Routing in Packet Switching

Lecture #7

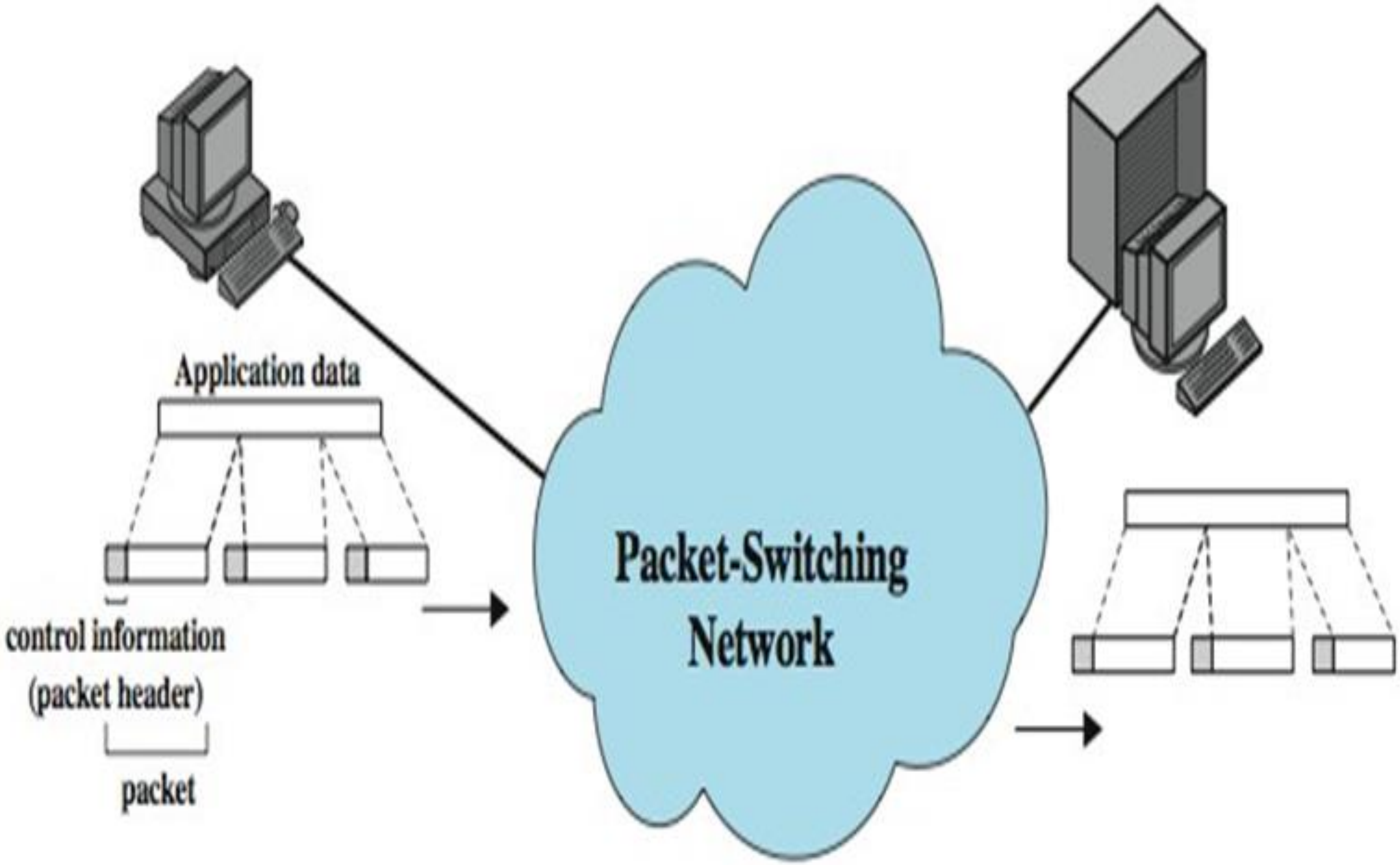
Agenda

- Packet Switching
- Routing Requirements
- Elements of Routing Techniques
- Fixed and Adaptive Routing

Packet Switching

- circuit switching designed for voice
- packet switching designed for data
- transmitted in small packets
  - packets contains user data and control info
  - user data may be part of a larger message
  - control information includes routing (addressing)
- packets are received, stored briefly (buffered) and passed on to the next node

Packet Switching



Packet Switching

- Advantages
  - Better line efficiency - shared by many
  - Can adjust data rates for different devices
  - Prioritization option - high priority packets first
- Disadvantages
  - Transmission delay in nodes - buffers & processing
  - Variable delays can cause jitter
  - Overhead for address and network status info

Packet Switching Techniques

- station breaks long message into packets
- packets sent one at a time to the network
- packets can be handled in two ways:
  - <u>datagram</u>
    - each packet is treated independently with no reference to previous packets
  - <u>virtual circuit</u>
    - a preplanned route is established before any packets are sent

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call	Overhead bits in each packet	Overhead bits in each packet

ROUTING TECHNIQUES

Routing Requirements

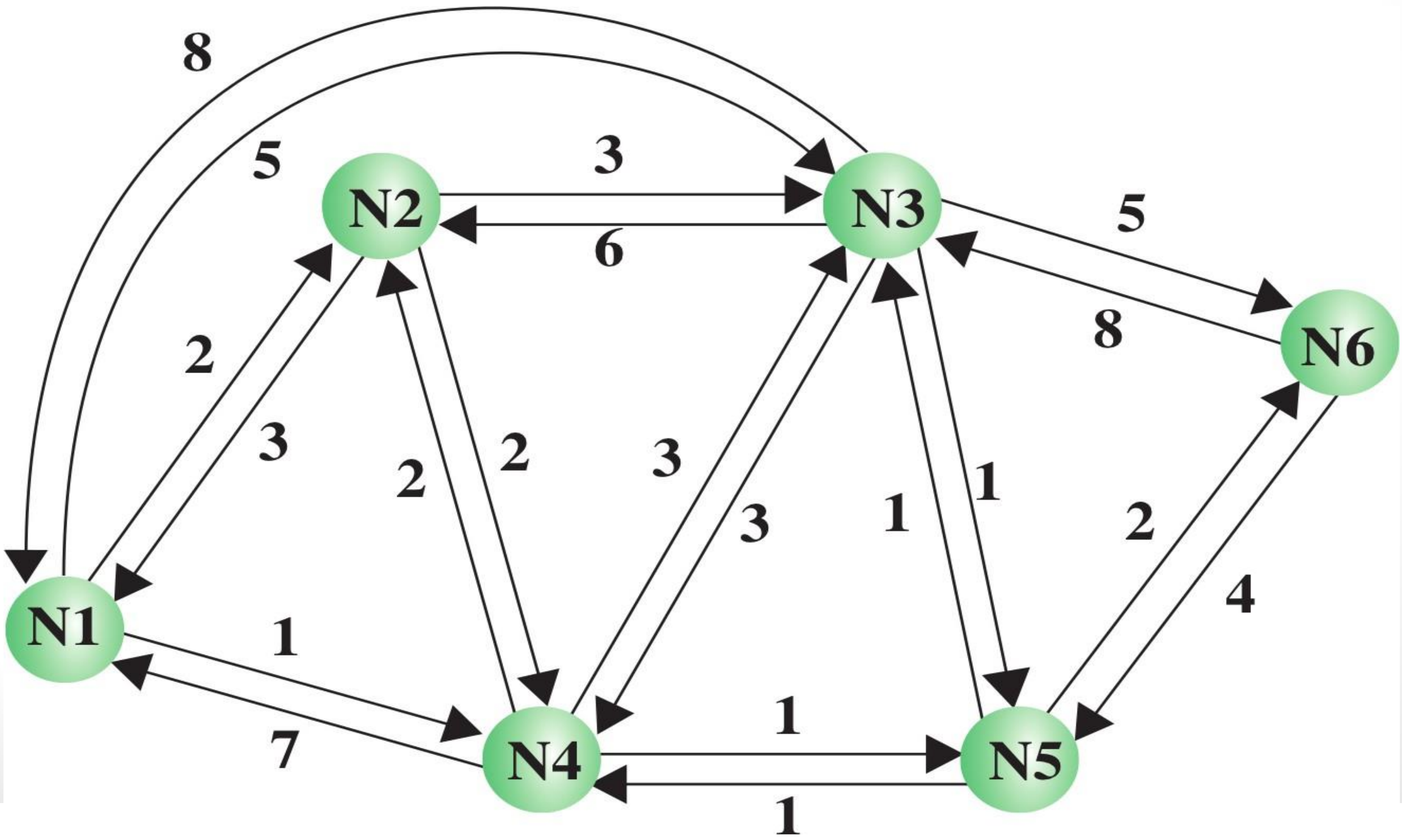
- Routing can be defined as the process of **moving** data **packets** from source to destination.
- It is usually performed by a **device** called a **router**.
- Routing function must have the following:
  - correctness- arrives the right destination
  - simplicity- overhead complexity and delay
  - robustness – overcome local failures / overloads
  - Stability – do not overload other areas to overcome failure
  - fairness – all transfers are important
  - Optimality – short paths
  - efficiency – routing functions require overhead

Performance Criteria

- used for selection of route
- simplest is to choose "**minimum hop**"
  - passes through least number of nodes
- can be generalized as "**least cost**" routing
  - cost associated with each link in network
- because "least cost" is more flexible it is more common than "minimum hop"

Packet-Switched Routing Example

- Consider N1 to N6



- Shortest path 1-3-6 (cost 5 + 5 = 10)
- Least cost 1-4-5-6 (cost 1 + 1 + 2 = 4)

Elements of Routing Techniques

Performance Criteria	Network Information Source
Number of hops	None
Cost	Local
Delay	Adjacent node
Throughput	Nodes along route
	All nodes
Decision Time	
Packet (datagram)	**Network Information Update Timing**
Session (virtual circuit)	Continuous
	Periodic
Decision Place	Major load change
Each node (distributed)	Topology change
Central node (centralized)	
Originating node (source)	

Routing Decision – Time & Place

- Decision Time
  - Datagram packet - made for each packet
  - Virtual circuit - made when circuit established
    - Fixed or dynamically changing due to conditions
- Decision Place
  - Centralized – made by designated node
  - Distributed – made by each node
    - More complex, but more robust
  - Source – made by source station

Network Information Source

- routing decisions usually based on
  - knowledge of network topology
  - traffic load
  - link cost
- distributed routing – made by each node
  - local knowledge
  - information from adjacent nodes
  - information from all nodes on a potential route
- central routing
  - collect information from all nodes

Routing Information Update Timing

- Depends on routing strategy
- Fixed routing
  - Information never updated
- Adaptive routing
  - Regular updates to be able to adapt to changing conditions
  - Updates themselves consume network resources

Strategy 1:Fixed Routing

- use a single permanent route for each pair of source-to-destination nodes
- determined using a least cost algorithm
- route is fixed
  - until a change in network topology
  - based on expected traffic or capacity
- advantage is simplicity
- disadvantage is lack of flexibility
  - does not react to network failure or congestion
  - can store alternative routes at a node

Routing Tables

- A node determines least-cost paths to all possible destinations
- No need to store entire path; store only next node in path (and optionally cost of path)
- Path information stored in *routing table* (or directory)

Destination	*Next*	*Path Cost*
Node 1	Node x	$c1$
Node 2	Node y	$c2$
.	.	

- Routing table may be stored on central node or distributed amongst each node
- Separation of routing and forwarding:

  Routing: strategies, protocols and algorithms are used to create routing table

  Forwarding: routing table used to determine where to send the data to next

Centralised Routing Table Example

Routing table stored on one node

		From Node					
		1	2	3	4	5	6
To Node	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	—

Distributed Routing Tables Example

Each node has its own routing table

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

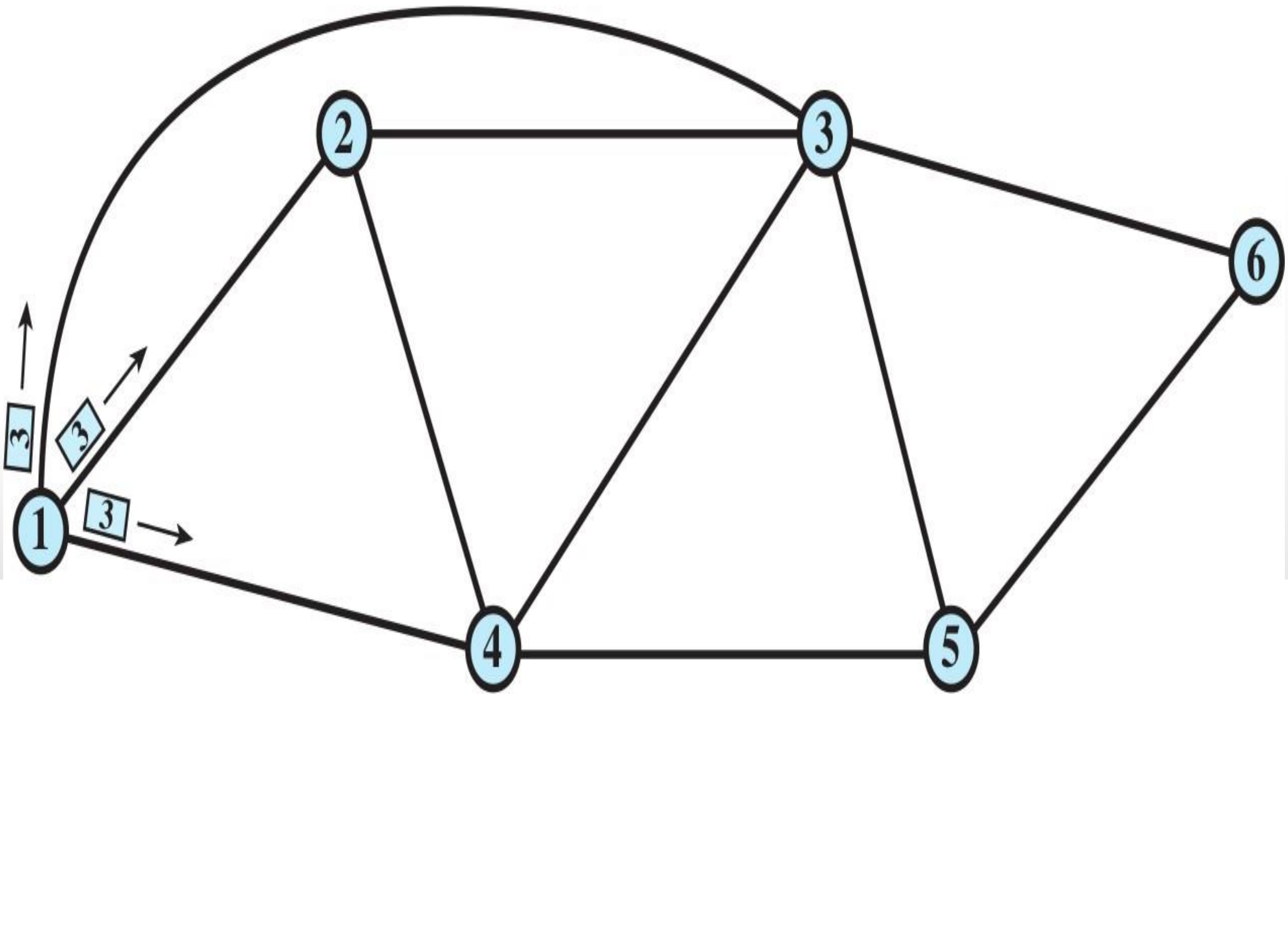
Destination	Next Node
1	5
2	5
3	5
4	5
5	5

Strategy 2: Flooding

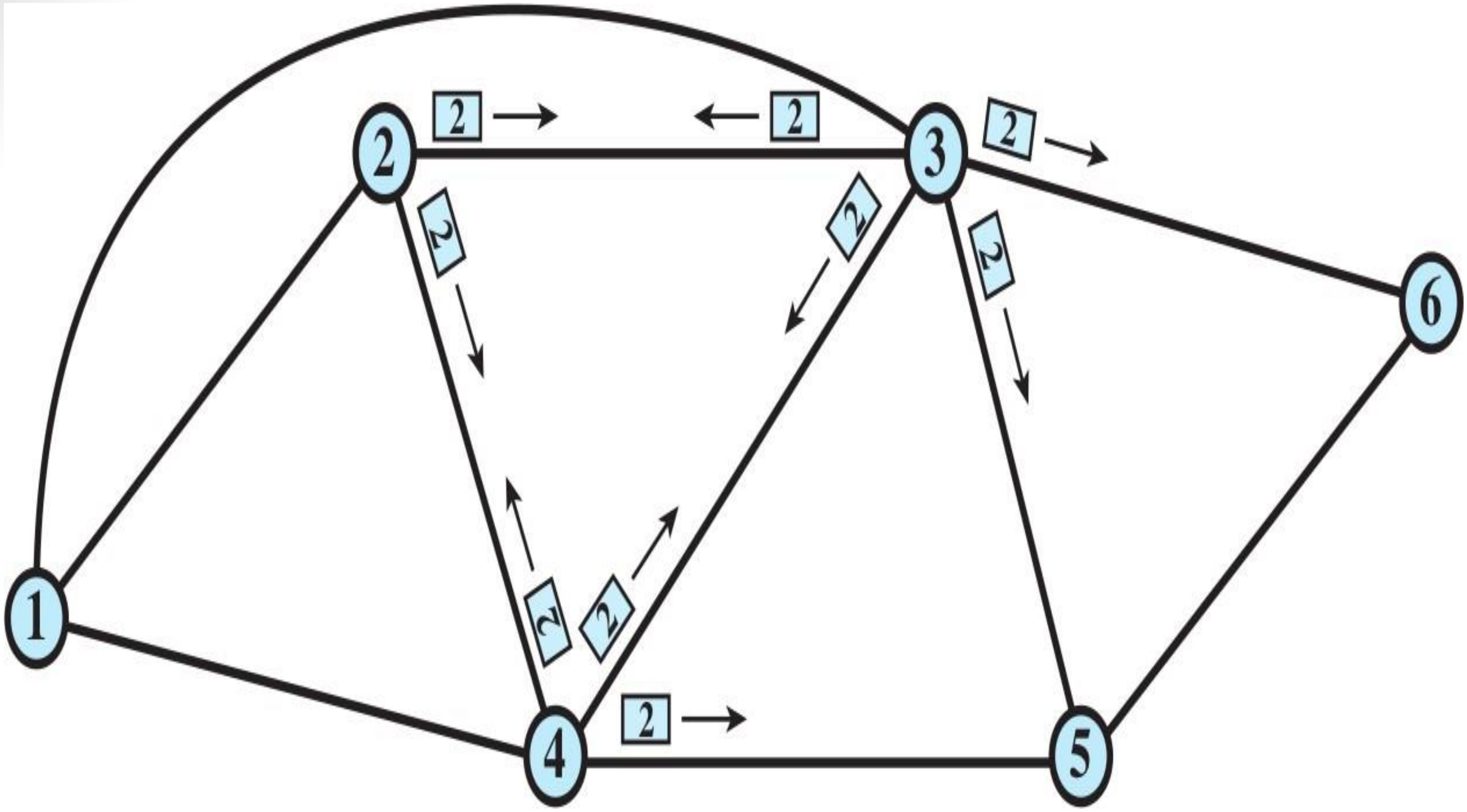
- Instead of choosing a route before sending the data, just send the data to everyone
  - A copy of the original packet is sent to all neighbours of the source
  - Each node that receives the packet, forwards a copy of the packet to all of its neighbours
- Advantages:
  - All possible routes are tried; at least one packet will take minimum hop route, e.g. setup a virtual circuit
  - All nodes are visited, e.g. distributing network status (topology) information
  - Simple
- Disadvantages:
  - Inefficient: need to send many copies of packet to get one packet from source to destination
  - Using hop limit and/or selective flooding, packet may not reach destination

Flooding Example

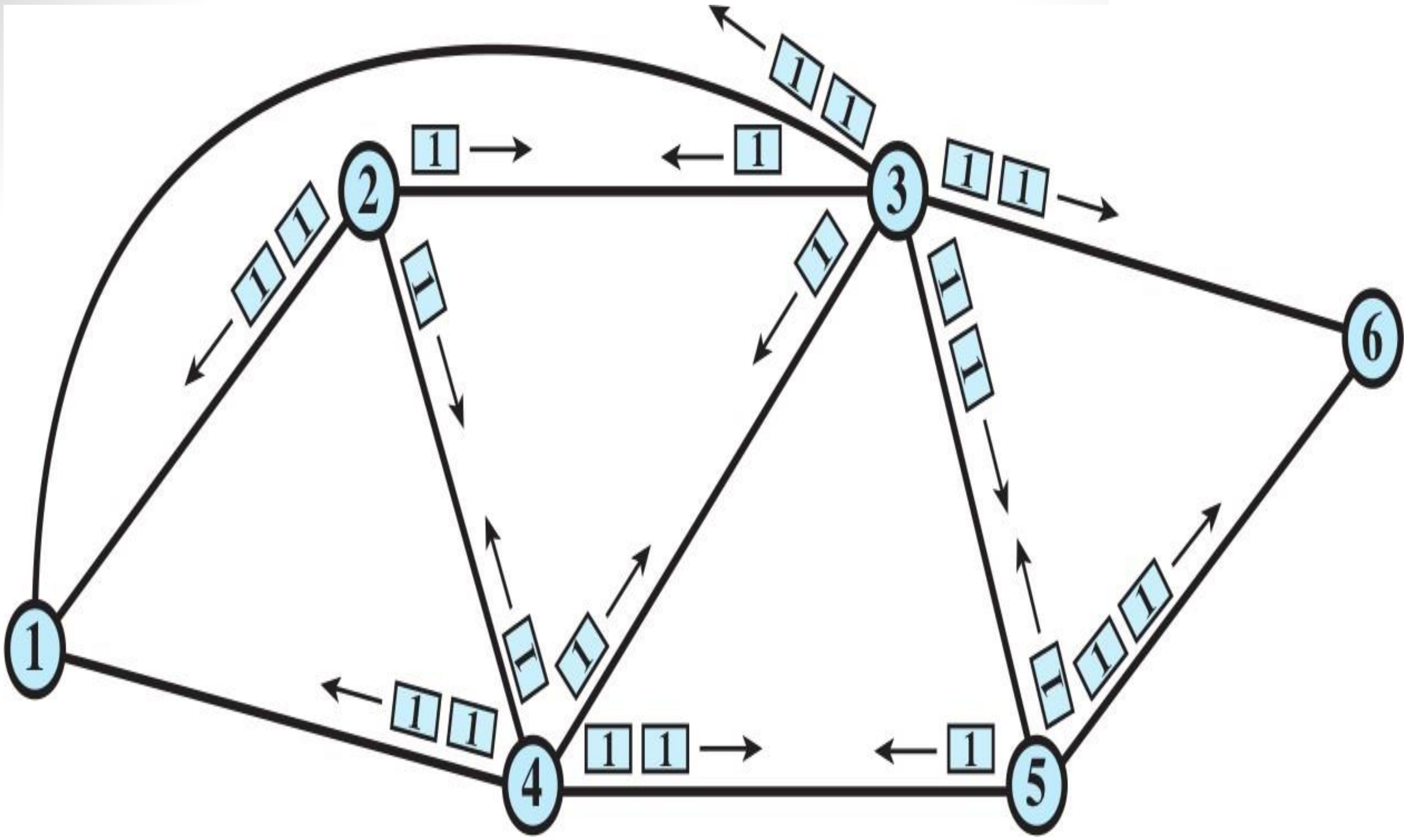
Destination is node 6; Hop limit is 3



Flooding Example



Flooding Example



Properties of Flooding

- All possible routes are tried
  - Highly robust – overcome failed links
  - Can broadcast messages
- At least one packet took minimum hop route
  - Can be used to establish routes or virtual circuits
- All nodes reachable are visited (in hop count)
  - Can be used to send routing information
- High traffic load – big disadvantage

Strategy 3: Adaptive Routing

- Use a least-cost routing algorithm to determine a route, and adapt the route as network conditions change
- Used in almost all packet switching networks, e.g. the Internet
- Requires network status information from:
  1. Local to node: route to output link that has shortest queue (rarely used)
  2. Adjacent nodes: delay/link status, then least-cost routing
  3. All nodes: similar to option 2

Adaptive Routing

- used by almost all packet switching networks
- routing decisions change as conditions on the network
  change due to failure or congestion
- requires information about network

- Disadvantages:
  - decisions more complex
  - Tradeoff
    - quality of network information vs overhead to exchange it
  - reacting too quickly can cause oscillation (from congestion)
  - reacting too slowly means information may be irrelevant

Adaptive Routing Advantages

- Improved network performance
  - User view
- Aid in congestion control
  - Balance loads
  - Delay onset of severe congestion
- Benefits depend on
  - Soundness /validity of design
  - Nature of network load

Adaptive Routing Classes

- Classification based on source of information
  - Local (isolated)
    - Route to outgoing link with shortest queue
    - Can include bias for each destination
    - Rarely used – does not use readily available information
  - Adjacent nodes
    - Use delay and outage information from adjacent nodes
    - Can be distributed or centralized
  - All nodes
    - Similar to adjacent – usually centralized