05. The Network Layer: Control Plane

Includes chapters 5.1, 5.2, and 5.6 only.

5.1 Introduction

As opposed to the data plane, the control plane determines the full route for a diagram or packet instead of which outbound link to forward to like the data plane does.

Traditionally, the routing has been done per router where a routing algorithm runs in each and every router, meaning both forwarding and routing functions are contained in each router. Examples of per router protocols are OSPF and BGP.

Logically centralized control is software-based control where a centralized controller computes and distributes forwarding tables to be used in each and every router. SDN is an example of logically centralized control, where the main server communicates to each router to define rules.

5.2 Routing Algorithms

Routing algorithms view the network of routers as a graph, $G = \langle N, E \rangle$ where N is the set of nodes, and E is the set of edges. Each edge may be assigned a cost which is used to judge how expensive (in terms of latency, etc.) taking one route (edge from $N_1 \rightarrow N_2$) is. If all costs are equal, the cheapest path is the path with the fewest nodes.

It's not as simple as figuring out the cheapest path, because organization X may rule that none of their data should go through links in organization Z network, making the matter more difficult.

There are primarily two types of routing algorithms:

1. Centralized routing algorithm: this algorithm knows every node, edge, and cost in the networking, making it easy to determine the lowest cost path. These are so-called Link-State algorithms (LS).

2. Decentralized routing algorithm: calculation is done in an iterative, distributed manner by the routers. No node in the network has knowledge of all costs, so by exchanging information with its neighbors, the routers can determine costs. An example is a distance-vector algorithm (DV).

A link-state algorithm knows about the costs of each node in the network, making it possible to determine the cheapest way easily. This can be done with Dijkstra's algorithm for finding the shortest path between a weighted graph. It's quite performant, but there may occur oscillations if the cost is based on link traffic because you may overload a smaller route because it had little traffic when measured.

In a decentralized routing algorithm, each node waits for a change in local link cost (maybe the neighbor disconnected/lost another link), then you should recompute an estimated distance. If the distance has changed, you should notify your neighbors.

5.6 ICMP: The Internet Control Message Protocol

ICMP is a protocol that architecturally lies on top of the IP protocol (such as TCP/UDP). It is used between routers to communicate for use in their routing algorithms. ICMP has a set of pre-defined messages that may be sent.

ICMP Type	Code	Description
0	0	echo reply (to ping)
3	0	destination network unreachable
3	1	destination host unreachable
3	2	destination protocol unreachable
3	3	destination port unreachable
3	6	destination network unknown
3	7	destination host unknown
4	0	source quench (congestion control)
8	0	echo request
9	0	router advertisement
10	0	router discovery
11	0	TTL expired
12	0	IP header bad