Networking Technologies and Applications

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November 5, 2020

Routing - Router

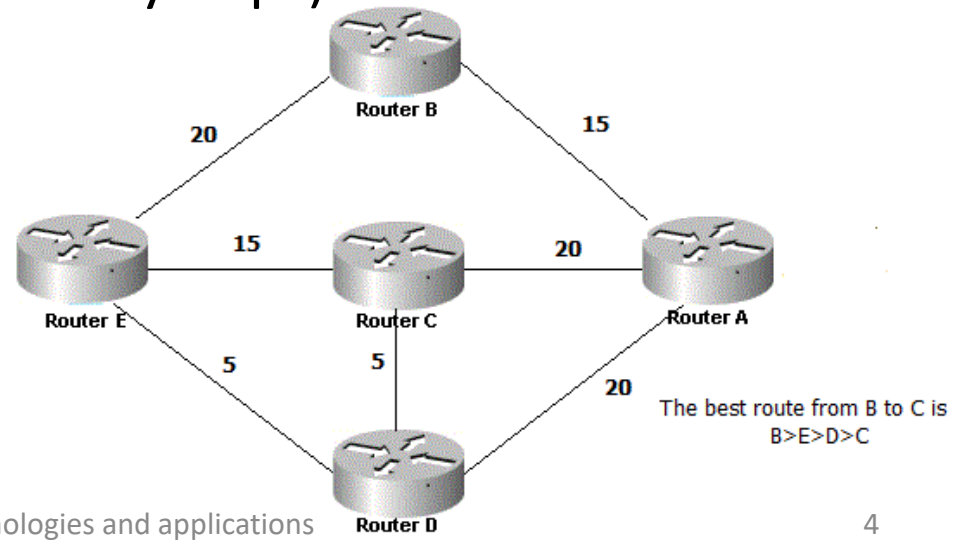
- Routing
  - Process through which the packets are directed to the destination node
  - Based on the routing tables and the used routing protocols, the internal routers determine the path
- Router
  - The node handling the routing process
  - Communicate with each other
  - Receive and store information from their neighbors
  - Create and maintain **routing tables**
    - Content: <destination address, outgoing interface> pairs

Router

- The router can be
  - a module of the operating system
    - Unix, Novell
  - Dedicated device (not only software, but hardware as well) – much faster
    - Cisco, Juniper, Alcatel-Lucent, Huawei, NEC, etc.
- **Capacity of a router**
  - How many packets can be transmitted in a time interval (packet/s)
  - E.g. Alcatel Lucent 7750 SR
    - 9.6 Tb/s, 10700 Mpps
    - Routing table – 22.000.000 (IPv4), 12.000.000 (IPv6)

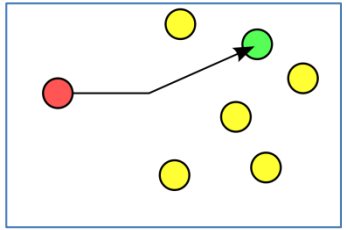
Tasks of a router

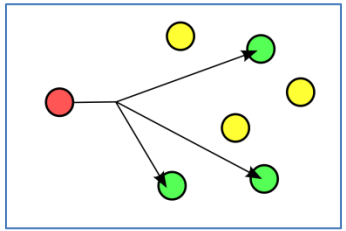
- Selecting the optimal path for a given packet
- Based on several aspects (metrics):
  - Length of the route (how many hops)
  - Cost
  - Bandwidth, speed
  - Reliability
  - Delay

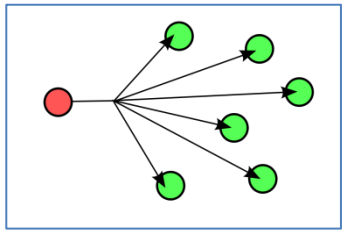


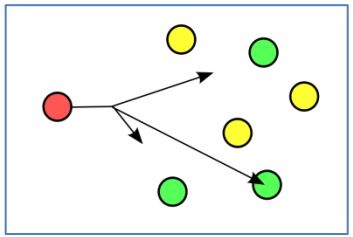
Routing semantics

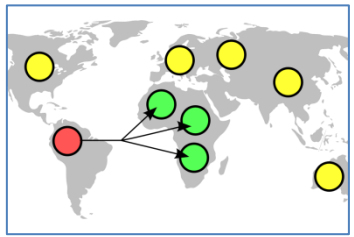
- **Unicast** – sending a packet to one specific destination
- **Anycast** – sending a packet to anyone (e.g., the closest one) from a group
- **Multicast** – sending a packet to a group
- **Geocast** – sending a packet to everyone in a given geographical area
- **Broadcast** – sending a packet to everyone in the (sub)network











Classification of routing protocols

- Static:
  - the routing table filled manually
  - Never refreshed automatically
- Dynamic:
  - The routers communicate with each other, routing tables are built dynamically, based on the current network topology

- Single path:
  - One single path stored towards each destination
- Multi path:
  - Many (or all) paths stored towards each destination
  - These protocols can handle load balancing

Classification of routing protocols

- Flat:
  - Each router knows about every destination
  - Old model, for smaller networks
- Hierarchical:
  - Routers do not know the path towards each destination
  - If an unknown destination address is seen, the packet is directed towards a well known direction (default route)
  - The size of the routing tables remains scalable

- Inter-domain
  - Responsible for routing the packet between domains
- Intra-domain
  - Responsible for routing inside a domain

Classification of routing protocols

- Hop-by-hop:
  - Each router decides where to forward the packet in an autonomous way
  - Based on (partial) topology information gathered from the neighbors
- Source routing:
  - The sender decides the route of the packet (and includes it in the IP packet header)
  - Routers only advertise availability information
  - Packets are just forwarded based on the header, no routing decision is taken
- The are intermediate solutions as well

Classification of routing protocols

- Distance vector protocols
  - Routers communicate only with their neighbors
  - Each routers tells its neighbor:
    - What is the cost of the route he knows to a given destination
    - Does not specify what is that route, who is the next hop
  - Routers gather the ads from their neighbors, and choose the node that advertised the cheapest route
    - Packets are directed towards this neighbor
  - They add their own cost, and advertise the updated route information

Classification of routing protocols

- Link state protocols

  1. Discover the network topology

  2. Find the shortest path in this graph

  Routers advertise the status of their interfaces (i.e., the costs of their links)

  - Information is exchanged with all the other routers in the network
  - Everyone builds his own network topology
    - Everyone builds the same topology

Distance-Vector Protocols

Bellman-Ford protocols

Classical Bellman-Ford algorithm

$\mathbf{d_{ij}}$:= the cost of link i-j (infinity, if no link)

- Real cost, delay, packet loss rate, etc.

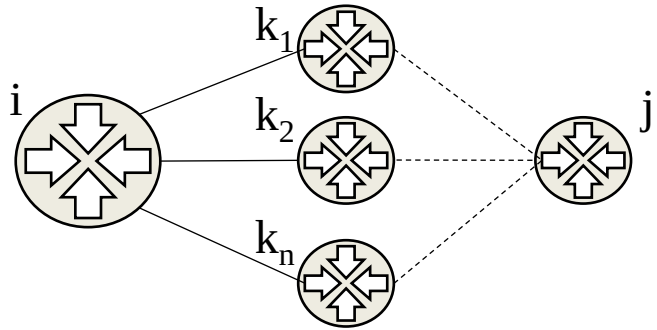
- **Additivity**
  - The cost of a route is the sum of the costs of the links composing that route

$\mathbf{D_{ij}}$:= minimum cost between *i* and *j*

Bellman equation:

$\mathbf{D_{ii}} = 0$, for each *i*

$\mathbf{D_{ij}} = \min_k \{\mathbf{d_{ik}} + \mathbf{D_{kj}}\}$



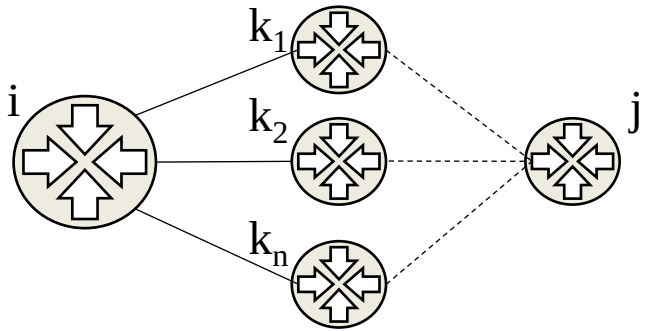
Distributed Bellman-Ford Algorithm

$D^{i}_{kj}(t)$ = minimal distance from ***k*** to ***j*** –ig, that router ***i*** is aware of at time ***t***

$\mathbf{D_{ii}} = 0$, for each *i*

$\mathbf{D_{ij}}(t) = \min_k \{\mathbf{d_{ik}} + D^{i}_{kj}(t)\}$

- The algorithm can run autonomously in each router



Distance-vector protocols

- RIPv1 (RFC 1058, ’88)
  - Routing Information Protocol
    - Rest In Pieces ☺
- RIPv2 (RFC 2453, ’98)
- RIPng (RFC 2080, ‘97)
  - IPv6 version

- EIGRP
  - Enhanced Interior Gateway Routing Protocol
  - Cisco proprietary standard

Distance Vector protocols

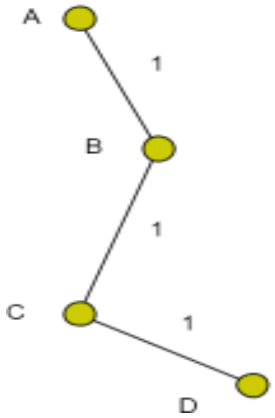
- Store distance vectors for each route
  - Data triples:
    - Destination
    - Cost
    - Next hop node (where to forward)
  - Periodically refreshed among neighbors
    - Update messages (2 parts):
      - Destination, cost
    - If a router learns about a better path, it updates its table
      - Learns about a new neighbor, or learns a better path from an old neighbor
      - The information spreads (slowly)

Properties

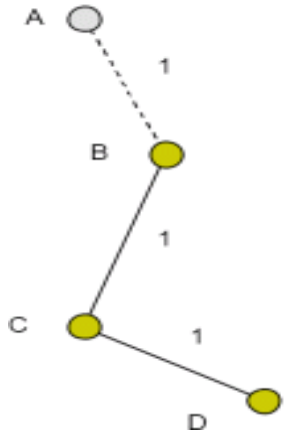
- Simple, but not perfect:
  - Link costs can change
  - Links can be broken
    - Cost of a broken link set to infinity
      - An integer value that is larger than any real possible value (by default, 16 for RIP)
  - In case of topology change, routing tables are refreshed gradually
    - Periodically (e.g., each 30 s) update message sent
      - If 6 updates are missed, cost set to infinity
    - Neighbors also update their entries
  - Converges, but slowly
    - Can be used only in small networks

Counting to infinity

- When advertising the costs of reaching a destination, costs can be incremented endlessly



B	C	D
1	2	3



B	C	D
3	2	3

B	C	D
3	4	3

B	C	D
5	4	5

Solution

- Split horizon method
  - If C learns a route from B, it will not advertise it back to B
- Poisoned Reverse method
  - If C learns a route from B, it will advertise it back to B with a cost set to infinity