INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-626-A
Data Communication and Industrial Networks (DC-IN)

Lecture #7
Routing

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Agenda

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

ROUTING TECHNIQUES

Routing Requirements

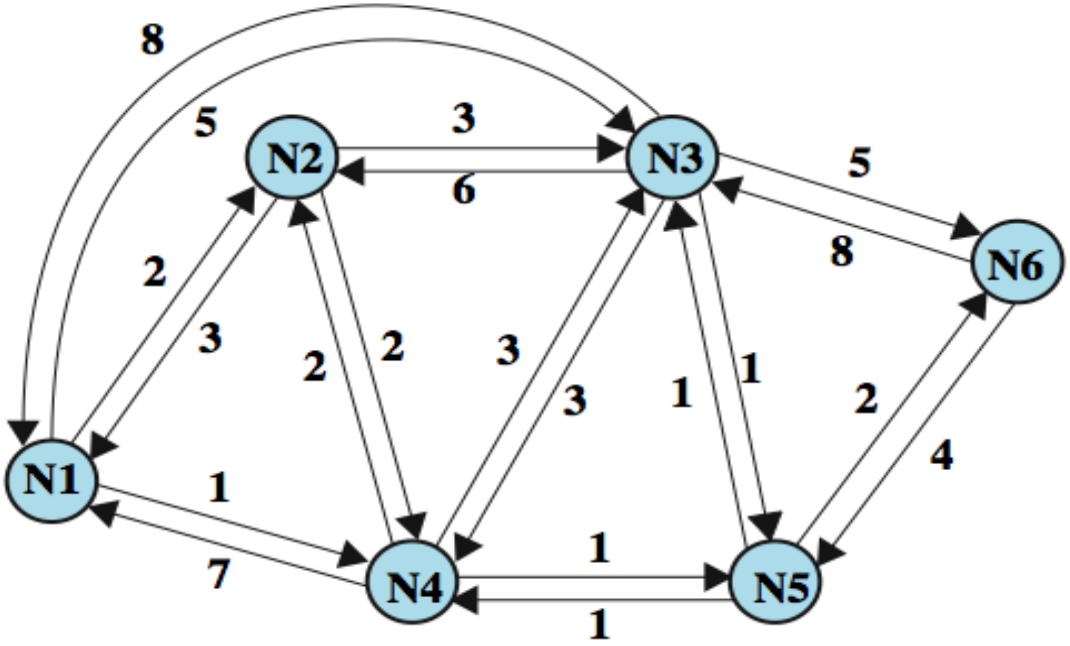
- Routing can be defined as the process of **moving** data **packets** from source to destination.
- It is usually performed by a **device** called a **router**.
- Routing function must have the following:
  - correctness- arrives the right destination
  - simplicity- overhead complexity and delay
  - 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 Number of hops Cost Delay Throughput **Decision Time** Packet (datagram) Session (virtual circuit) **Decision Place** Each node (distributed) Central node (centralized) Originating node (source)	**Network Information Source** None Local Adjacent node Nodes along route All nodes **Network Information Update Timing** Continuous Periodic Major load change Topology change

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

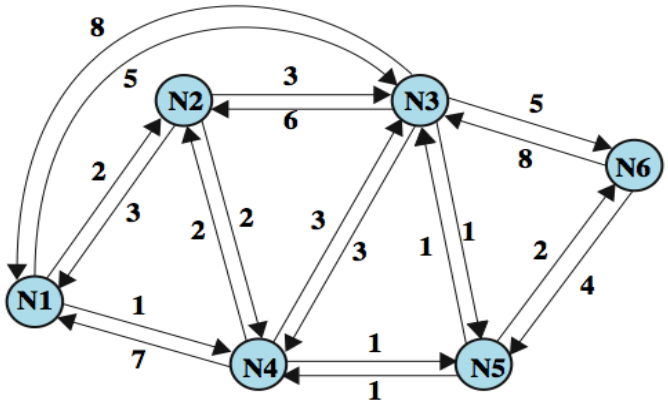
- routing decisions usually based on
  - knowledge of network topology
  - traffic load
  - link cost
- distributed routing – made by each node
  - local knowledge
  - information from adjacent nodes
  - information from all nodes on a potential route
- central routing
  - collect information from all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

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



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	—

Fixed Routing Tables

Find route 1-6

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 Routing Strategy

- packet sent by node to every neighbor
- eventually multiple copies arrive at destination
- no network information required
- each packet is uniquely numbered so duplicates can be discarded
- need to limit incessant retransmission of packets
  - nodes can remember identity of packets retransmitted
  - can include a hop count in packets

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

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

- For more details, refer to:
  - Chapters 12 , W. Stallings, **Data and Computer Communications**, 8th ed.
- The lecture is available online at:
- Lecture notes are found at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12133
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