chapter 5 : control plane

Data plane ⇐ - forwarding : move packets from router's input to output.

control plane ⇐ - routing : determine routers taken by packets (route) from source to destination.

structuring control plane

per router (traditional)	logically centralized control (software defined networking)
⇓	⇓
individual routing algorithm components in every router	remote controller computes & installs forwarding tables.

Routing protocols

↳ Goal : find best path from sending host to recieving ones
↳ by cost, fastest, least congested

Routing Algorithm classification

① global : all routers have complete topology & link costs (e.g. link state)
② decentralized : iterative computation & exchange of info with only neighbors (e.g. distance vector)
③ static : routes change slowly over time. (user manually adds an algorithm to each router)
④ dynamic : routes change more quickly.

Dijkstra's Link-state

- centralized (network topology known to all nodes)
- iterative

- if x is a neighbor of y then initially $c_{xy} = z$ else $c_{xy} = \infty$
- complexity : $O(n^2)$ (not most efficient)
- message complexity also $O(n^2)$

⟹ oscillations possible when link costs depend on traffic.

Distance vector

- based on Bellman ford equation (dynamic programming)

$$D_x(y) = \min_v \{c_{x,v} + D_v(y)\}$$

↳ to go from x to y first find the minimum cost through a vector (v) + your cost to v

- iterative, asynchronous, an iteration can be caused by:
  1. local link cost change
  2. DV update message from neighbors.
- distributed, self stopping : each node notifies neighbors only when it's DV changes.
  (if necessary ⊆ (if something changed))
  - neighbors then notify their neighbors.
  - nothing changes if no notification.
- initially a node has distance estimates to it's neighbors only.

"good news travel fast" "bad news travel slow"

	"LS"	"DV"
message complexity	$O(n^2)$	varies
speed of convergence	$O(n^2)$ for both messages & algorithm. - oscillation can happen	varies - may have routing loops & count to infinity
robustness (if router malfunctions)	- router can advertise wrong link cost - routers compute only their own table	- router can advertise wrong path cost. ⟹ black holing - errored DV propagate through network.

- intra-AS : routing among router within same AS (Network).
  - ↳ routers in same AS must run same intra-AS protocol.
  - ↳ gateway router: router at edge of an AS that is linked to other ASes.

inter-AS: routing among ASes.

- in gateway routers they have both intra & inter domain routing

intra-AS

Protocols: → RIP (DV) (no longer used) (RFC 1723)
→ EIGRP (DV) (RFC 7868)
→ OSPF (LS) (IS-IS protocol) (not RFC standard)
(RFC 2328) ↳ a protocol similar to ospf

OSPF

- open & public - LS
- secure : all message authenticated (to prevent malicious intrusion)

hierarchical OSPF

2 level hierarchy → backbone
↘ local areas.

- LS advertisments only in the area.
- area border router : advertizes the distances to destinations of its own area to backbone
- boundary router : connects to other ASes
- backbone router runs OSPF to backbone.
- local routers → flood LS in area only
  - ↘ compute routing within area
  - ↘ Forward packets outside of area via area border router

BGP (Border Gateway protocol)

↳ Inter-AS protocol (eBGP)

used to: ① obtain reachability to a destination info from neighbor ASes.
② determine routes to other network based on reachability & policy.
③ propagate reachability to all AS internal routers (iBGP)
④ advertise to neighbors reachibility info

* gateway routers run eBGP & iBGP
* BGP is a "Path vector"
* BGP session: 2 BGP routers exchange messages over semi-permanent TCP connection.
* BGP Messages:
  * open: opens a TCP connection to remote BGP peer & authenticates sending BGP peer.
  * Update: advertises new path or removes old one.
  * keep alive: keep connection alive when no updates & acks OPEN.
  * Notification: reports errors in previous msg & used to close connections.
* BGP advertised route ⟶ prefix: destination being advertised
  ↳ attributes ⇒ AS-PATH: list of ASes which prefix advertisment has passed
  NEXT-HOP: indicates specific internal-AS router to next-hop AS.
* routing can be policy based more than cost effictive.
* Hot potato routing: when a ~~host~~ router chooses the least intra-domain cost local gateway router without worrying about inter-domain cost.
* route selection based on
  ① policy
  ② shortest AS-Path
  ③ closest Next-Hop (hot Potato)
  ④ additional criteria
* intra focuses on performance while inter focuses on policy.