Distance Vector Routing
DV Routing Outline

- Internet Context
- Network Layer Routing (**K&R slides)
- Quick Routing Overview
- Distance Vector Routing (my version)
  - Adapted from Tanenbaum & Perlman Texts
- Distance Vector Routing (K&R version)
- Summary
Internet Context
Metropolitan Area Network (MAN)

- Gateway
- To the Internet or wide area network
- Backbone
- Organization Servers
- Departmental Server

Leon-Garcia & Widjaja: Communication Networks
Wide Area Network (WAN)

Interdomain level

Border routers

Autonomous system or domain

Border routers

Internet service provider

LAN level

Intradomain level

Leon-Garcia & Widjaja: Communication Networks
Modern Internet Backbone

National Internet Service Providers

National service provider A

National service provider B

National service provider C

Network Access Point

NAP

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Network Layer Routing
Network Layer

- transport segment from sending to receiving host.
- on sending side, encapsulates segments into datagram packets.
- on receiving side, delivers segments to transport layer.
- network layer protocols in every host and router.
- router examines header fields in all IP datagrams passing through it.
Two Key Network Layer Functions

- **forwarding**: move packets from router’s input to appropriate router output.

- **routing**: determine route taken by packets from source to destination.

**analogy:**

- **routing**: process of planning trip from source to destination

- **forwarding**: process of getting through single interchange
Interplay between Routing and Forwarding

Routing algorithm

<table>
<thead>
<tr>
<th>header value</th>
<th>output link</th>
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<tr>
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Value in arriving packet’s header
Host, router network layer functions:

Transport Layer: TCP, UDP

- Routing protocols
  - path selection
  - RIP, OSPF, BGP

- IP protocol
  - addressing conventions
  - datagram format
  - packet handling conventions

- ICMP protocol
  - error reporting
  - router “signaling”

Data Link Layer

Physical Layer
Quick Routing Overview
Routing

Routing algorithm:: that part of the Network Layer responsible for deciding on which output line to transmit an incoming packet.

- Remember: For virtual circuit subnets the routing decision is made ONLY at set up.

Algorithm properties:: correctness, simplicity, robustness, stability, fairness, optimality, and scalability.
Routing Classification

Adaptive Routing

- based on current measurements of traffic and/or topology.
  1. centralized
  2. isolated
  3. distributed

Non-Adaptive Routing

- routing computed in advance and off-line
  1. flooding
  2. static routing using shortest path algorithms
Internetwork Routing [Halsall]

Adaptive Routing

Centralized
[IGP] Intradomain routing
[IGP] Interior Gateway Protocols

Distance Vector routing
[RCC] [RIP]

Distributed

Interdomain routing
[IGP] [OSPF, IS-IS, PNNI]

Interdomain routing
[BGP, IDRP]

Isolated

Exterior Gateway Protocols

Distance Vector routing
[EGP] [RIP]
Adaptive Routing Design

Design Issues:

1. How much overhead is incurred due to gathering the routing information and sending routing packets?

2. What is the time frame (i.e., the frequency) for sending routing packets in support of adaptive routing?

3. What is the complexity of the routing strategy?
Adaptive Routing

Basic functions:
1. **Measurement of pertinent network data.**
2. **Forwarding of information to where the routing computation will be done.**
3. **Compute the routing tables.**
4. **Convert the routing table information into a routing decision and then dispatch the data packet.**
Centralized Routing
Distance Vector Routing

{Tanenbaum & Perlman version}
Historically known as the old ARPANET routing algorithm {or known as Bellman-Ford (BF) algorithm}.

BF Basic idea: each router maintains a Distance Vector table containing the distance between itself and ALL possible destination nodes.

Distances, based on a chosen metric, are computed using information from the neighbors’ distance vectors.

Distance Metric: usually hops or delay
Distance Vector Routing

Information kept by DV router

1. each router has an ID
2. associated with each link connected to a router, there is a link cost (static or dynamic).

Distance Vector Table Initialization

Distance to itself = 0
Distance to ALL other routers = infinity number
1. A router transmits its **distance vector** to each of its neighbors in a routing packet.

2. Each router receives and saves the most recently received **distance vector** from each of its neighbors.

3. A router recalculates its **distance vector** when:
   a. It receives a **distance vector** from a neighbor containing different information than before.
   b. It discovers that a link to a neighbor has gone down (i.e., **a topology change**).

   The DV calculation is based on minimizing the cost to each destination.
Figure 5-9. (a) A subnet. (b) Input from A, I, H, K, and the new routing table for J.
Distance Vector Routing

{Kurose & Ross version}
Bellman-Ford Equation (dynamic programming)

Define
\[ d_x(y) := \text{cost of least-cost path from } x \text{ to } y \]

Then
\[ d_x(y) = \min_{v} \{c(x,v) + d_v(y)\} \]

where min is taken over all neighbors v of x.
Clearly, $d_v(z) = 5$, $d_x(z) = 3$, $d_w(z) = 3$

B-F equation says:

$$d_u(z) = \min \{ c(u,v) + d_v(z), c(u,x) + d_x(z), c(u,w) + d_w(z) \}$$

$$= \min \{ 2 + 5, 1 + 3, 5 + 3 \} = 4$$

The node that achieves minimum is next hop in shortest path $\rightarrow$ forwarding table.

Namely, packets from $u$ destined for $z$ are forwarded out link between $u$ and $x$. 

Bellman-Ford Example
Distance Vector Algorithm (3)

- \( D_x(y) \) = estimate of least cost from \( x \) to \( y \)
- Node \( x \) knows cost to each neighbor \( v \):
  \[ c(x, v) \]
- Node \( x \) maintains distance vector
  \[ D_x = [D_x(y) : y \in N] \]
- Node \( x \) also maintains its neighbors' distance vectors
  - For each neighbor \( v \), \( x \) maintains
    \[ D_v = [D_v(y) : y \in N] \]
Distance Vector Algorithm (4)

**DV Basic idea:**
- From time-to-time, each node sends its own distance vector estimate to neighbors.
- Asynchronous
- When a node \( x \) receives a new DV estimate from any neighbor \( v \), it saves \( v \)'s distance vector and it updates its own DV using B-F equation:

\[
D_x(y) \leftarrow \min_v \{ c(x,v) + D_v(y) \} \quad \text{for each node } y \in N
\]

- Under minor, natural conditions, the estimate \( D_x(y) \) converges to the actual least cost \( d_x(y) \).
Distance Vector Algorithm (5)

Iterative, asynchronous: each local iteration caused by:
- local link cost change
- DV update message from neighbor

Distributed:
- each node notifies neighbors only when its DV changes
  - neighbors then notify their neighbors if necessary.

Each node:

wait for (change in local link cost or msg from neighbor)

recompute estimates

if DV to any destination has changed, notify neighbors
D_x(y) = \min\{c(x,y) + D_y(y), c(x,z) + D_z(y)\}
= \min\{2+0, 7+1\} = 2

D_x(z) = \min\{c(x,y) + D_y(z), c(x,z) + D_z(z)\}
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\]
Link cost changes:
- node detects local link cost change.
- updates routing info, recalculates distance vector.
- if DV changes, it notifies neighbors

At time $t_0$, $y$ detects the link-cost change, updates its DV, and informs its neighbors.

"good news travels fast"

At time $t_1$, $z$ receives the update from $y$ and updates its table. It computes a new least cost to $x$ and sends its neighbors its DV.

At time $t_2$, $y$ receives $z$'s update and updates its distance table. $y$'s least costs do not change and hence $y$ does not send any message to $z$. 
Link cost changes:
- good news travels fast
- bad news travels slow - “count to infinity” problem!
- 44 iterations before algorithm stabilizes: see text!

Poisoned reverse:
- If Z routes through Y to get to X:
  - Z tells Y its (Z’s) distance to X is infinite (so Y won’t route to X via Z)
- will this completely solve count to infinity problem?
The Network Layer is responsible for **routing** and **forwarding**.

The routing process is used to build forwarding lookup tables.

Forwarding uses the lookup table to move an incoming packet to the correct outgoing link queue.

Routing algorithms use link cost metrics such as hops or delay.

Distance Vector (DV) is an **intradomain adaptive routing algorithm** that does not scale well.
DV (originally the old ARPA algorithm) employs the Bellman-Ford shortest path algorithm and currently is used in the RIP, RIP-2, BGP, ISO IDRP and Novell IPX protocols.

DV routers:

- keep distances to **ALL intranet routers in a distance vector** which is periodically updated and transmitted to each of its neighbors.
- reacts to changes in its neighbors’ distance vectors and to topology changes (i.e., nodes and/or links coming up or going down).

In distance vector routing “bad news travels slowly and good news travels quickly”. 