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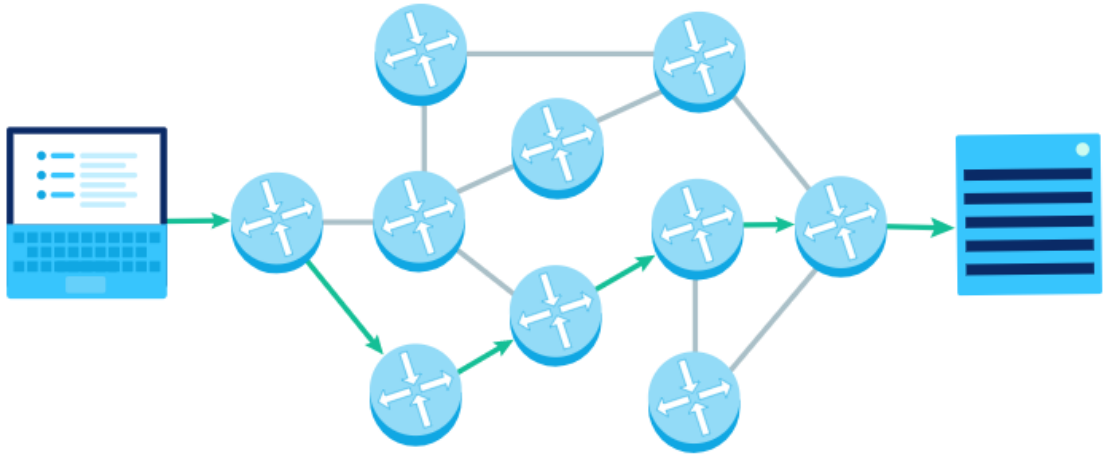
Computer Networks

(RCS-601)

Routing - I



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Routing

- ***Routing*** is a process of selecting path along which the data can be transferred from source to the destination. Routing is performed by a special device known as a *router*.

- ***Router*** is a networking device that forwards the packet based on the information available in the packet header and forwarding table. A Router works at the network layer in the OSI model and internet layer in TCP/IP model.

- ***Routing Algorithms*** are used for routing the packets. Routing algorithm initializes and maintains the ***routing table*** for the process of path determination.

- Routing Algorithms use the ***metric*** to determine the best path for the packet delivery. The ***metric*** is the standard of measurement such as *hop count, bandwidth, delay, current load on the path* etc. used by the routing algorithm to determine the optimal path to the destination.

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Desirable properties of a Routing Algorithm

- **Correctness:** The routing should be done properly and correctly so that the packets may reach their proper destination.
- **Simplicity:** The routing should be done in a simple manner so that the overhead is as low as possible. With increasing complexity of the routing algorithms the overhead also increases.
- **Robustness:** Once a major network becomes operative, it may be expected to run continuously for years without any failures. The algorithms designed for routing should be robust enough to handle hardware and software failures.
- **Stability:** The routing algorithms should be stable under all possible circumstances.
- **Fairness:** Every node connected to the network should get a fair chance of transmitting their packets. This is generally done on a first come first serve basis.
- **Optimality:** The routing algorithms should be optimal in terms of throughput and minimizing mean packet delays.

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Design Parameters of a Routing Algorithm

- **Performance Criteria:** Number of hops, Cost, Delay, Throughput, etc.
- **Decision Time:** Per packet basis (Datagram) or per session (Virtual-circuit) basis
- **Decision Place:** Each node (distributed), Central node (centralized), Originated 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

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Classification of a Routing Algorithm

- Static (Nonadaptive) Routing *vs* Dynamic (Nonadaptive) Routing
- Single-Path *vs* Multi-path Routing
- Flat *vs* Hierarchical (based on network topology) Routing
- Intra-domain *vs* Inter-domain Routing

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Static (Nonadaptive) Routing *vs* Dynamic (Adaptive) Routing

This category is based on **how and when the routing tables are set-up and how they can be modified, if at all.**

- In the Static routing, the routing table is set up and modified manually whereas in the Dynamic routing the table is built automatically with the help of the routing protocols.
- Dynamic routing is preferred over static routing because of the major issue in static routing where in case of link/node failure the system cannot recover because of the changed network condition.

Single-path *vs* Multi-path Routing

This category is based upon ***the number of paths a router stores for a single destination*.**

- ***Single path algorithms*** learn routes and select a single best route to each destination. These algorithms are incapable of load balancing traffic.

- ***Multi-path routing algorithms*** learn routes and can select more than one path to a destination. These protocols are better for performing load balancing.

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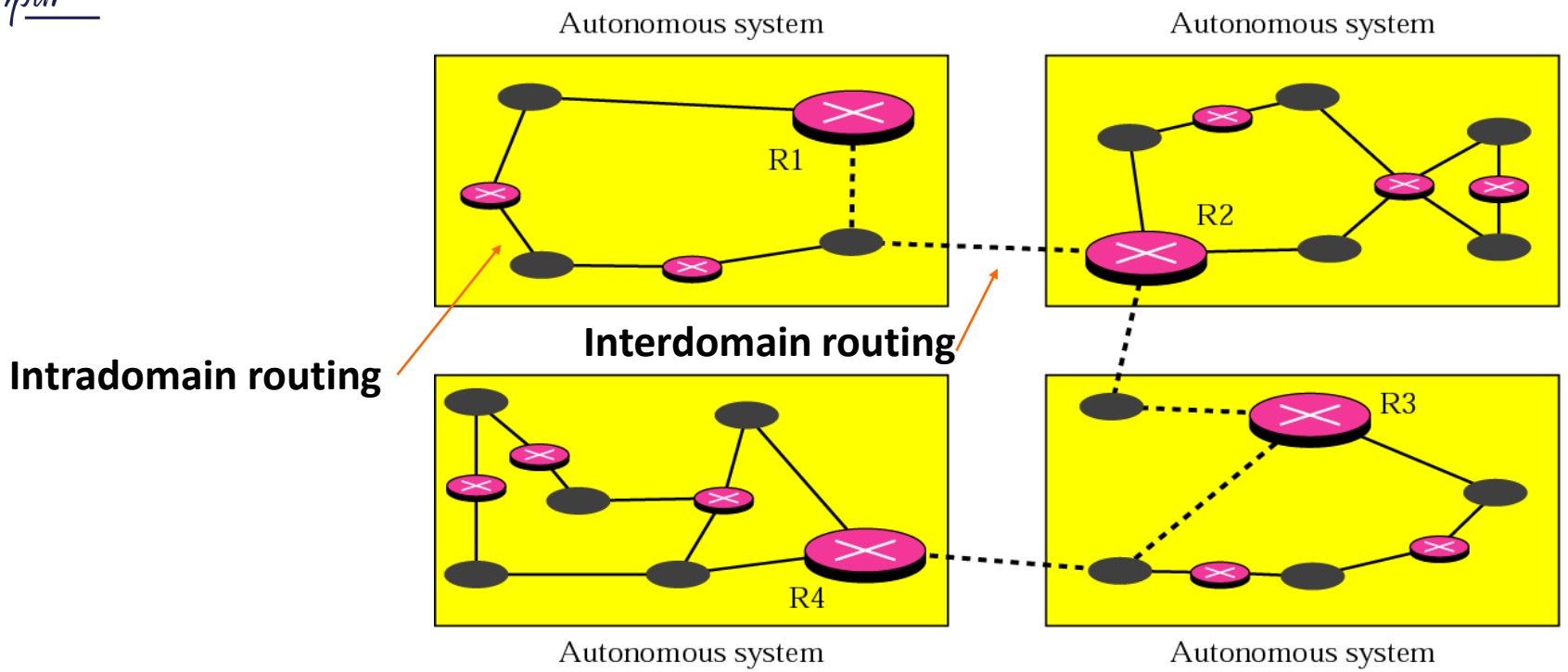
Flat *vs* Hierarchical Routing

- ***Flat routing algorithm*** propagates all routing information throughout the network.
- ***Hierarchical routing algorithm*** divides large networks into smaller areas for routing.

Intradomain *vs* Interdomain Routing

- ***Intra-domain (within domain)*** is any routing on your own network. For that you can use RIP and OSPF routing protocols.
- ***Inter-domain (between domains)*** is any routing protocols that you have setup between two different networks. These are usually called Autonomous Systems (AS). The main inter-domain protocol is BGP. Most of the time when talking about inter-domain is routing on the internet.

Autonomous Systems



- An ***autonomous system (AS)*** is a group of networks and routers under the authority of a single administration.
- An internet or a bigger collection of networks can be so large, one routing protocol cannot handle the task of updating routing tables of all routers. So, internet or a bigger collection of networks is divided into autonomous systems.

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Unicast Routing

Most of the traffic on the network known as unicast data or unicast traffic is sent with specified destination. Routing unicast data over the internet is called unicast routing. It is the simplest form of routing because the destination is already known.
Hence the router just has to look up the routing table and forward the packet to next hop.

There are three major algorithms for unicast routing:

- Distance Vector Routing
- Link State Routing
- Path-Vector Routing

Goal of Routing Algorithms:

(Optimality Principle & Sink Tree)

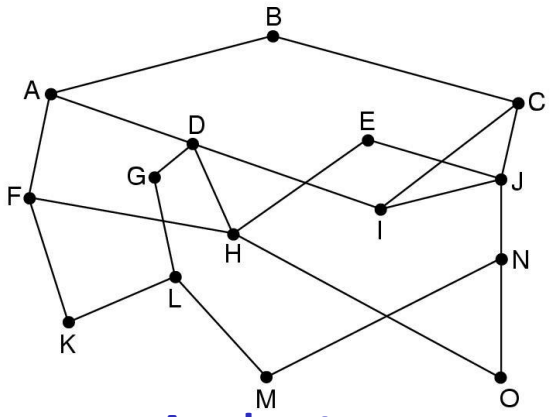
One can make a general statement about optimal routes without regard to network topology or traffic.

Optimality Principle *states that if router J is on the optimal path from router I to router K, then the optimal path from J to K also falls along the same route.*

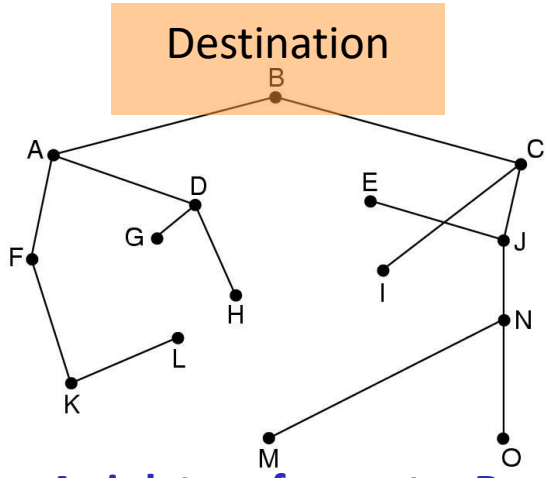
The set of optimal routes from all sources to a given destination form a tree rooted at the destination. Such a tree is called a **sink tree** that is illustrated in figure below, where the distance metric is the number of hops.

Note that - a sink tree is not necessarily unique; other trees with the same path lengths may exist.

The goal of all routing algorithms is to discover and use the sink trees for all routers.



A subnet



A sink tree for router B

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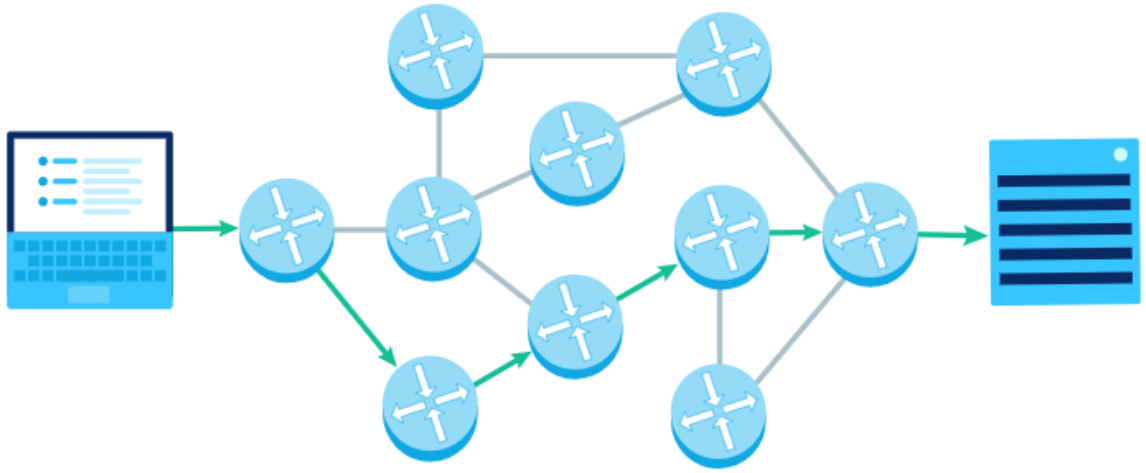
Static / Non Adaptive
Routing Algorithms



- Shortest Path Routing
- Flooding
- Flow Based Routing

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Shortest Path Routing

Algorithm of **Dijkstra**: shortest path in graph

- Several algorithms (like Dijkstra Shortest Path Algorithm) are available for computing the shortest path between two nodes of a graph.
- In **Dijkstra Shortest Path Algorithm**, each node is labeled with its distance from the source node along the best known path. Initially, no paths are known, so all nodes are labeled with infinity. As the algorithm proceeds and paths are found, the labels may change, reflecting better paths. A label may be either tentative or permanent. Initially, all labels are tentative. When it is discovered that a label represents the shortest possible path from the source to that node, it is made permanent and never changed thereafter.

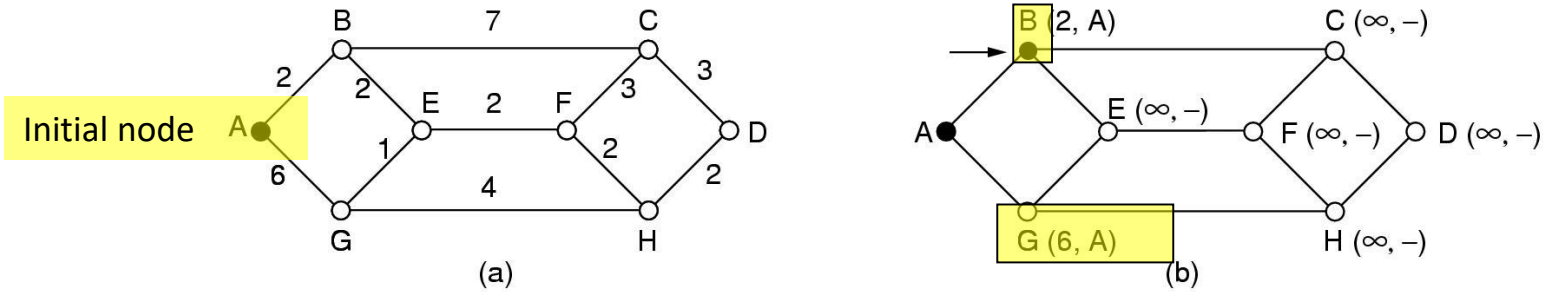
Graph

- Node = router
- Edge = communication line

Metric

- Number of hops
- Geographic distance
- Mean queueing
- Transmission delay

Shortest Path Routing (contd.)



Elements of algorithm:

- Mark all nodes as free: O
- Mark initial node as selected: ●
- repeat till destination is selected:
  - Label all free nodes reachable from selected nodes with shortest distance to a selected node
  - Select free node with shortest distance to a selected node and mark it as selected

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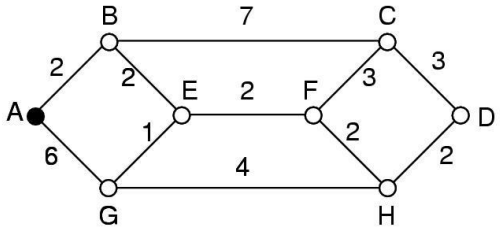
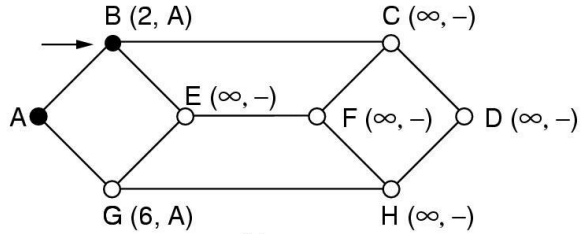
Shortest Path Routing (contd.)



(a)



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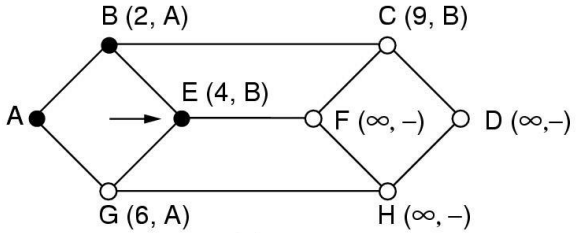

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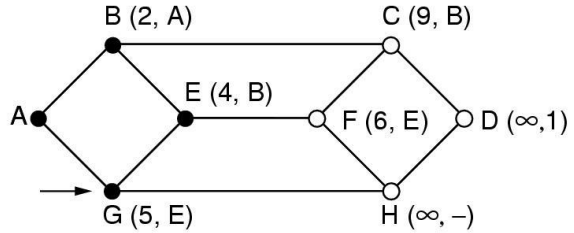
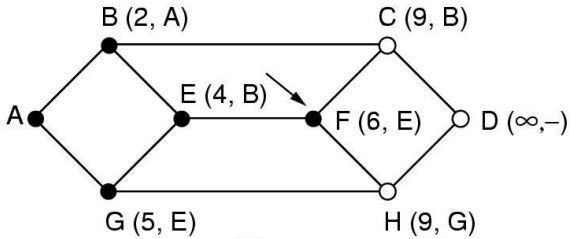
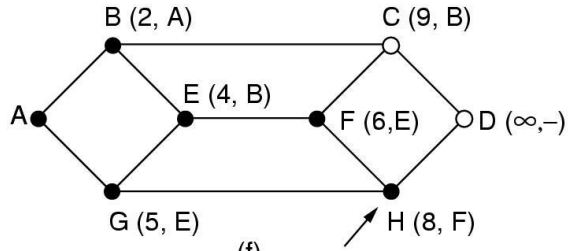


(d)



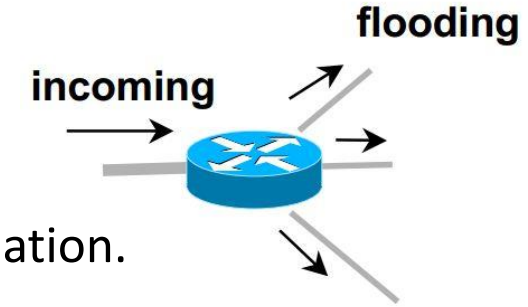
(e)



(f)

A -> B -> E -> F ->H -> D

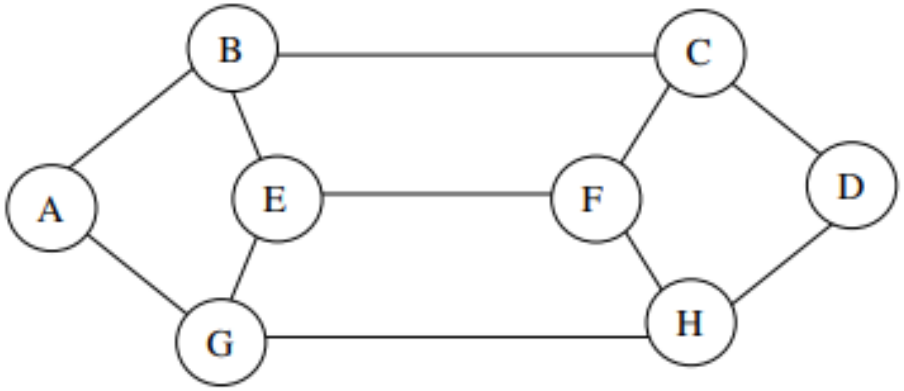
Flooding



- Simplest static routing algorithm that requires no network information.
- In ***flooding***, every incoming packet is sent out on every outgoing line except the one it arrived on.
- Flooding obviously generates vast numbers of duplicate packets, in fact, an infinite number unless some measures are taken to damp the process.
- One such measure is to have a hop counter contained in the header of each packet, which is decremented at each hop, with the packet being discarded when the counter reaches zero.
- Another technique is to keep the track of the packed that have been flooded, to avoid sending them a second time. For this, the source router put a sequence number in each packet it receives from its hosts.
- A variation of flooding that is slightly more practical is ***selective flooding***. In this algorithm the routers do not send every incoming packet out on every line, only on those lines that are going approximately in the right direction.

Flow Based Routing

- This is a static algorithm which uses topology and load condition (traffic) for deciding a route.
- To use this algorithm, following information **should be known in advance** -
  - Subnet Topology
  - Traffic Matrix
  - Line Capacity Matrix



For example, If there is always a huge amount of traffic from A to B in figure above, then it may be better to route traffic from A to C via AGEFC, even though this path is much longer than ABC.

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Thank you