice

- Resources dedicated to a particular call
- Much of the time a data connection is idle
- Data rate is fixed
  - Both ends must operate at the same rate

Packet switching - Basic Operation

Data transmitted in small packets

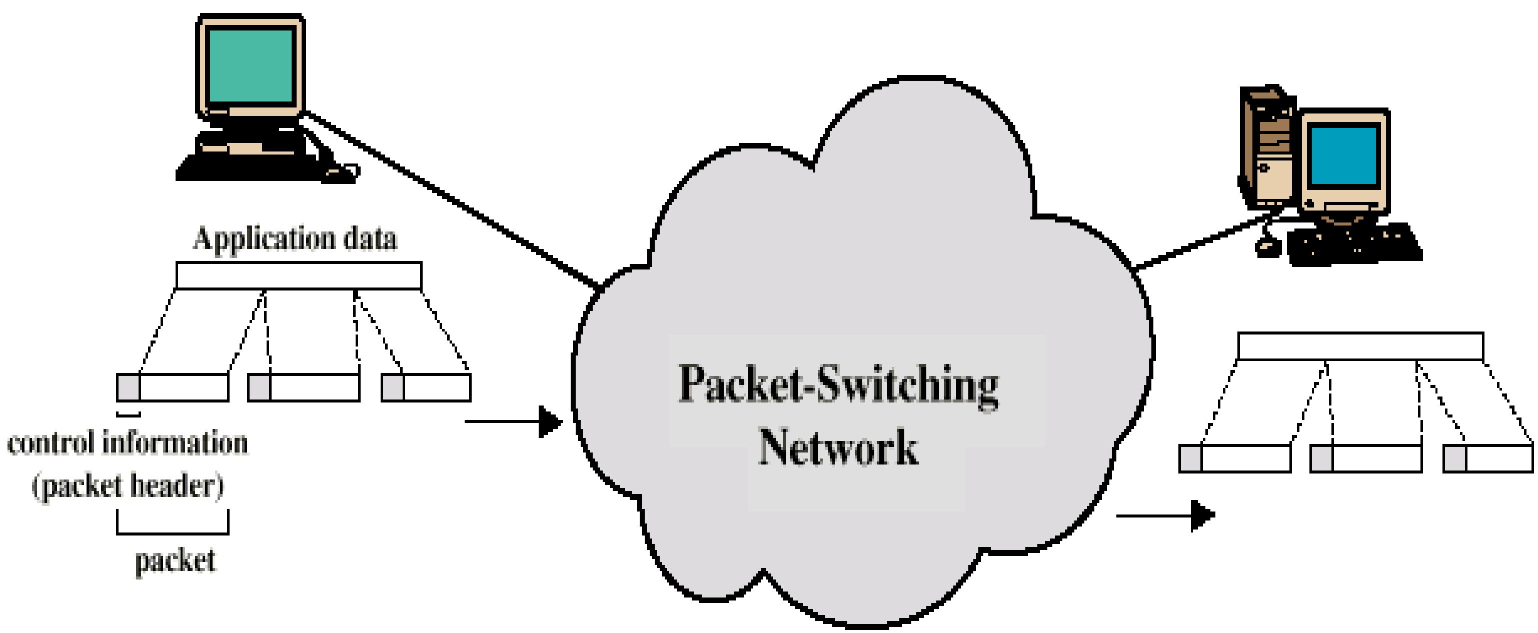
- Typically 1000 octets
- Longer messages split into series of packets
- Each packet contains a portion of user data plus some control info

Use of **Control info**

- Routing (addressing) info

Packets are received, stored briefly (buffered) and past on to the next node

- Store and forward



Advantages of packet switching

Line efficiency

- Single node to node link can be shared by many packets over time
- Packets queued and transmitted as fast as possible

Data rate conversion

- Each station connects to the local node at its own speed
- Nodes buffer data if required to equalize rates

Packets are accepted even when network is busy

- Delivery may slow down

Priorities can be used

Packet Switching Technique

Station breaks long message into packets

Packets sent one at a time to the network

Packets handled in two ways: **Datagram** or **Virtual circuit**

Virtual Circuits v Datagram

Virtual circuits

- Network can provide sequencing and error control
- Packets are forwarded more quickly
  - No routing decisions to make
- Less reliable
  - Loss of a node looses all circuits through that node

Datagram

- No call setup phase
  - Better if few packets
- More flexible
  - Routing can be used to avoid congested parts of the network
- Use of variant with acknowledgements

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Comparison of datagrams & virtual-circuit subnets

Network's External and Internal Operation

Interface between station and network node

- **Connection oriented**
  - Station requests logical connection (virtual circuit)
  - All packets identified as belonging to that connection & sequentially numbered
  - Network delivers packets in sequence
  - External virtual circuit service
  - e.g. X.25
  - Different from internal virtual circuit operation
- **Connectionless**
  - Packets handled independently
  - External datagram service
  - Different from internal datagram operation

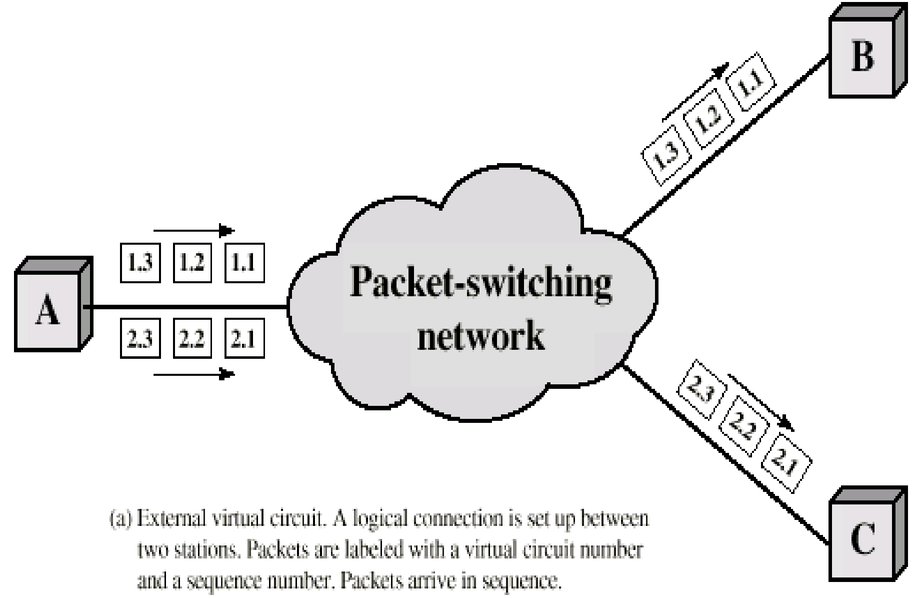
Combinations

External virtual circuit, internal virtual circuit

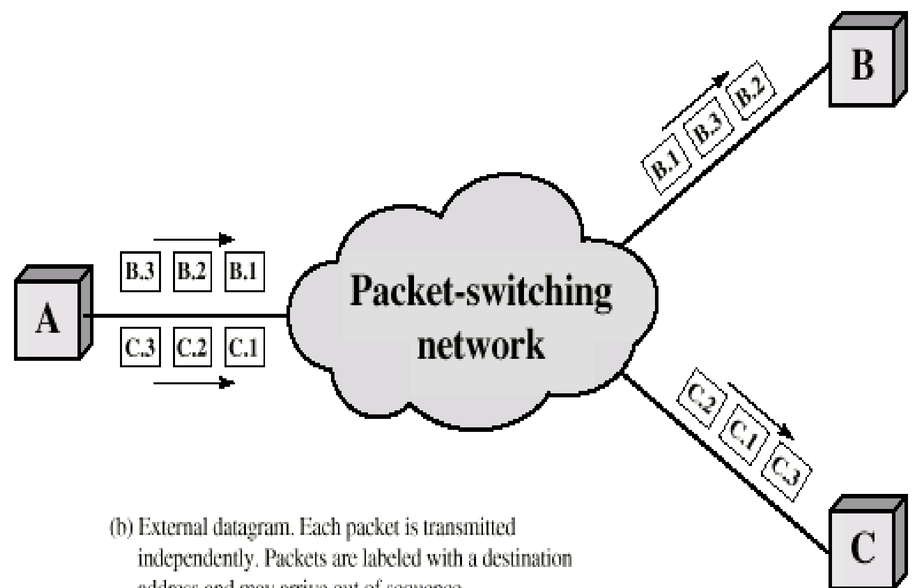
- Dedicated route through network

External virtual circuit, internal datagram

- Network handles each packet separately
- Different packets for the same external virtual circuit may take different internal routes
- Network buffers at destination node for re-ordering



(a) External virtual circuit. A logical connection is set up between two stations. Packets are labeled with a virtual circuit number and a sequence number. Packets arrive in sequence.



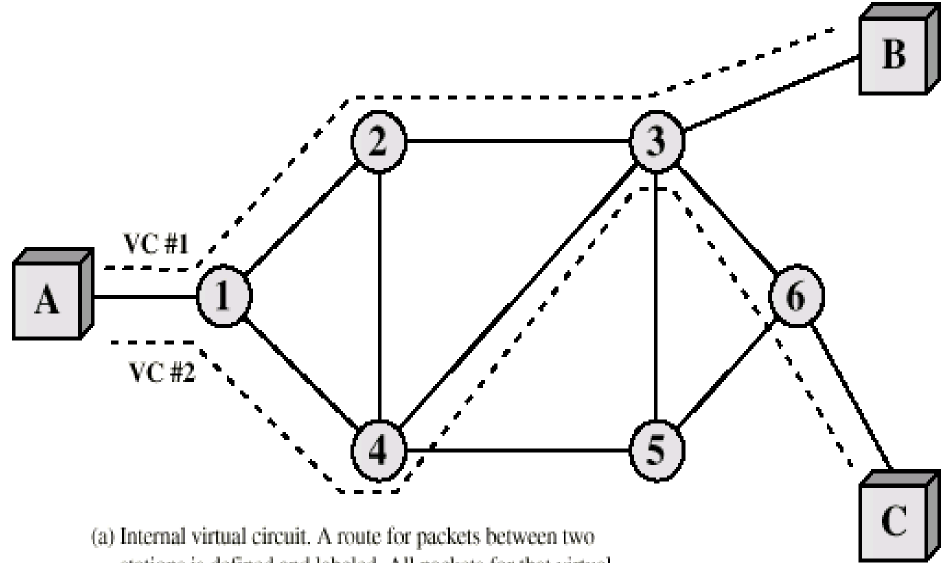
(b) External datagram. Each packet is transmitted independently. Packets are labeled with a destination address and may arrive out of sequence.

External datagram, internal datagram

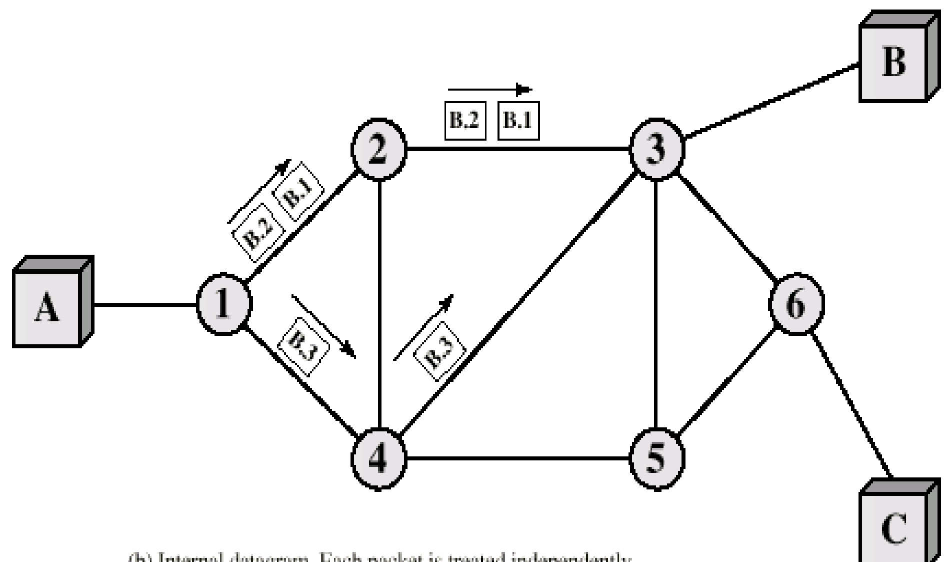
- Packets treated independently by both network and user

External datagram, internal virtual circuit

- External user does not see any connections
- External user sends one packet at a time
- Network sets up logical connections



(a) Internal virtual circuit. A route for packets between two stations is defined and labeled. All packets for that virtual circuit follow the same route and arrive in the same sequence.



(b) Internal datagram. Each packet is treated independently by the network. Packets are labeled with a destination address and may arrive at the destination node out of sequence.

Routing

Complex, crucial aspect of packet switched networks

Characteristics required

- Correctness
- Simplicity
- Robustness
- Stability
- Fairness
- Optimality
- Efficiency

Performance Criteria

Used for selection of route

Minimum hop

Least cost algorithms (shortest path)

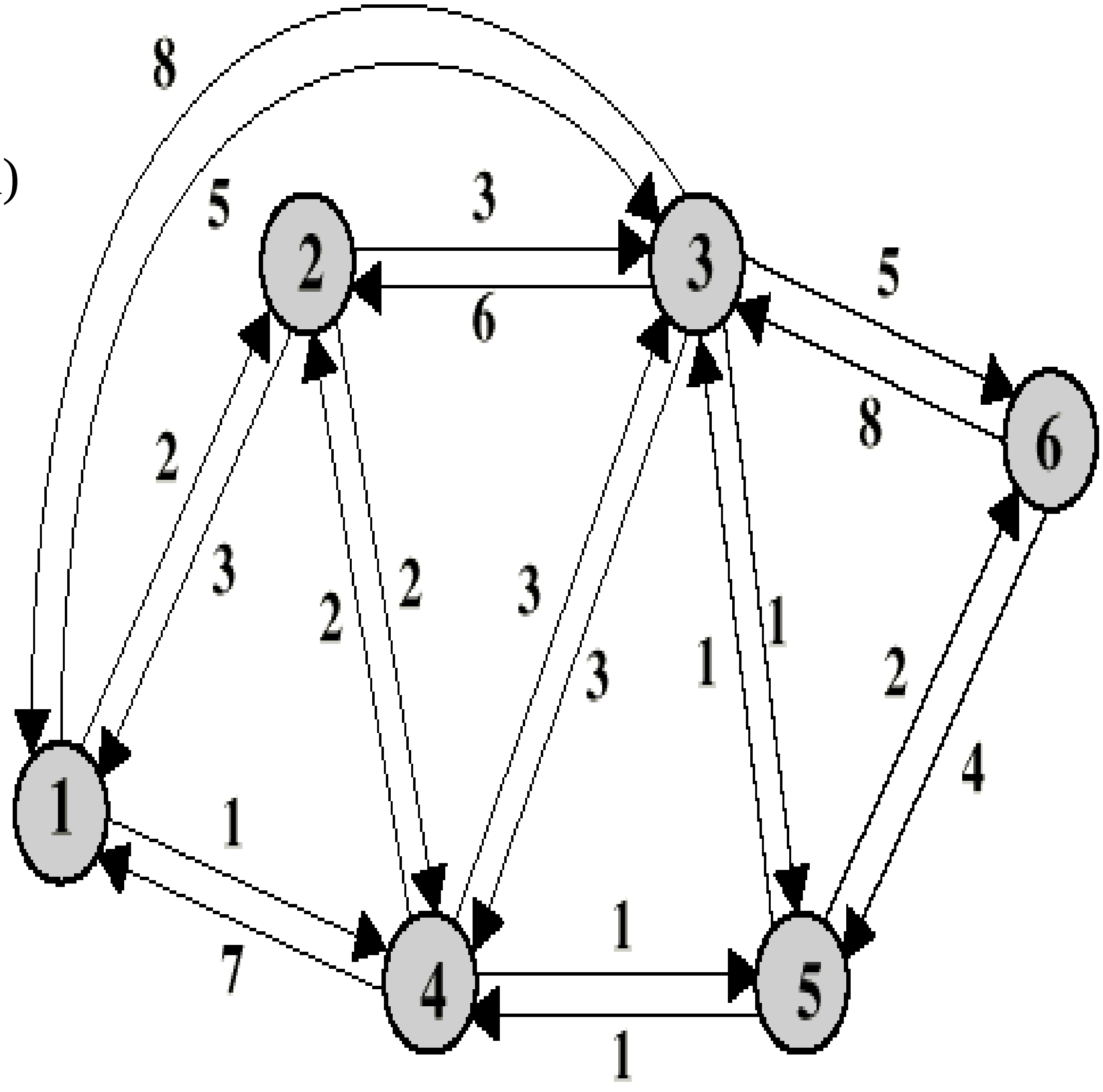
Dijkstra’s Algorithm

Implemented in link state packet

routing algorithms

Bellman-Ford algorithm

Used by distance vector based



Routing: Decision Time and Place

Time

On packet or virtual circuit basis

Place

Distributed routing

Made by each node

Centralized routing

Source-based routing

Network Information Source and Update Timing

Routing decisions usually based on knowledge of network (not always)

Distributed routing

Nodes use local knowledge

May collect info from adjacent nodes

May collect info from all nodes on a potential route

Central routing

Collect info from all nodes

Update timing

When is network info held by nodes updated

Fixed - never updated

Adaptive - regular updates

Routing Strategies

Fixed

Flooding

Random

Adaptive

Fixed Routing

Single permanent route for each source to destination pair

Determine routes using a *least cost algorithm*

Route fixed, at least until a change in network topology

CENTRAL ROUTING DIRECTORY

From Node

To 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

Flooding

No network info required

Packet sent by node to every neighbor

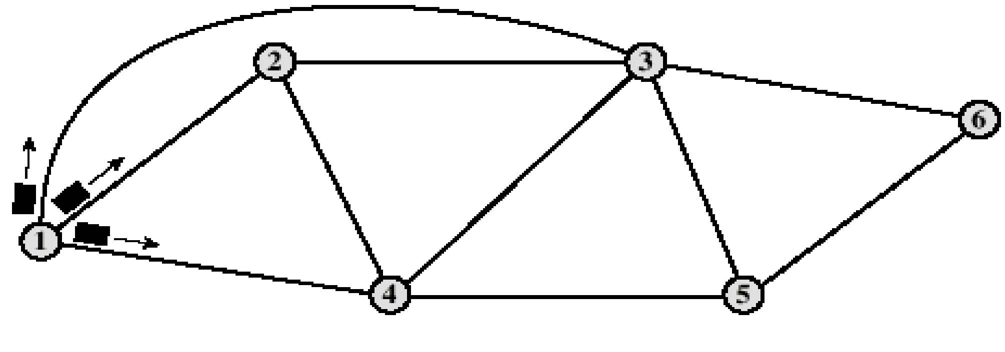
Incoming packets retransmitted on every link except incoming link

Eventually a number of copies will arrive at destination

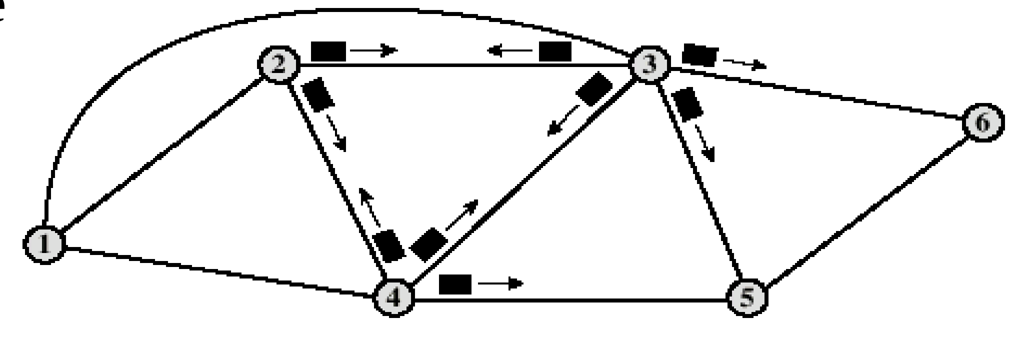
Each packet is uniquely numbered so duplicates can be discarded

Nodes can remember packets already forwarded to keep network load in bounds

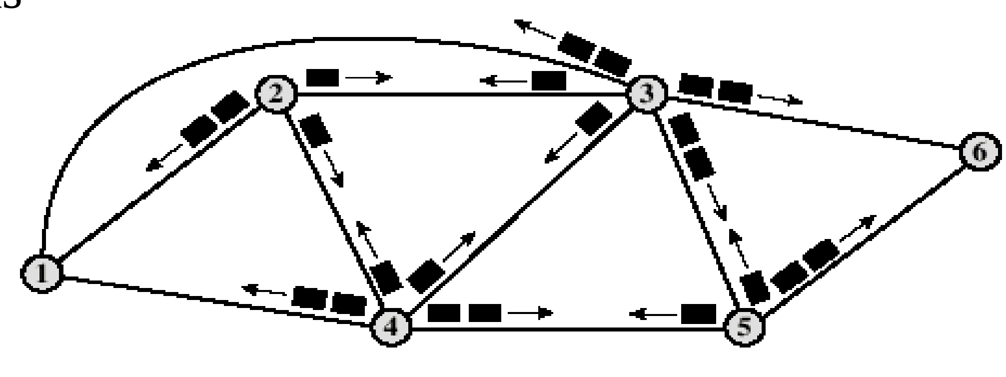
Can include a hop count in packets



(a) First hop



(b) Second hop



(c) Third hop

Properties of Flooding

All possible routes are tried

- Very robust

At least one packet will have taken minimum hop count route

- Can be used to set up virtual circuit

All nodes are visited

- Useful to distribute information (e.g. routing)

Random Routing

Node selects one outgoing path for retransmission of incoming packet

Selection can be random or round robin

Can select outgoing path based on probability calculation

No network info needed

Route is typically not least cost nor minimum hop

Adaptive Routing

Used by almost all packet switching networks

Routing decisions change as conditions on the network change

- Failure
- Congestion

Requires info about network

Decisions more complex

Tradeoff between quality of network info and overhead

Advantages

Improved performance

Aid congestion control

Complex system

- May not realize theoretical benefits

Classification

Based on information sources for network state

- **Local** (isolated)
  - Route to outgoing link with shortest queue
  - Can include bias for each destination
  - Rarely used - do not make use of easily available info
- **Adjacent** nodes – select information based on the neighbour’s experience (network delays or outages)
- **All** nodes – used for source based routing