Overview of Routing

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Outline

Routing Problem

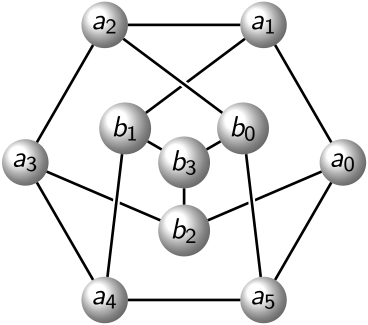
- Routing is the process of designing, discovering, and configuring network paths through the network for individual pairs of communicating end nodes with a set of desired requirements, such as, on
  - correctness,
  - fairness,
  - efficiency,
  - stability,
  - simplicity, and
  - robustness
- Routing vs forwarding
  - Forwarding is the sending of packets along a path

Network Model for Routing Optimization

- Model the network as a graph of nodes and links
  - Decide what to optimize (e.g., fairness vs. efficiency)
  - Decide how to update routes for changes in topology (e.g., failures)

Optimality Principle

- Each portion of a best path is also a best path[1]
  - For example, If b_3 is on the optimal path from a_2 to a_5, the optimal path from a_2 to b_3 and that of b_3 to a_5 also fall along the same route



[1] Richard Bellman. "On a routing problem". In: *Quarterly of applied mathematics* 16.1 (1958), pp. 87–90.

Sink Tree

- The union of best paths to a router is a tree called the sink tree
- Routing $\equiv$ Computing sink trees?
- A sink tree, unrealistic to compute in practice, provides a benchmark against which other routing algorithms can be measured or evaluated
- But what does it mean being the "best"?

Outline

Efficiency Consideration

An efficient routing algorithms minimizes the consumption of network resources or maximizes desired network performance

- Number of hops (link cost $\equiv 1$)
- Link cost
- Cost of a link and that of attached nodes
- Delay
- Throughput

Design Considerations

Compute a desired route, i.e., make the decision about the routes between any pair of end nodes, but

- Decision time. Compute the route on a packet or on a session basis (the example of a session can be a virtual circuit)
- Decision place. Which node or nodes are responsible for computing the route.
- Network information sources. Based on what data does a routing algorithm compute the routes?
- Update timing. When are the network information updated and when do we recompute the routes?

Decision Time

- Compute the route on a packet or on a session basis (the example of a session can be a virtual circuit)?
  - Data structures (e.g., forwarding tables)?

Decision Place

- Which node or nodes are responsible for computing the route.
  - Each node (distributed routing algorithms; network information sources?)
  - Central node (a designated control node; centralized routing algorithms; cyclic dependency and network information sources?)
  - Originating node (i.e., the source node; source routing algorithms; cyclic dependency and network information sources?)

Network Information Sources

- Based on what information (i.e., data) does a routing algorithm compute the routes?
  - Types of information
    - Topology of the network?
    - Traffic load?
    - Link cost?
    - None at all?
  - Sources (nodes) of information
    - Local?
    - Adjacent node?
    - Nodes along the route (cyclic dependency?)?
    - All nodes?
    - None at all?

Update Timing

Update timing, network information sources, and routing strategies (algorithms) are intertwined.

- Continuous
- Periodic
- Major traffic load change
- Topology change

Additionally, consider

- the amount of network information vs.
- the frequency of network information update vs.
- the quality of routing decision vs.
- the network resources consumed by transmitting the network information (and decisions), and computing the routes at nodes

Outline

Routing Strategies

- Strategies vs. algorithms vs. protocols?
- Routing strategies
  - Fixed. Configure a permanent route.
  - Flooding. A node transmits a packet to all its neighbors except the one from which the packet comes.
  - Random. A node selects randomly an outputing neighbors (except the one from which the packet comes) to retranmist the incoming packet to. For instance, select a neighbor based on,

$$P_i = \frac{R_i}{\sum_j R_j} \tag{1}$$

  - Adaptive. Recompute routing decisions as network conditions change.
    - Failure. A node or a link fails.
    - Congestion. There is a congestion in a portion of the network.

Example of Flooding

See Figure 19.3 in the textbook.

- All possible routes are tries.
- At least one copy of the packet arrives from the minimum-hop route
- All nodes directly and indirectly connected to the source nodes are visited.

Figure 19.3[2]

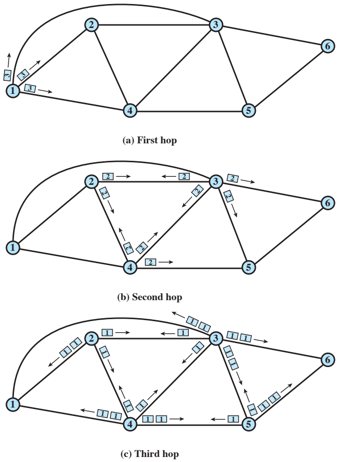


Figure 19.3 Flooding Example (hop count = 3)

[2] William Stallings. *Data and Computer Communications*. 10th. USA: Prentice Hall Press, 2013. ISBN: 0133506487.

Example of Adaptive Routing

See Figure 19.4 in the textbook.

- Can be either distributed or centralized

Figure 19.4[3]

Node 4's Bias
Table for
Destination 6

Next Node	Bias
1	9
2	6
3	3
5	0

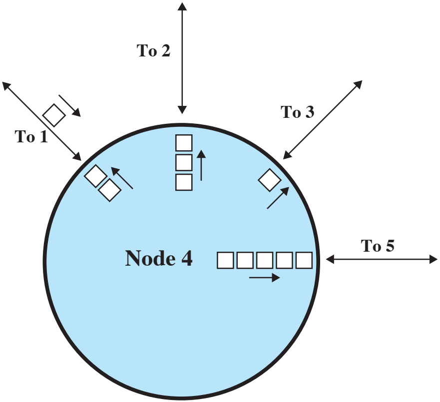


Figure 19.4 Example of Isolated Adaptive Routing

[3]William Stallings. *Data and Computer Communications*. 10th. USA: Prentice Hall Press, 2013. ISBN: 0133506487.