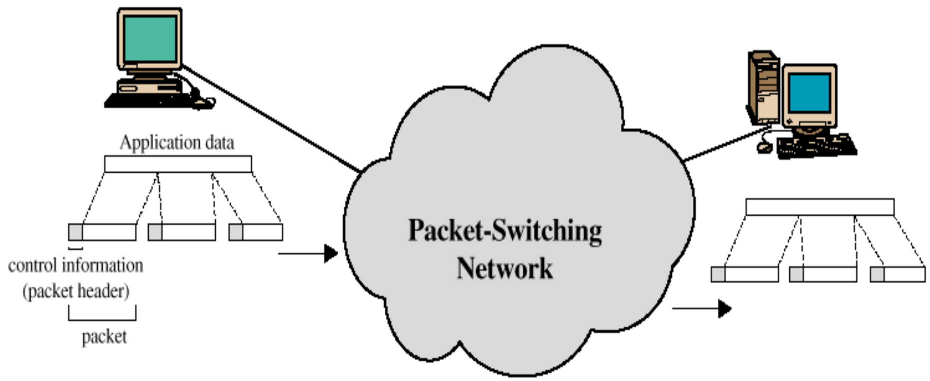
Packet Switching



Around 1970, research began on a new form of architecture for long distance communications: Packet Switching.

Introduction

- Packet Switching refers to protocols in which messages are divided into packets before they are sent. Each packet is then transmitted individually and can even follow different routes to its destination. Once all the packets forming a message arrive at the destination, they are recompiled into the original message.

Packet Switching Operation

- Data are transmitted in short packets. Typically an upper bound on packet size is 1000 octets.
- If a station has a longer message to send it breaks it up into a series of small packets. Each packet now contains part of the user's data and some control information.
- The control information should at least contain:
  - Destination Address
  - Source Address
- Store and forward - Packets are received, stored briefly (buffered) and past on to the next node

Advantages

- 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

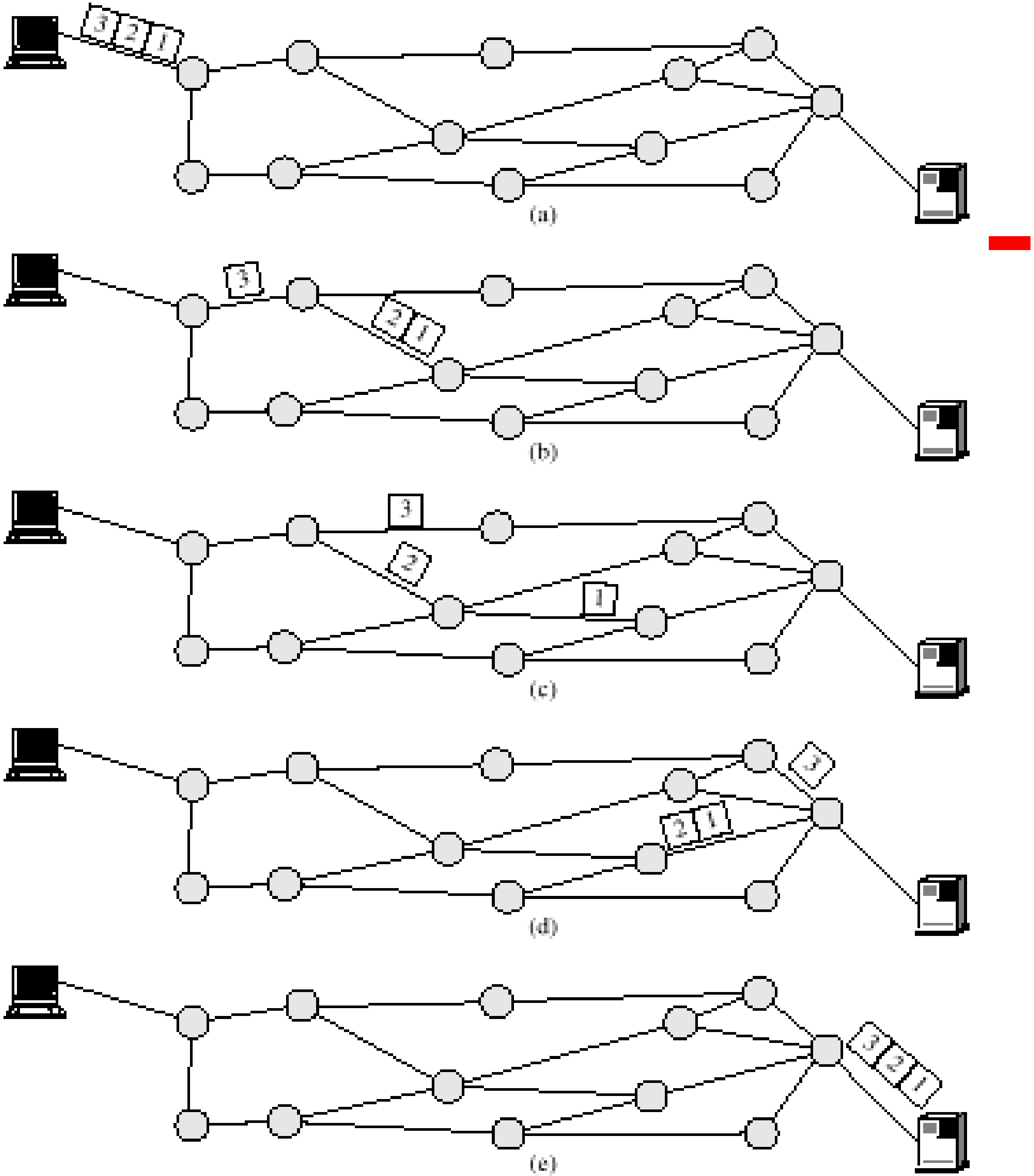
Switching Technique - Virtual Circuits and Datagrams

- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets handled in two ways
  - Datagram
  - Virtual circuit

Datagram Packet Switching

- In datagram approach each packet is treated independently with no reference to packets that have gone before. No connection is set up.
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets
- More processing time per packet per node
- Robust in the face of link or node failures.

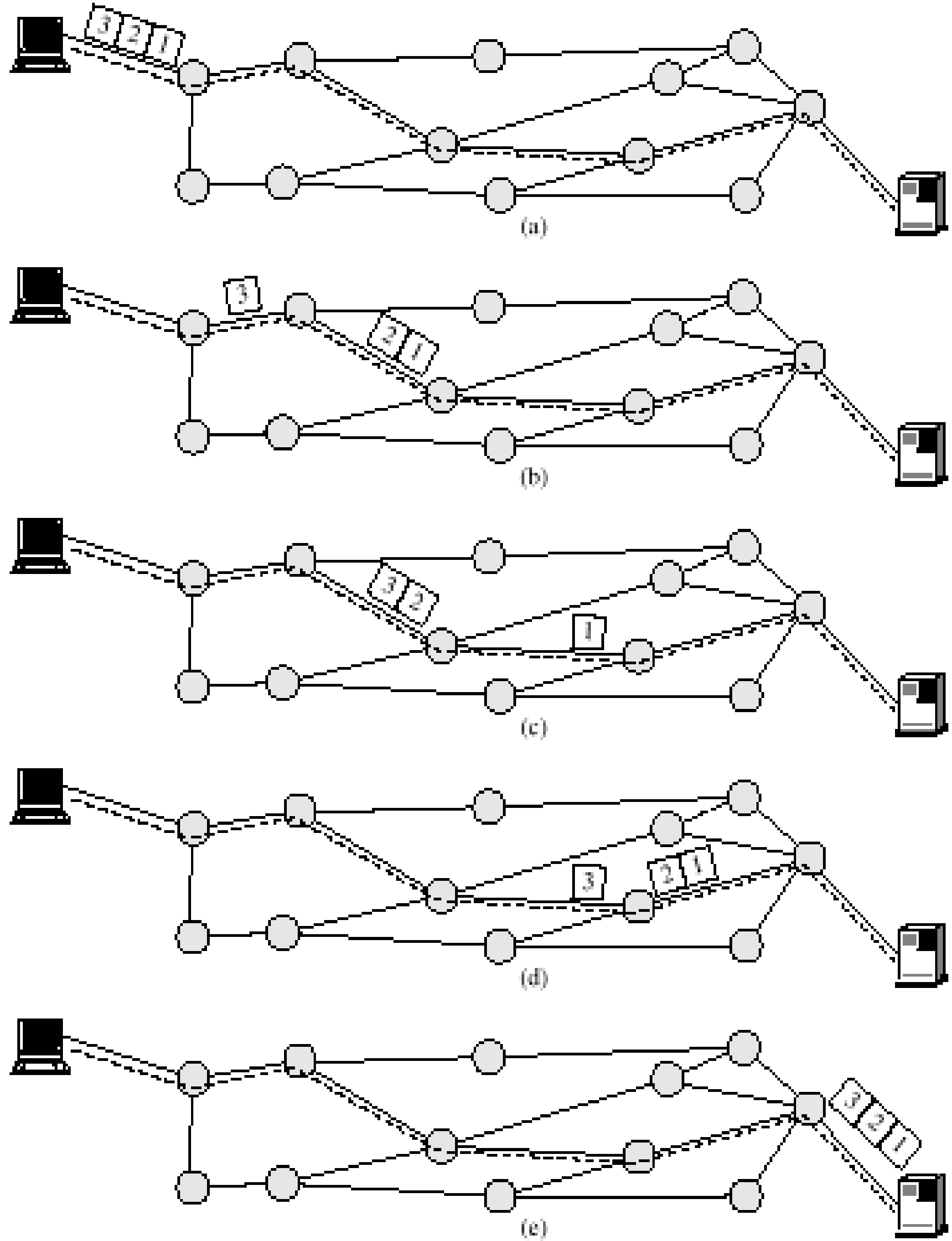
Packet Switching Datagram Approach



Virtual Circuit Packet Switching

- In the Virtual Circuit approach a pre-planned route is established before any packets are sent.
- There is a call set up before the exchange of data (handshake).
- All packets follow the same route and therefore arrive in sequence.
- Each packet contains a virtual circuit identifier instead of destination address
- More set up time
- No routing decisions required for each packet - Less routing or processing time
- Susceptible to data loss in the face of link or node failure
- Clear request to drop circuit
- Not a dedicated path

Packet Switching Virtual Circuit Approach



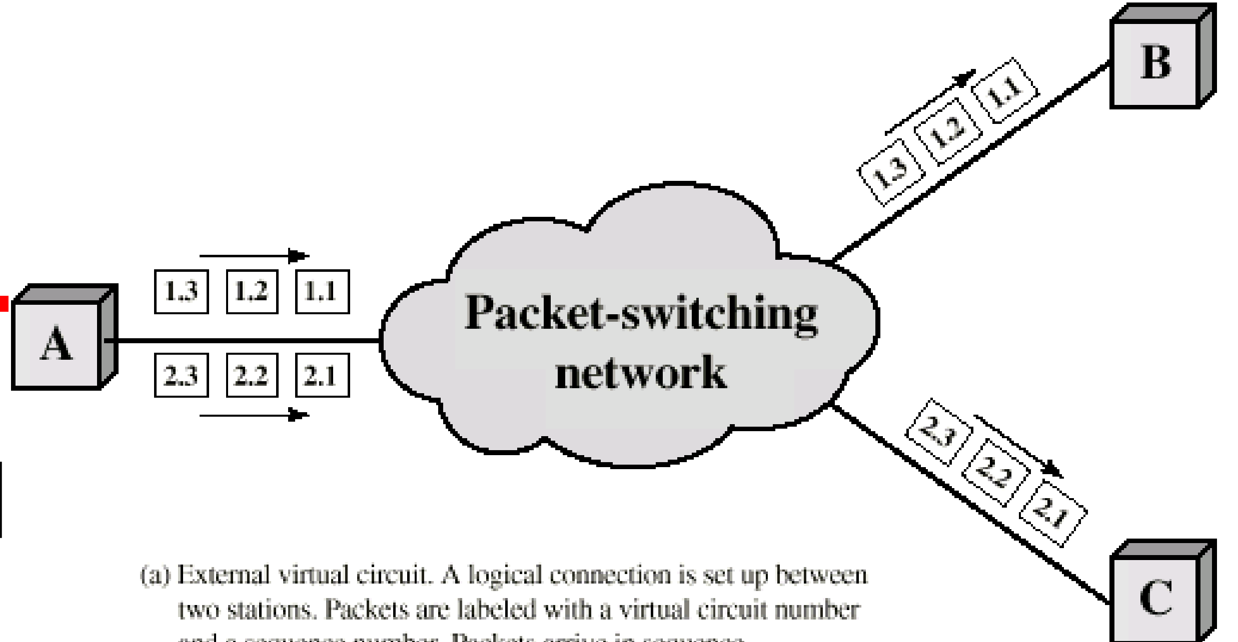
Virtual Circuits vs. Datagram

- 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

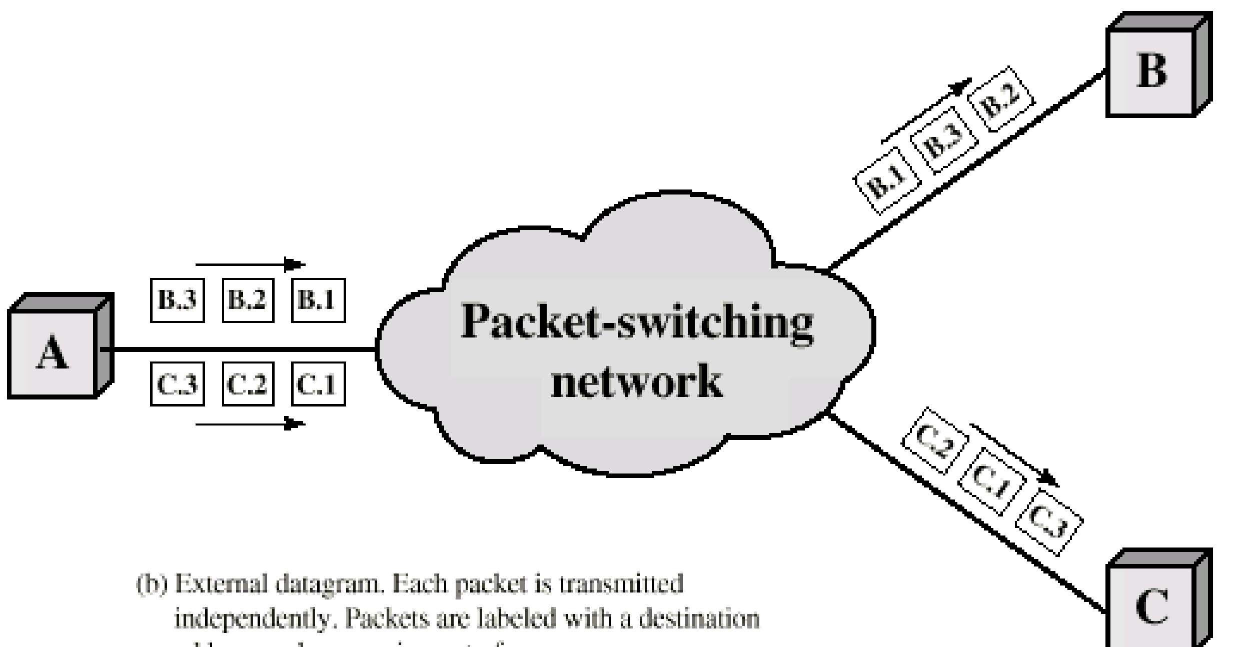
Packet switching - datagrams or virtual circuits

- 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

External Virtual Circuit and Datagram Operation

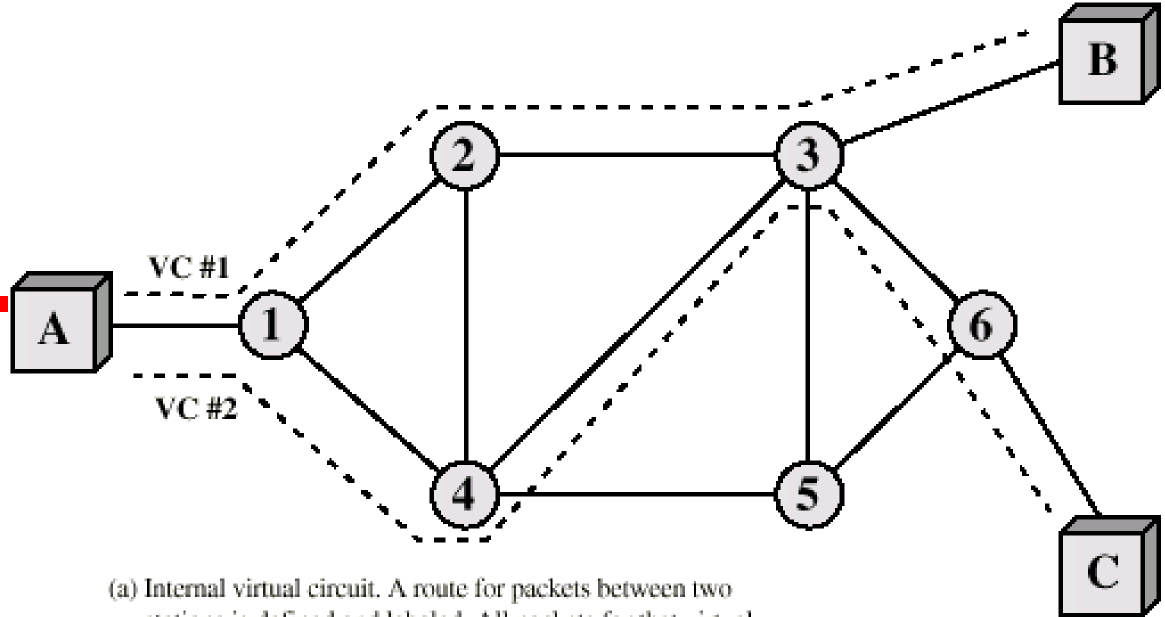


(a) External virtual circuit. A logical connection is set up between two stations. Packets are labeled with a virtual circuit number and a sequence number. Packets arrive in sequence.

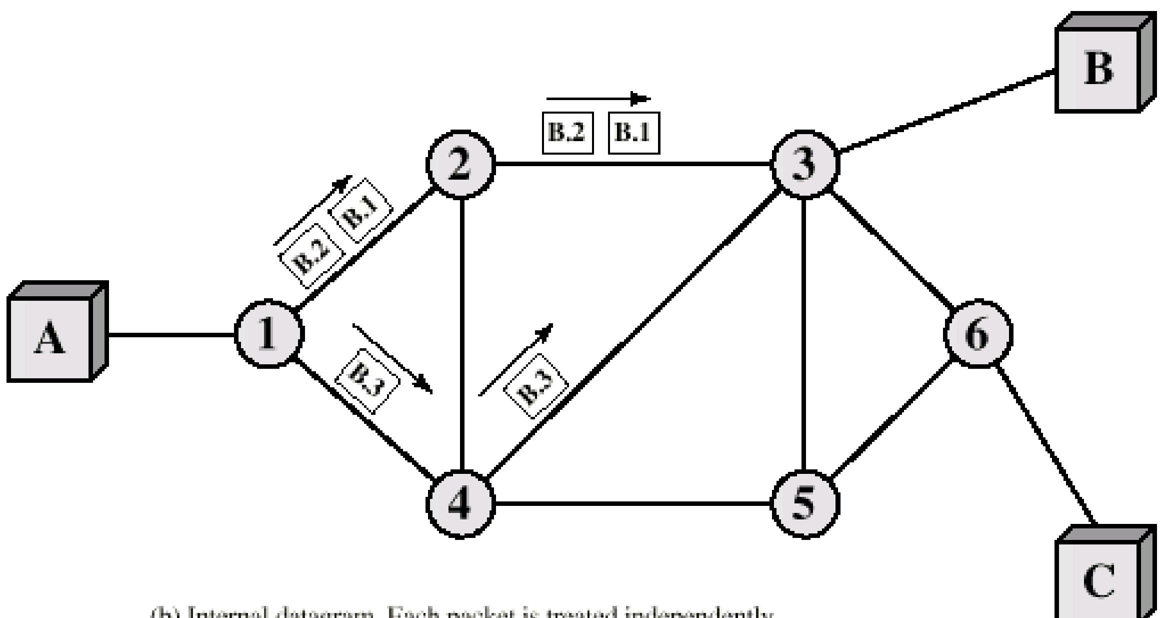


(b) External datagram. Each packet is transmitted independently. Packets are labeled with a destination address and may arrive out of sequence.

Internal Virtual Circuit and Datagram Operation



(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.

Circuit vs. Packet Switching

- Performance
  - Propagation delay
  - Transmission time
  - Node delay

Comparison with Circuit Switching - Event Timing

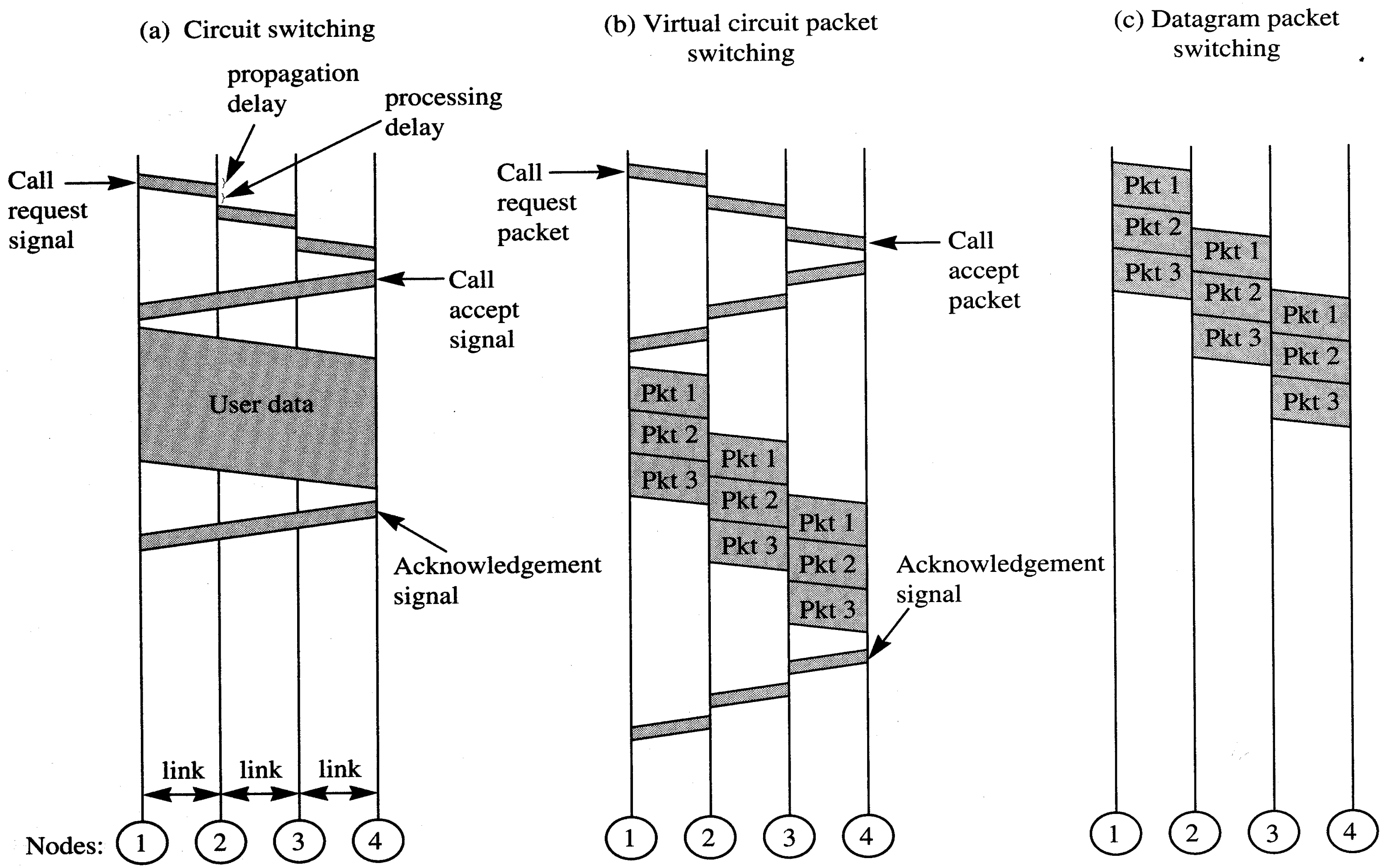


FIGURE 8.3. Event timing for circuit switching and packet switching.

Comparison with Circuit Switching

Item	Circuit-switched	Packet-switched
Dedicated "copper" path	Yes	No
Bandwidth available	Fixed	Dynamic
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Each packet follows the same route	Yes	No
Call setup	Required	Not needed
When can congestion occur	At setup time	On every packet
Charging	Per minute	Per packet

Routing

- Complex, crucial aspect of packet switched networks
- Characteristics required
  - Correctness
  - Simplicity
  - Stability
  - Fairness
  - Efficiency

Routing Performance Criteria

- Used for selection of route
- Minimum hop
- Least cost
  - Using some algorithm
- Delay
- Throughput

Routing Decision Time and Place

- Time
  - Packet basis
  - virtual circuit basis
- Place
  - Distributed
    - Made by each node
  - Centralized
  - Source (originating node)

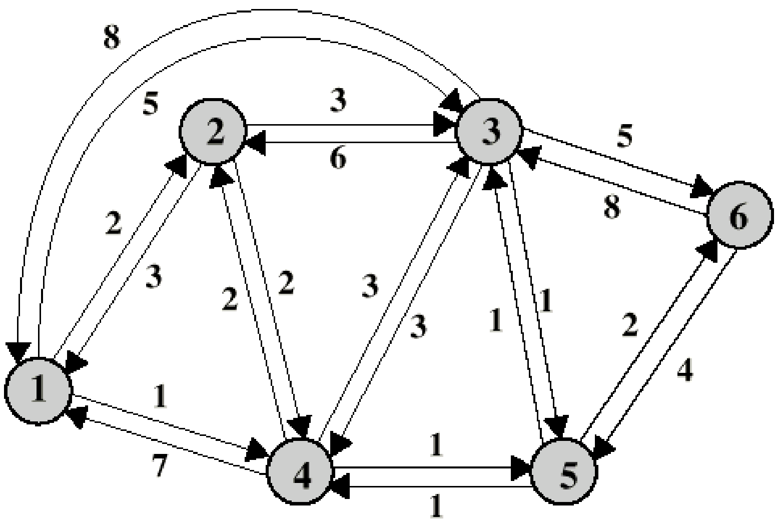
Fixed Routing

- 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

Fixed Routing Tables

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

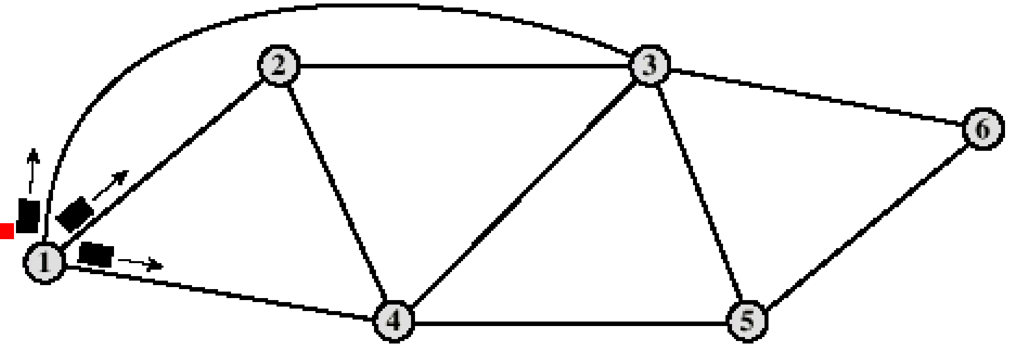
Node 6 Directory

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

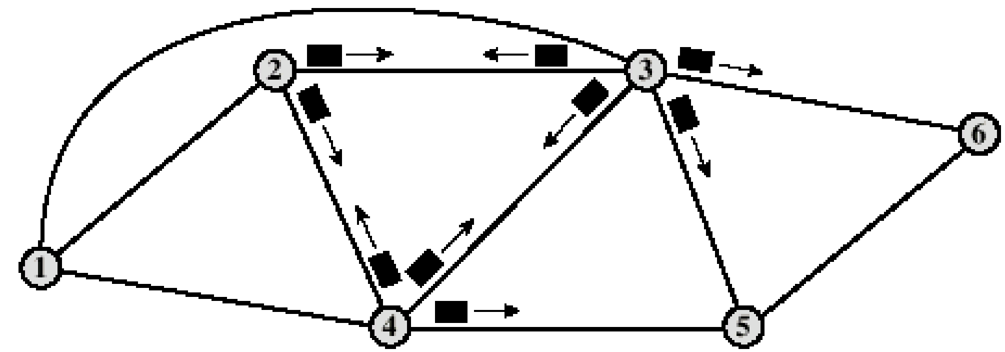
Flooding

- 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

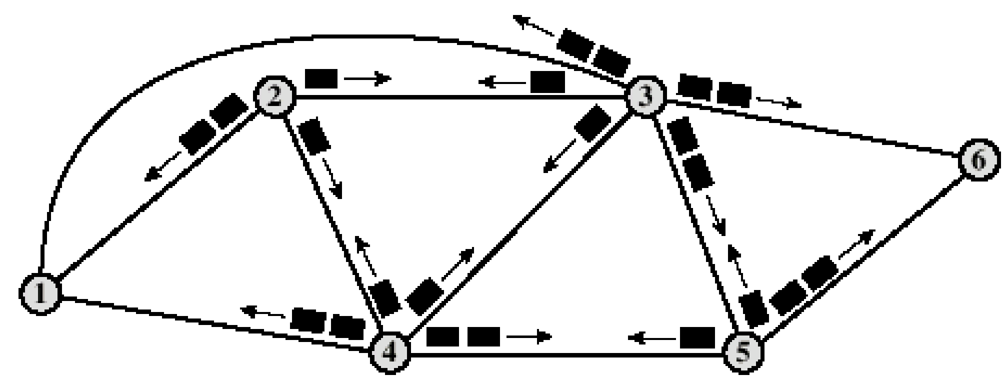
Flooding Example



(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
- Reacting too quickly can cause oscillation
- Too slowly to be relevant

Adaptive Routing - Advantages

- Improved performance
- Aid congestion control (See chapter 12)
- Complex system
  - May not realize theoretical benefits

Packet Switching Evolution

- X.25 packet-switched network
- Router-based networking
- Switching vs. routing
- Frame relay network
- ATM network

Switching vs Routing

- **Switching**
- path set up at connection time
- simple table look up
- table maintainance via signaling
- no out of sequence delivery
- lost path may lose connection
- much faster than pure routing
- link decision made ahead of time, and resources allocated then

- **Routing**
- can work as connectionless
- complex routing algorithm
- table maintainance via protocol
- out of sequence delivery likely
- robust: no connections lost
- significant processing delay
- output link decision based on packet header contents - at every node