Lecture 20: Network Layer & Internet Protocol Continued

Adam Hawley

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1 Intra-Domain Routing

Routing is needed for forwarding packets in a datagram (connectionless) network, or for establishing virtual circuits in a VC (connection oriented) network. Routing algorithms or protocols create routing tables from which one may derive the neccesary forwarding tables. These in turn, define the output port through which a packet will be forwarded.

Most routing protocols work only for 10s or 100s of nodes and hence they are referred to as **interior gateway protocols (IGPs)** or (**intra-domain routing protocols**). To make them scale, internetworks employ a hierarchical routing structure based on **domains**.

- A **domain** is an internetwork where all routers are under a single administritative entity (e.g. university campus).
- Each domain uses IGPs to route packages within its boundaries and uses gateway routes to forward packets to other domains (inter-domain routing).

1.1 Graph Representation of Routing

Routing is a graph-theoretic problem and requires one to calculate the lowest-cost path between two nodes.

- Nodes are hosts, switches, routers or networks
- Edges are network links, each associated with a cost.
- Cost of a path is the sum of the costs of all traversed edges.

There are two main types of algorithms for solving the problem:

- Global routing: all routers have complete topology and link cost info — "link state" algorithms.
- Decentralised routing: router knows link costs to neighbours — "distance vector" algorithms.

1.2 Link State Routing Algorithm

Dijkstra's Shortest Path Algorithm is based on a link state broadcast, aiming to provide all nodes with the same information. After k iterations, the algorithm knows the least cost path to k destinations. Notation is as follows:

c(x,y) Link cost from node x to y, $c = \infty$ if not direct neighbours

D(V) Current value of cost of path from source to destination v.

p(v) Predecessor node along path from source to v.

N' Set of nodes whose least cost path is definitively known.

1.3 Distance-Vector Routing Algorithm

One classic example is the **Bellman-Ford routing algorithm** (1957) and **Ford-Fulkerson algorithm** (1962). It is a **dynamic routing algorithm** and was used in the Internet Protocol under the name RIP (Routing Information Protocol).

Each node stores an array (a **vector**) containing the currently believed distances to all other nodes. Initially this distance is ∞ for all nodes except the considered node's immediate neighbours. Vectors are distributed to a node's immediate neigbours.

1.4 Dimension-Order Routing

Some network configurations can be vulnerable to deadlock. Deadlock arises when a cyclic resources dependency occurs and the messages become blocked forever. Dimension-order routing can avoid deadlock by removing one of the conditions: circular dependency.

- XY Routing:
  - Forbid any Y to X turn
  - It is deterministic
- West-first Routing:
  - Forbid the west turns only
  - Partially adaptive

2 Inter-Domain Routing

2.1 Border Gateway Protocol (BGP)

BGP is the de facto inter-domain routing protocol for the Internet. It supports route coordination across domains, referred as **"autonomous systems" (AS)**. BGP provides routers a means to:

e(xternal)BGP Obtain subnet reachability information from neighbouring ASs.

i(nternal)BGP Propogate reachability information to all AS-internal routers.

Determine *good* routes to other networks based on reachability information and policy.

See lecture slides for example.