3.5.3 Open Shortest Path First

- Open Shortest Path First (OSPF) is also an intradomain routing protocol like RIP, but it is based on the link-state routing protocol we described earlier in the chapter.
- OSPF is an open protocol, which means that the specification is a public document.(https://www.rfc-editor.org/rfc/rfc2328.html)

Metric

- In OSPF, like RIP, the cost of reaching a destination from the host is calculated from the source router to the destination network. However, each link (network) can be assigned a weight based on the throughput, round-trip time, reliability, and so on. An administration can also decide to use the hop count as the cost.
- An interesting point about the cost in OSPF is that different service types (TOSs) can have different weights as the cost.
- Figure 3.5.3.1 shows the idea of the cost from a router to the destination host network. We can compare the figure with Figure 3.5.2.1 for the RIP.

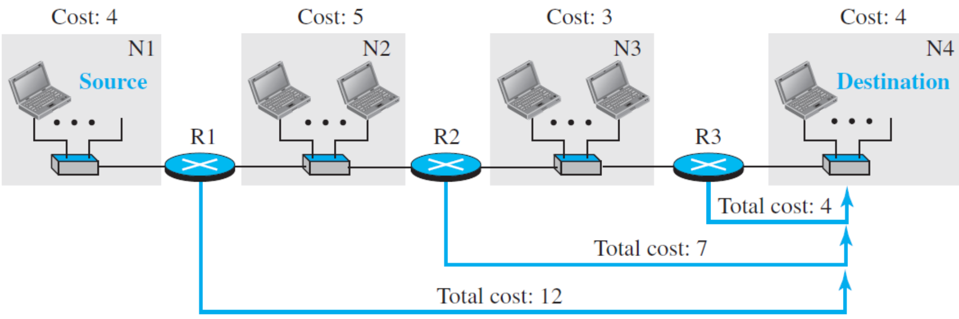

Figure 3.5.3.1 Metric in OSPF

Forwarding Tables

- Each OSPF router can create a forwarding table after finding the shortest-path tree between itself and the destination using Dijkstra's algorithm, described earlier in the chapter.
- Figure 3.5.3.2 shows the forwarding tables for the simple AS in Figure 3.5.3.1.
- Comparing the forwarding tables for the OSPF and RIP in the same AS, we find that the only difference is the cost values. In other words, if we use the hop count for OSPF, the tables will be exactly the same.
- The reason for this consistency is that both protocols use the shortest-path trees to define the best route from a source to a destination.

Forwarding table for R1

Destination network	Next router	Cost
N1	——	4
N2	——	5
N3	R2	8
N4	R2	12

Forwarding table for R2

Destination network	Next router	Cost
N1	R1	9
N2	——	5
N3	——	3
N4	R3	7

Forwarding table for R3

Destination network	Next router	Cost
N1	R2	12
N2	R2	8
N3	——	3
N4	——	4

Figure 3.5.3.2 Forwarding tables in OSPF

Areas

- Compared with RIP, which is normally used in small ASs, OSPF was designed to be able to handle routing in a small or large autonomous system.
- However, the formation of shortest-path trees in OSPF requires that all routers flood the whole AS with their LSPs to create the global LSDB. Although this may not create a problem in a small AS, it may have created a huge volume of traffic in a large AS.
- To prevent this, the AS needs to be divided into small sections called areas. Each area acts as a small independent domain for flooding LSPs. In other words, OSPF uses another level of hierarchy in routing: the first level is the autonomous system, the second is the area.
- However, each router in an area needs to know the information about the link states not only in its area but also in other areas.
- For this reason, one of the areas in the AS is designated as the backbone area, responsible for gluing the areas together. The routers in the backbone area are responsible for passing the information collected by each area to all other areas.
- In this way, a router in an area can receive all LSPs generated in other areas. For the purpose of communication, each area has an area identification. The area identification of the backbone is zero.
- Figure 3.5.3.3 shows an autonomous system and its areas.

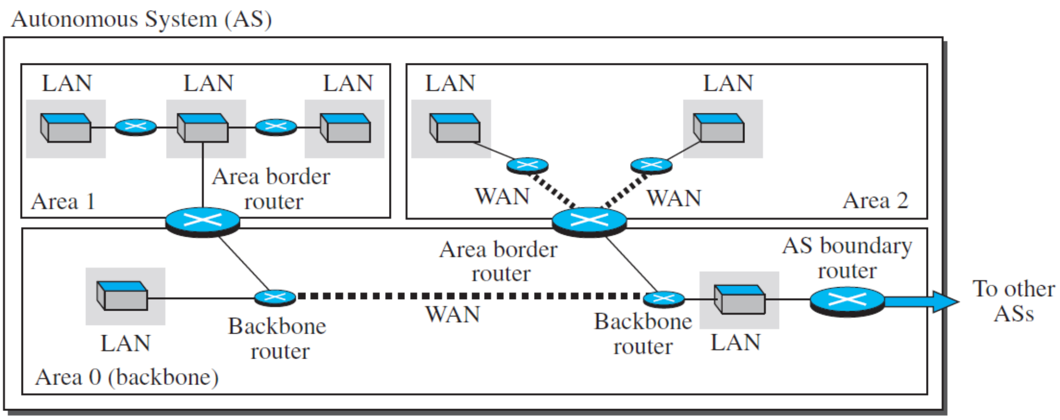

Figure 3.5.3.3 Areas in an autonomous system

Link-state advertisements

- OSPF is based on the link-state routing algorithm, which requires that a router advertise the state of each link to all neighbors for the formation of the LSDB.
- When we discussed the link-state algorithm, we used the graph theory and assumed that each router is a node and each network between two routers is an edge.
- The situation is different in the real world, in which we need to advertise the existence of different entities as nodes, the different types of links that connect each node to its neighbors, and the different types of cost associated with each link. This means we need different types of advertisements, each capable of advertising different situations.
- We can have five types of link-state advertisements:

  - router link,
  - network link,
  - summary link to network,
  - summary link to AS border router,
  - and external link.
- Figure 3.5.3.4 shows these five advertisements and their uses.

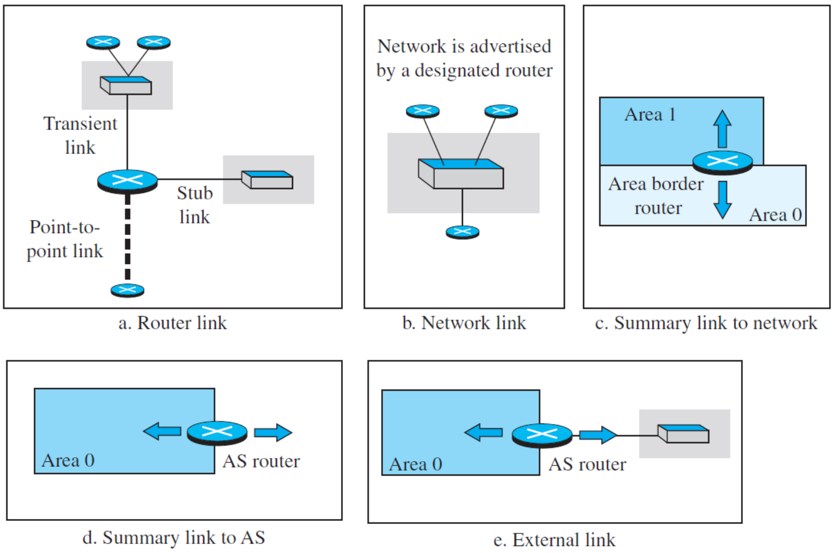

Figure 3.5.3.4 Five different LSPs

- Router link.
  - A router link advertises the existence of a router as a node.
  - In addition to giving the address of the announcing router, this type of advertisement can define one or more types of links that connect the advertising router to other entities.
  - A transient link announces a link to a transient network, a network that is connected to the rest of the networks by one or more routers. This type of advertisement should define the address of the transient network and the cost of the link.
  - A stub link advertises a link to a stub network, a network that is not a through network. Again, the advertisement should define the address of the network and the cost.
  - A point-to-point link should define the address of the router at the end of the point-to-point line and the cost to get there.
- Network link.
  - A network link advertises the network as a node.
  - However, since a network cannot do announcements itself (it is a passive entity), one of the routers is assigned as the designated router and does the advertising.
  - In addition to the address of the designated router, this type of LSP announces the IP address of all routers (including the designated router as a router and not as speaker of the network), but no cost is advertised because each router announces the cost to the network when it sends a router link advertisement.

- Summary link to network.
    - This is done by an area border router; it advertises the summary of links collected by the backbone to an area or the summary of links collected by the area to the backbone. As we discussed earlier, this type of information exchange is needed to glue the areas together.
- Summary link to AS.
    - This is done by an AS router that advertises the summary links from other ASs to the backbone area of the current AS, information which later can be disseminated to the areas so that they will know about the networks in other ASs. The need for this type of information exchange is better understood when we discuss inter-AS routing (BGP).
- External link.
    - This is also done by an AS router to announce the existence of a single network outside the AS to the backbone area to be disseminated into the areas.

OSPF Implementation

- OSPF is implemented as a program in the network layer, using the service of the IP for propagation.
- An IP datagram that carries a message from OSPF sets the value of the protocol field to 89. This means that, although OSPF is a routing protocol to help IP to route its datagrams inside an AS, the OSPF messages are encapsulated inside datagrams.
- OSPF has gone through two versions: version 1 and version 2.
- Most implementations use version 2.

OSPF Messages

- OSPF is a very complex protocol; it uses five different types of messages.
- In Figure 3.5.3.5 , we first show the format of the OSPF common header (which is used in all messages) and the link-state general header (which is used in some messages).
- We then give the outlines of five message types used in OSPF.
    - The hello message (type 1) is used by a router to introduce itself to the neighbors and announce all neighbors that it already knows.
    - The database description message (type 2) is normally sent in response to the hello message to allow a newly joined router to acquire the full LSDB.
    - The link state request message (type 3) is sent by a router that needs information about a specific LS.
    - The link-state update message (type 4) is the main OSPF message used for building the LSDB. This message, in fact, has five different versions (router link, network link, summary link to network, summary link to AS border router, and external link), as we discussed before.
    - The link-state acknowledgment message (type 5) is used to create reliability in OSPF; each router that receives a link-state update message needs to acknowledge it.

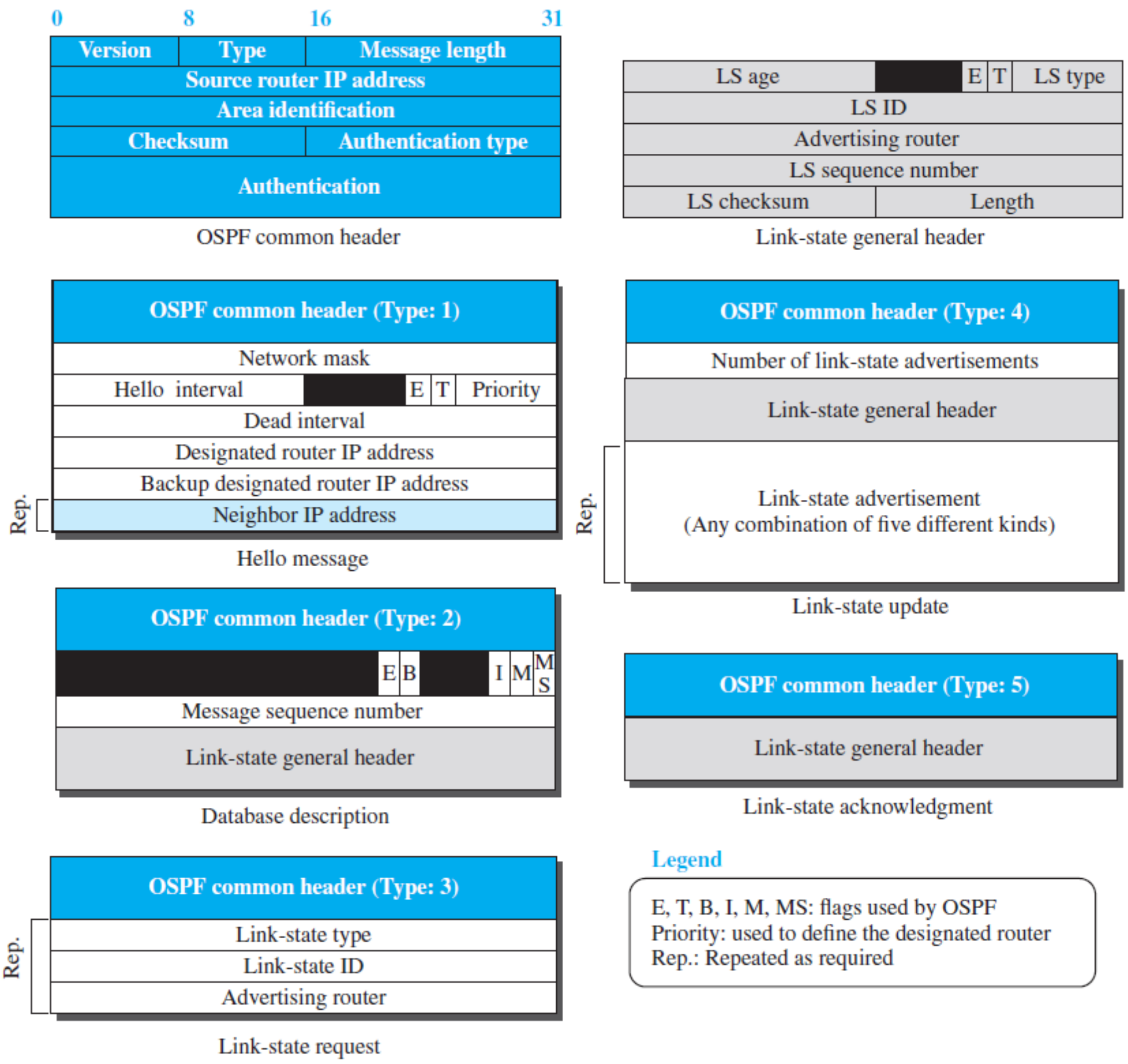

Figure 3.5.3.5 OSPF Message Formats

Authentication

- OSPF common header has the provision of Authentication in its common header.
- This prevents a malicious entity from sending OSPF messages to a router and causing the router to become part of the routing system to which it actually does not belong.

OSPF Algorithm

- OSPF implements the link-state routing algorithm we discussed in the previous section. However, some changes and augmentations need to be added to the algorithm:
    - After each router has created the shortest-path tree, the algorithm needs to use it to create the corresponding routing algorithm.
    - The algorithm needs to be augmented to handle sending and receiving all five types of messages.

Performance

- Update Messages.

  - The link-state messages in OSPF have a somewhat complex format.
  - They also are flooded to the whole area. If the area is large, these messages may create heavy traffic and use a lot of bandwidth.
- Convergence of Forwarding Tables.
  - When the flooding of LSPs is completed, each router can create its own shortest-path tree and forwarding table; convergence is fairly quick. However, each router needs to run Dijkstra's algorithm, which may take some time.
- Robustness.
  - The OSPF protocol is more robust than RIP because, after receiving the completed LSDB, each router is independent and does not depend on other routers in the area.
  - Corruption or failure in one router does not affect other routers as seriously as in RIP.