Chapter 13

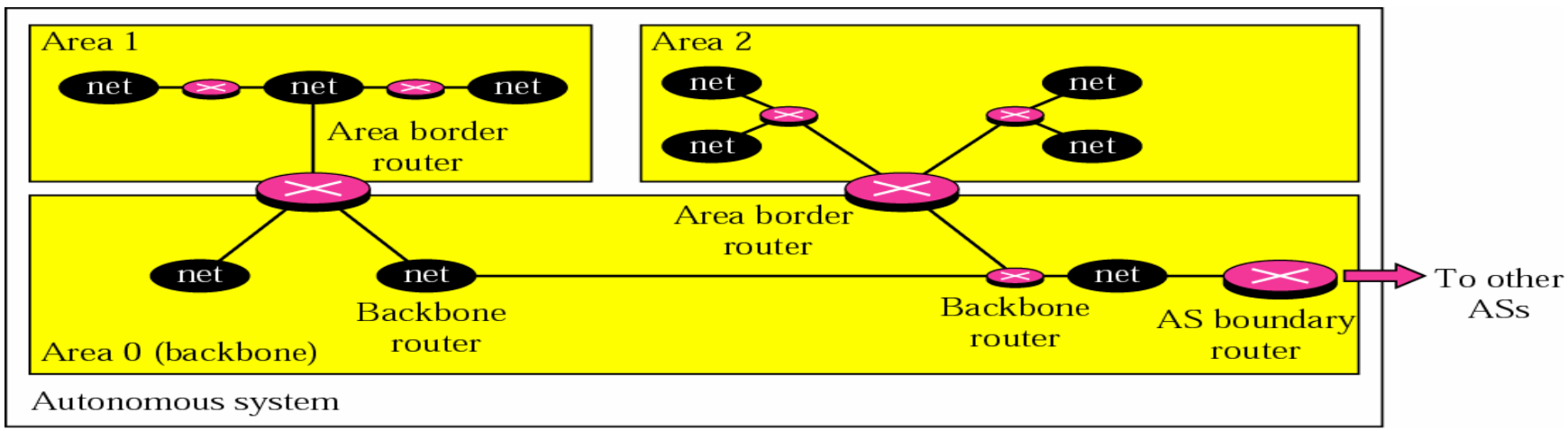
Routing Protocols (RIP, OSPF, BGP)

Part 2

- ✓ **INTERIOR AND EXTERIOR ROUTING**
- ✓ **RIP**
- ➢ **OSPF**
- ➢ **BGP**

13.3 OSPF: Open (i.e. specification publicly available) Shortest Path First

- An interior routing protocol
  - its domain is an Autonomous System (AS)
- For efficiency & faster routing, an AS is divided into "*Areas*"
  - An area is a group of hosts, routers, and networks.
    - Each area has an *Area Identifier*.
  - Inside an area, routing information floods the entire area
  - At the border of an area, special *Area Border Routers* send a summary to other areas.
  - All areas must connect to the special Backbone Area (ID=0)which connects this AS to other Autonomous Systems.

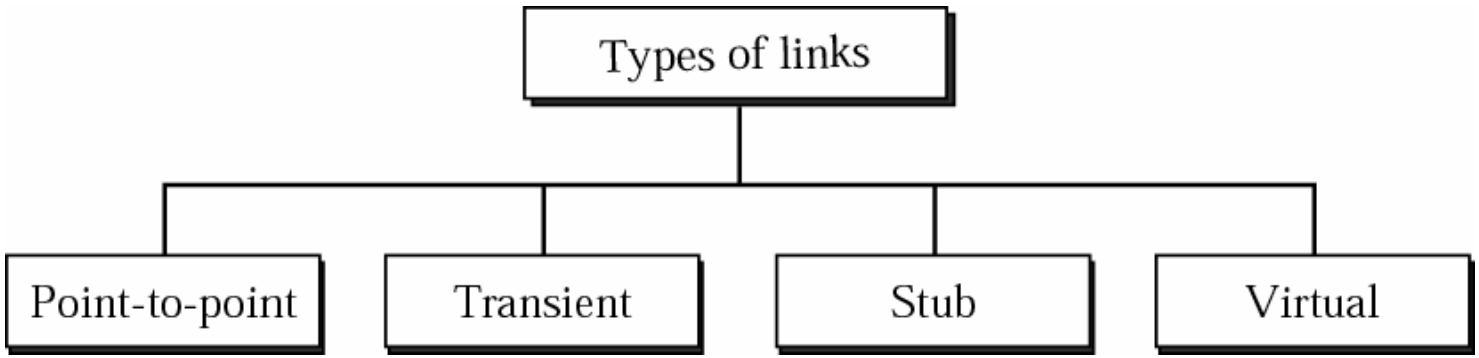


Link State Routing (LSR)

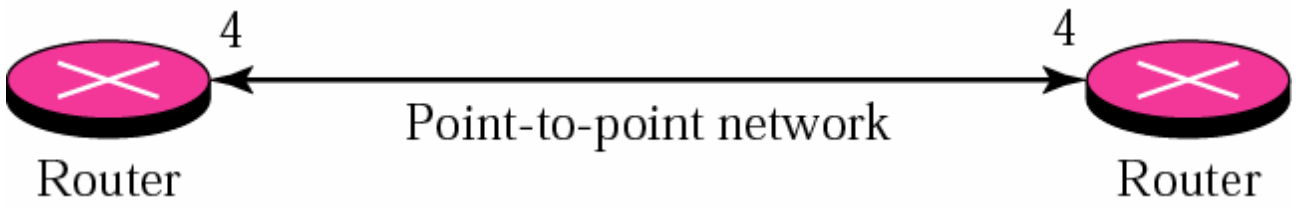
- A process used by OSPF so that each router shares its knowledge about neighbors with all routers in the area.
- Fundamentals of LSR :
  1. Sharing knowledge about the neighborhood.
  2. Sharing with every router in the area, using flooding.
  3. Share only when there is a change.
- LSR's objective: Each router should have the exact topology (*directed weighted graph*) of the Autonomous System at all times.
- Each router locally runs Dijkstra shortest path algorithm to determine a shortest-path tree to all networks with itself as the root node.

Links

- OSPF terminology: *Link* = connection.
- Administrators assign a “metric” (i.e. cost) to each link.
- Links could be directional or bi-directional
  - Bi-directional links may, or may not, cost the same in each direction



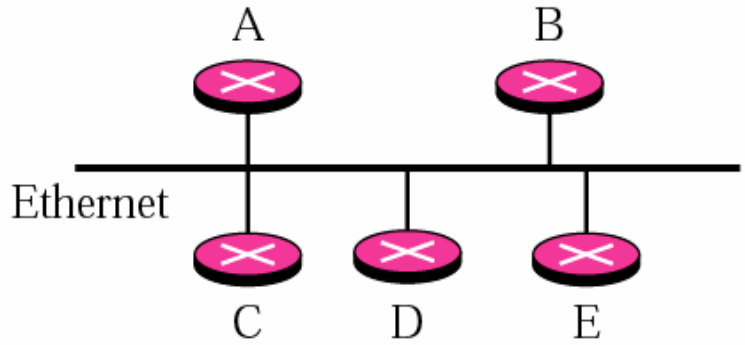
Point-to-point Link



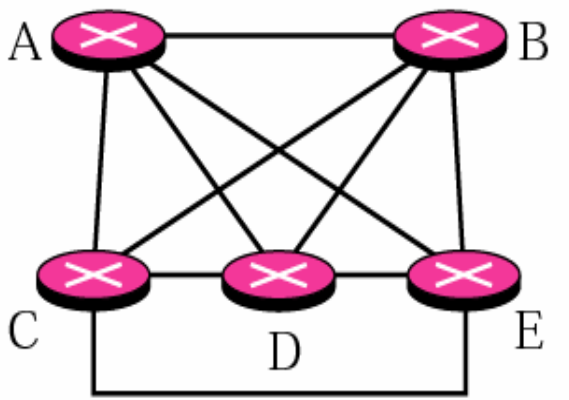
- Connects two routers without any intermediate host or routers.
  - e.g. a telephone line or a T1 line.
- No network address
- Represented as a bi-directional edge connecting the two nodes
  - Equal metrics (cost) for both directions
  - Each router has exactly *one* neighbor.

Transient Link

- A network with two or more routers
- Each router has several neighbors.
- Too many neighborhood advertisements!



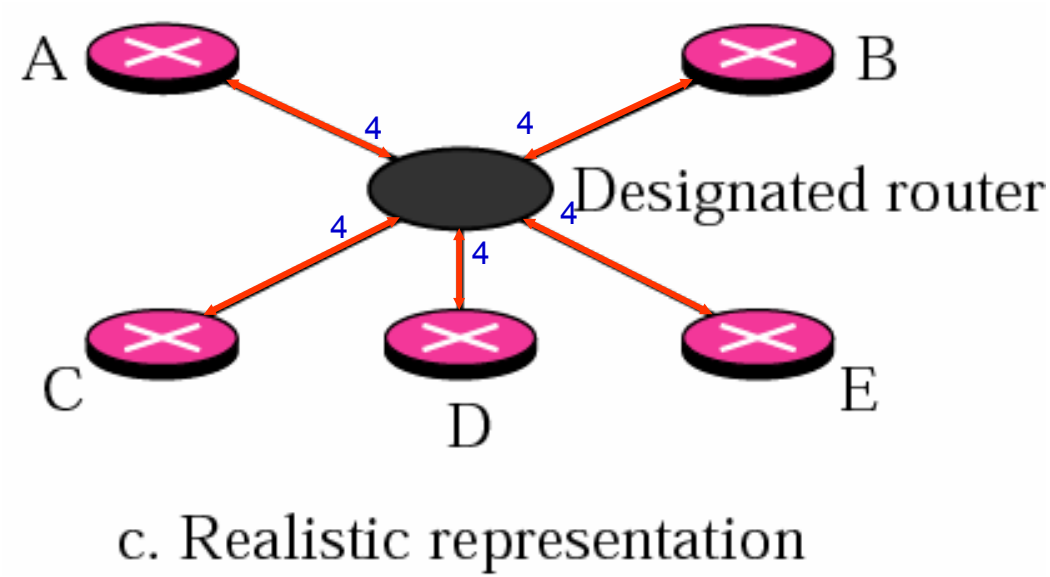
a. Transient network



b. Unrealistic representation

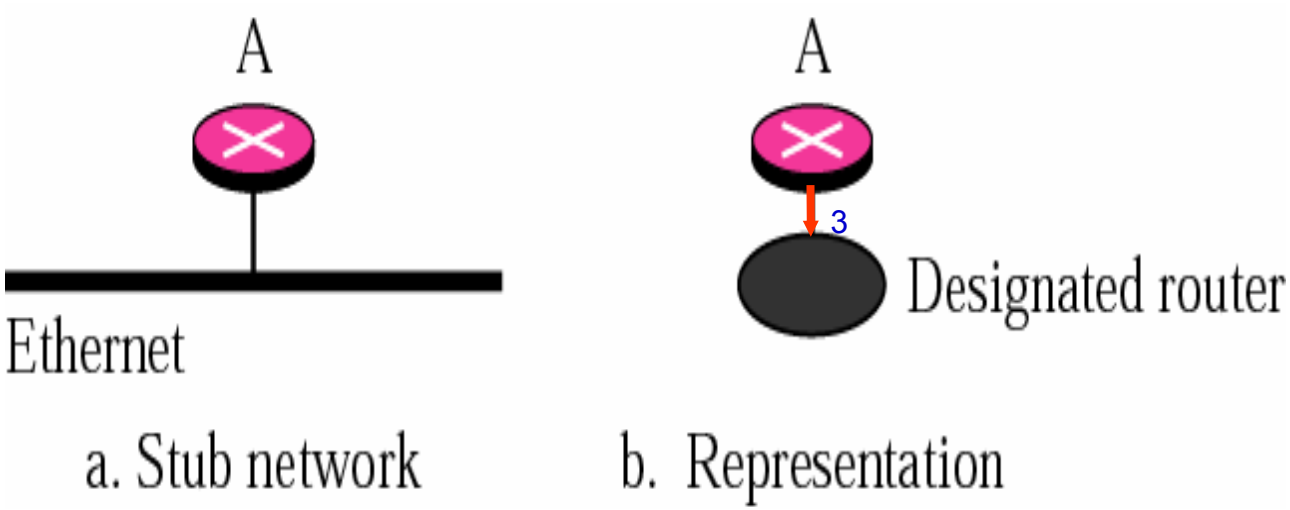
Transient Link – A Realistic Representation

- A Router is chosen from among the routers to be a *Designated Router* (DR), representing the network. It still represents itself.
- Each router advertises one neighbor
- The DR advertises all the router as neighbors
- Bi-directional edges with metrics (cost values) only going into the network (i.e. the DR)



c. Realistic representation

Stub link

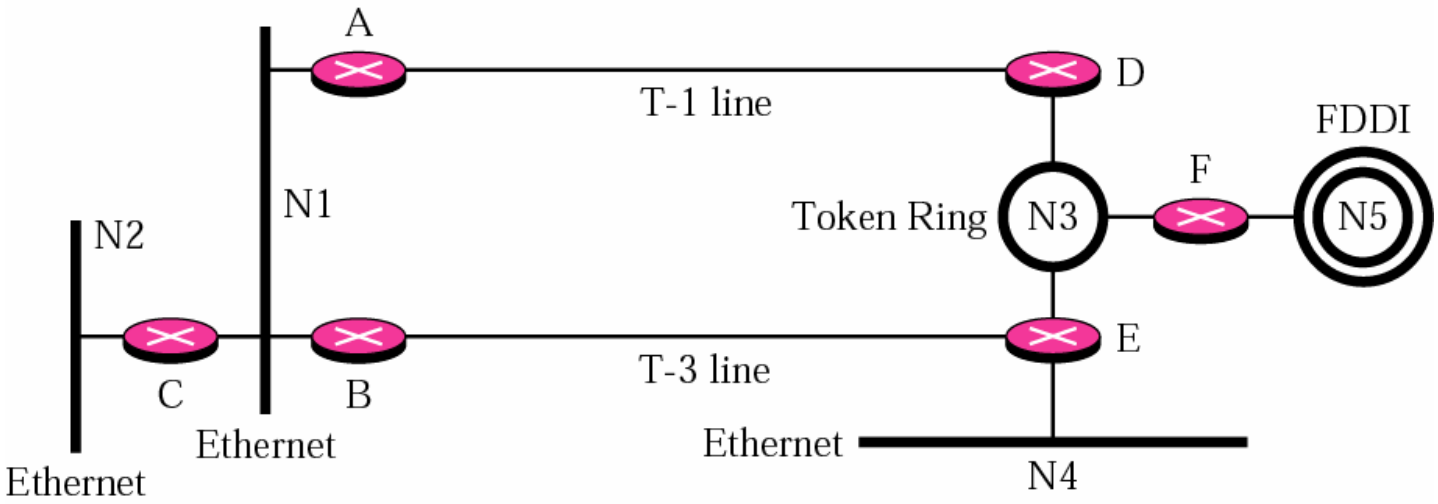


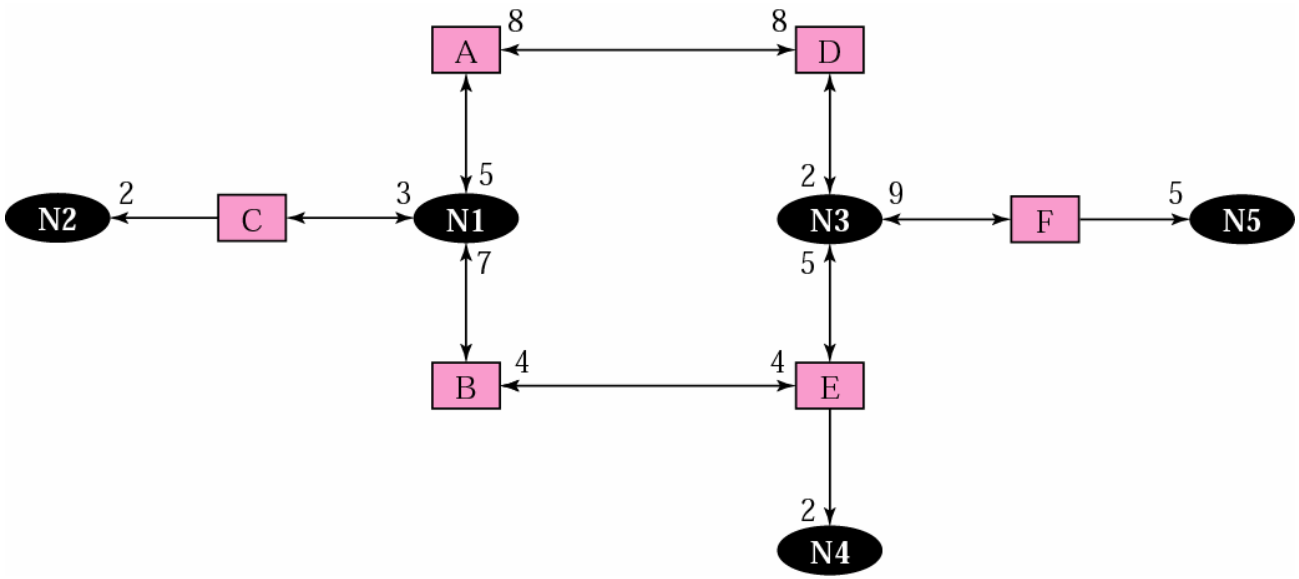
- A network with exactly ONE router.
- One-directional edge from router to the network (represented by the DR).

Virtual Link

- Set up by the AS administration to make up for a broken connection
- May actually span several routers in order to virtually connect two routers who lost their real connection.

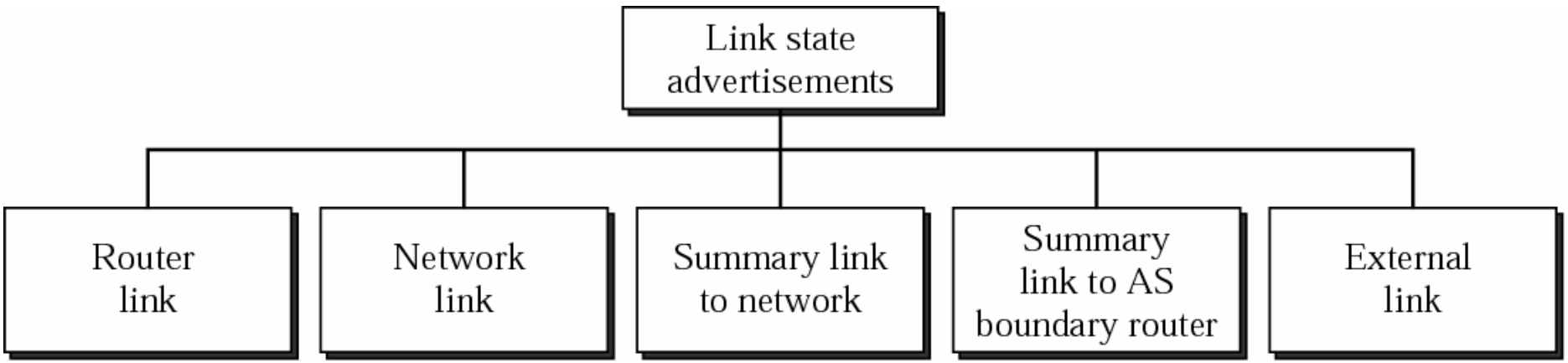
Example of an Internetwork & Its Graphical Representation



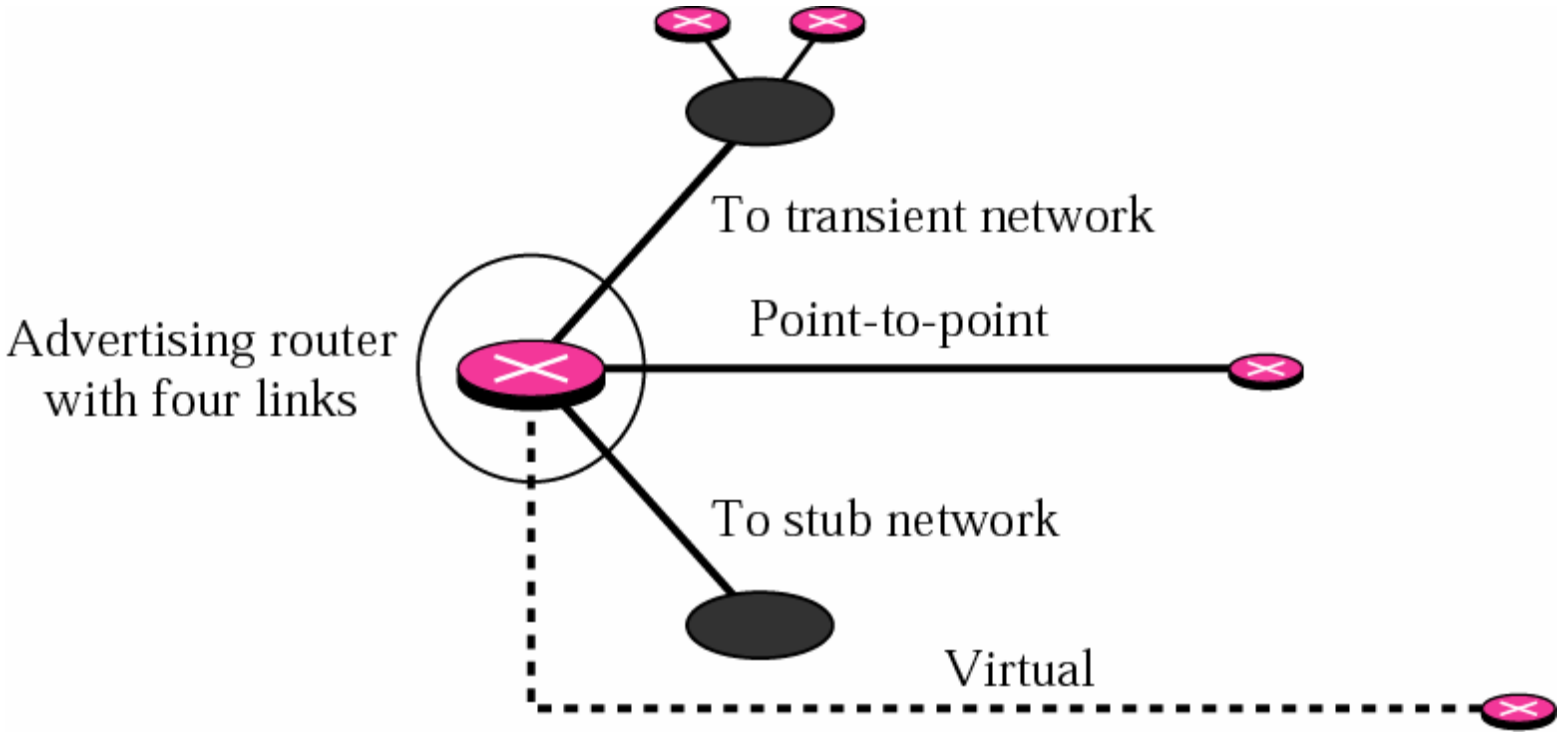


Types of Link State Adertisements (LSAs)

- Each entity (i.e. a true or a designated router) shares its neighborhood information via LSA.

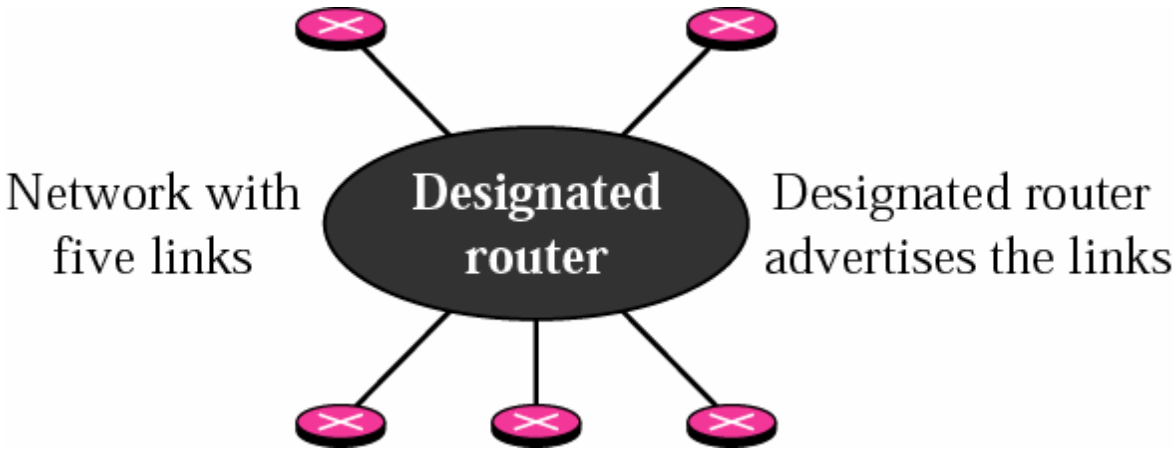


Router link



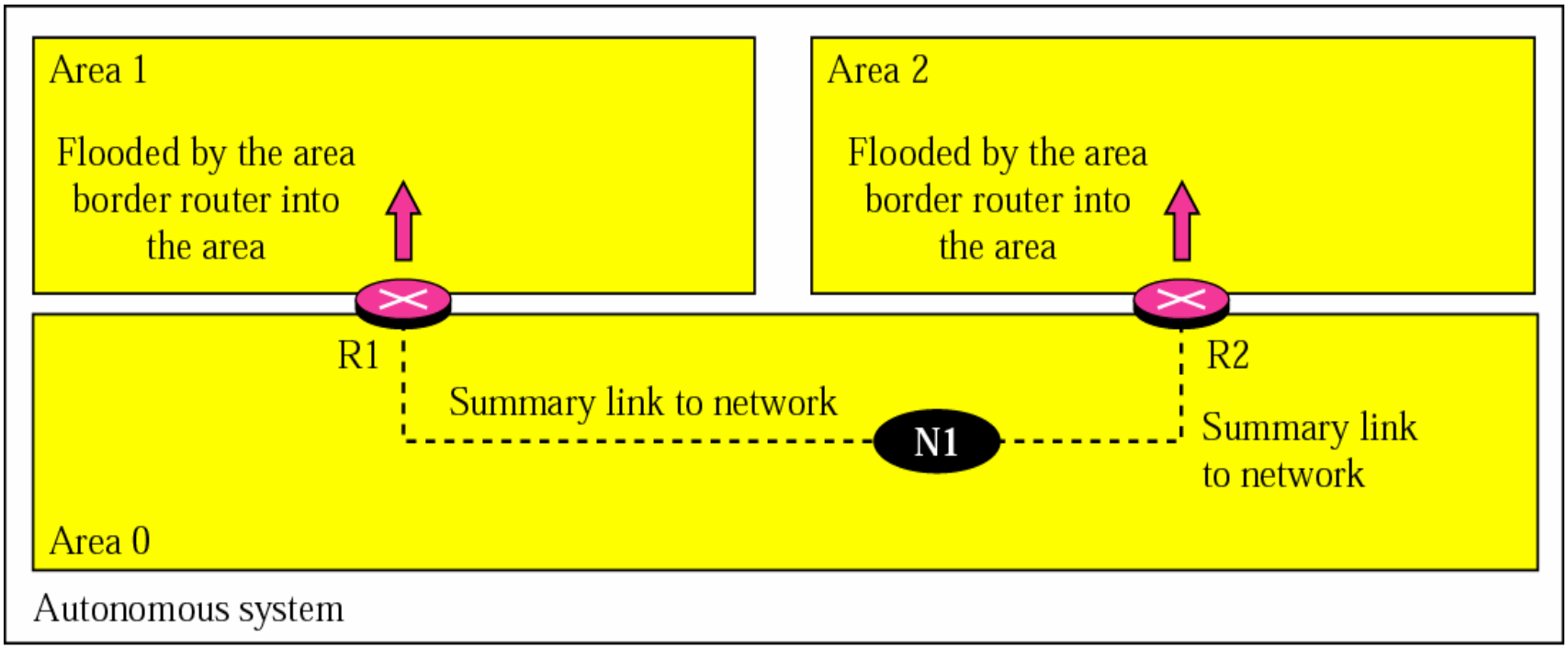
- Generated by a true router to announce all of its links, and who is on the other side of the link (i.e. the neighbor)

Network link



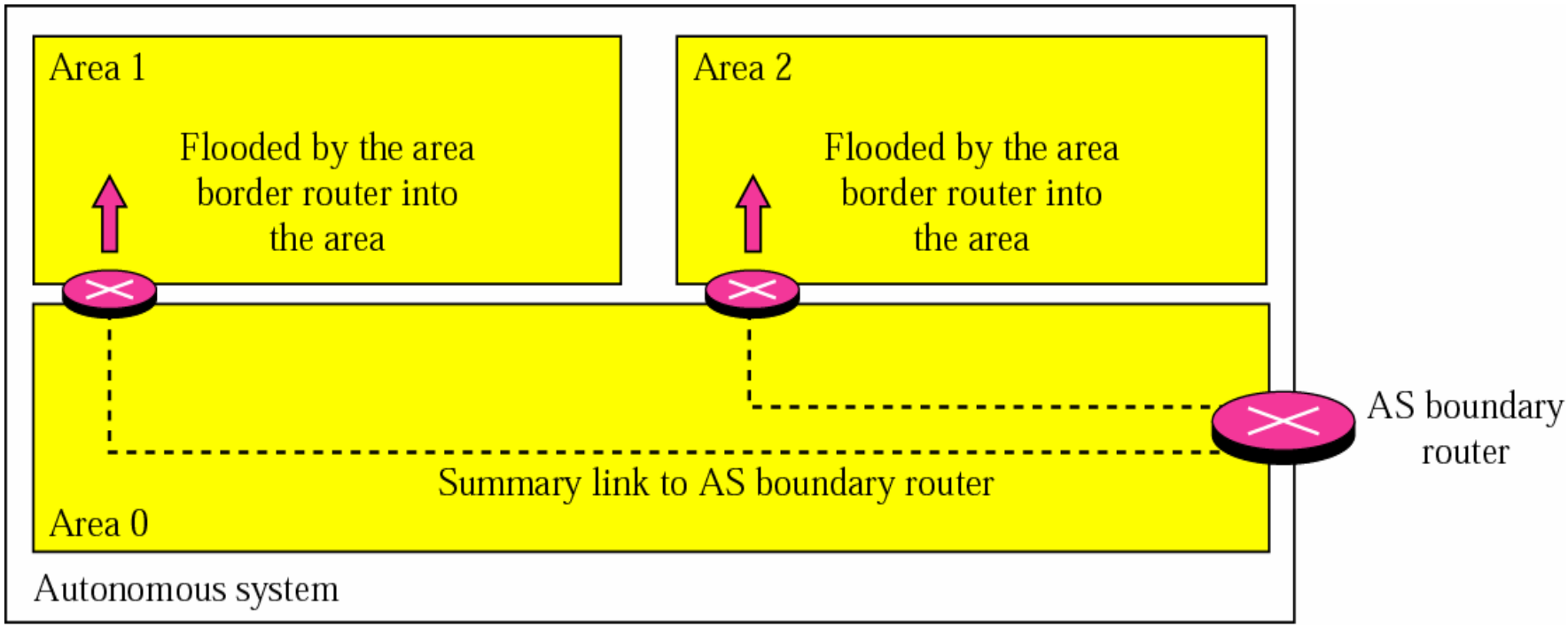
- Generated by a designated router to announce all the true routers connected to a network.

Summary link to network



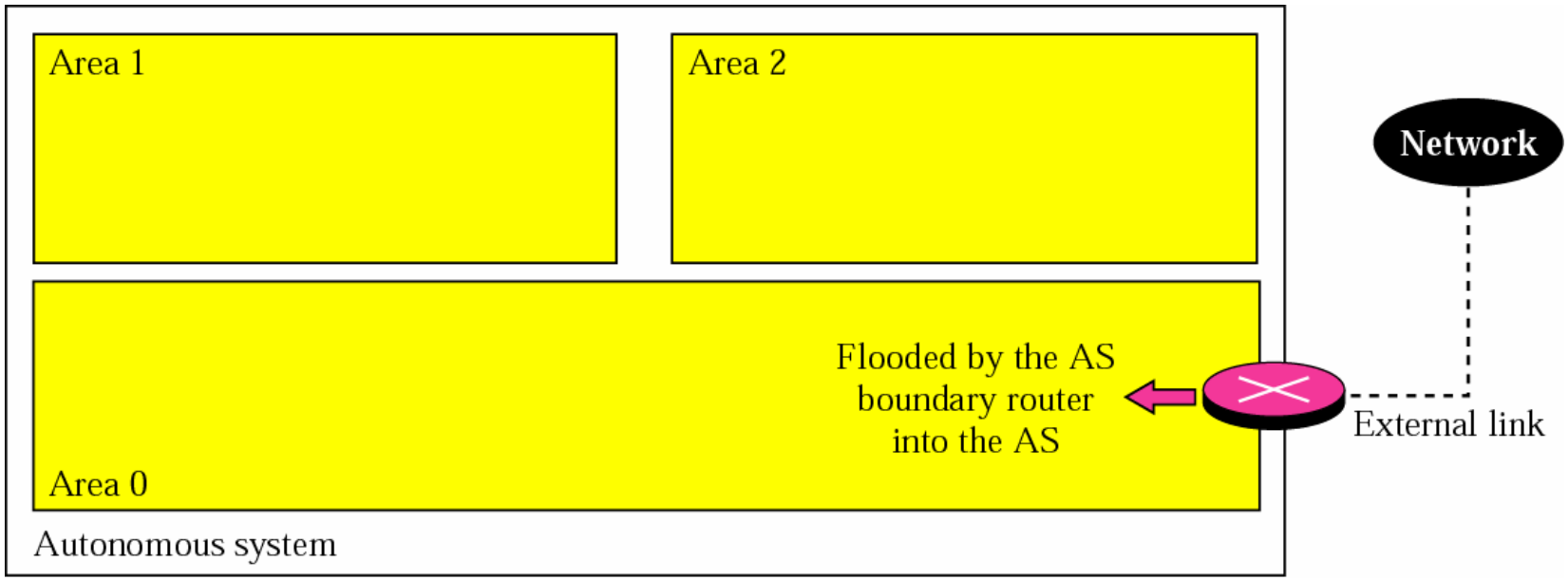
- Generated by an Area Border Router to announce a network from one area to another.

Summary link to AS boundary router



- Generated by an Autonomous System Boundary Router, and dissipated by ABR into areas, to announce the ASBR to all routers in the AS.

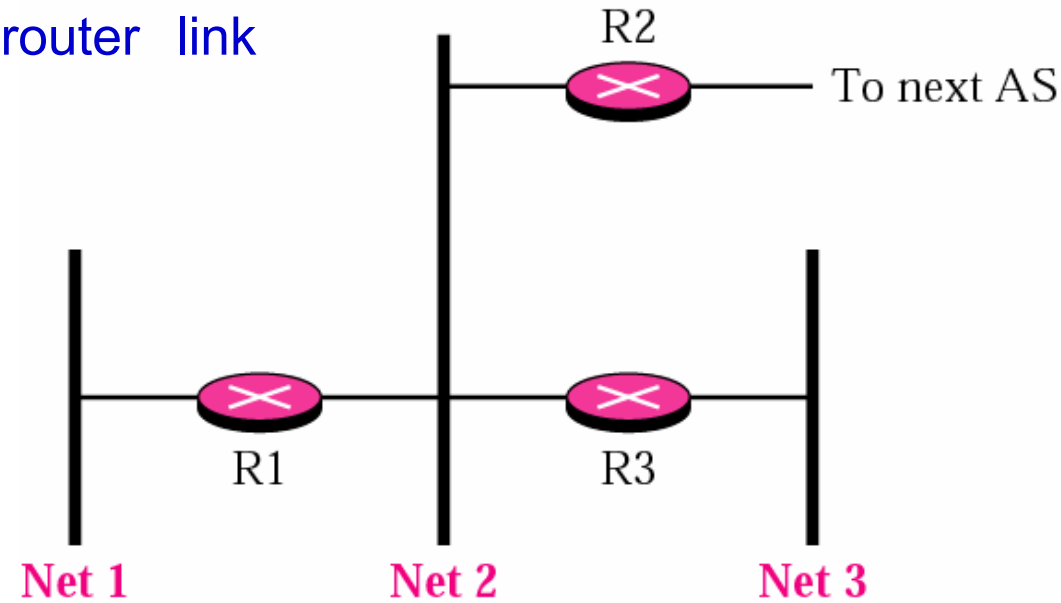
External link



- Generated by an Autonomous System Boundary Router, and dissipated by ABR into all areas, to announce an external network to the routers of the AS.
- The ASBR uses the routing table created by the exterior routing protocol to get such information.

Example 3

Which router(s) sends out router link LSAs?



Solution

All routers advertise router link LSAs.

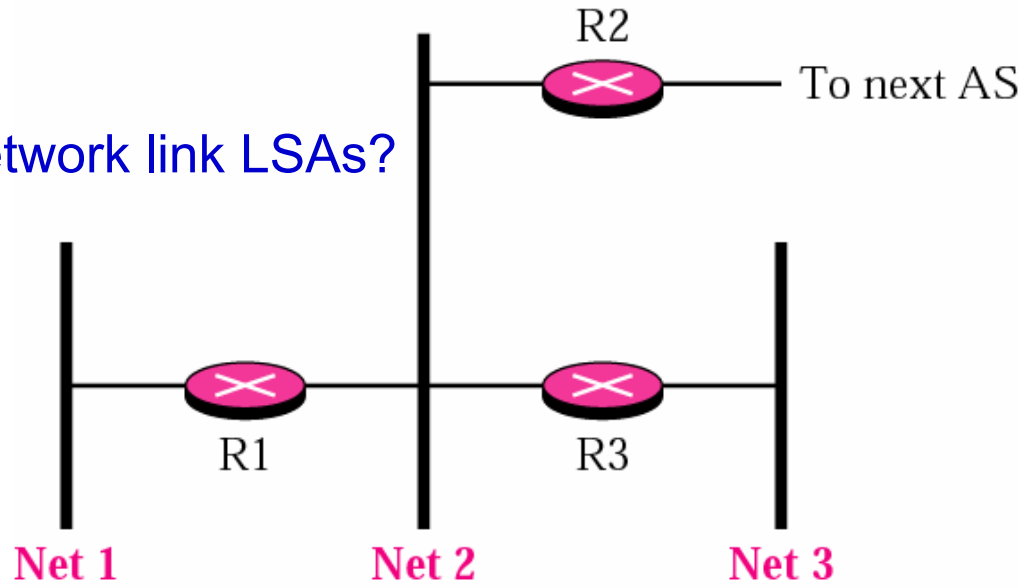
R1 has two links, Net1 and Net2.

R2 has one link, Net2 in this AS.

R3 has two links, Net2 and Net3.

Example 4

Which router(s) sends out the network link LSAs?



Solution

All three network must advertise network links:

Advertisement for Net1 is done by R1 because it is the only router and therefore the designated router.

Advertisement for Net2 can be done by either R1, R2, or R3, depending on which one is chosen as the designated router.

Advertisement for Net3 is done by R3 because it is the only router and therefore the designated router.

Link State Database

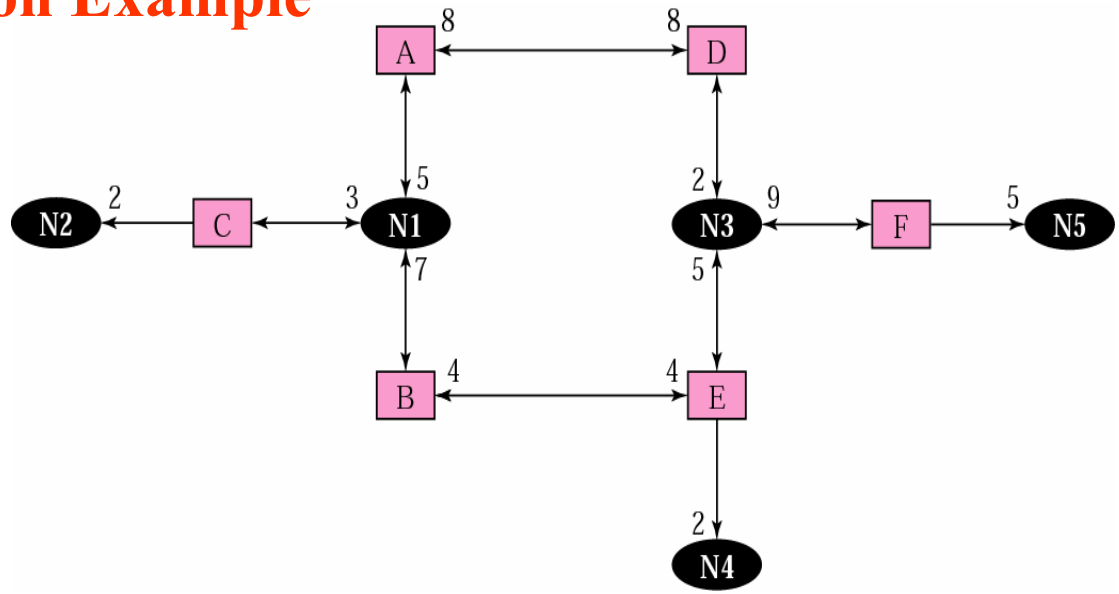
- A tabular representation of the Area topology as seen by a router based on the received router and network link LSAs.
- In OSPF, all routers of an area have the same link state database.
- Dijkstra algorithm operates on this database to create the routing table of an OSPF router.
  - It finds the least expensive (“shortest”) path from the router to all networks in the area.
  - The cost of reaching and out-of-area network is determined by summary and external LSAs

Dijkstra's Shortest-Path Algorithm

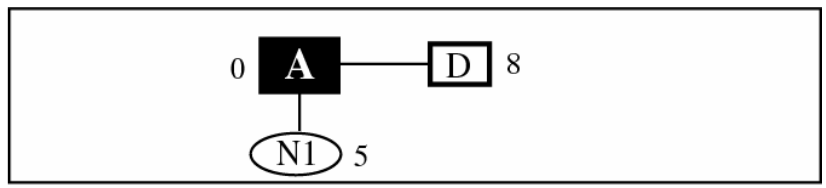
- Objective: Find the least expensive path from a certain router $\mathcal{R}$ to all other nodes in the area.
- Label of a node $\in$ { ***Permanent , Tentative , Unknown*** }
- Let $\mathcal{R}$ be the starting router.
  - Set Cost($\mathcal{R}$) = 0 , Cost (all other routers) = ∞.
  - Mark $\mathcal{R}$ and all its neighbors as ***Tentative***, others as ***Unknown***.
- Repeat while (non-permanent nodes still exist)
  - Mark the least expensive ***Tentative*** node as ***Permanent***.
  - Assign cumulative cost to all its non-permanent neighbors and mark the ***Unknown***s as ***Tentative***s
    - if some neighbors already had a cost value, keep the smallest.
- End.
- Check http://www.deakin.edu.au/~agoodman/graph/dijkstra1.htm for an excellent demonstration.

Shortest Path Calculation Example

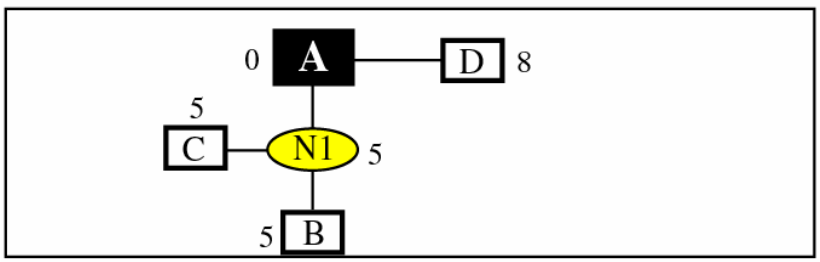
- Building the routing table for Router A



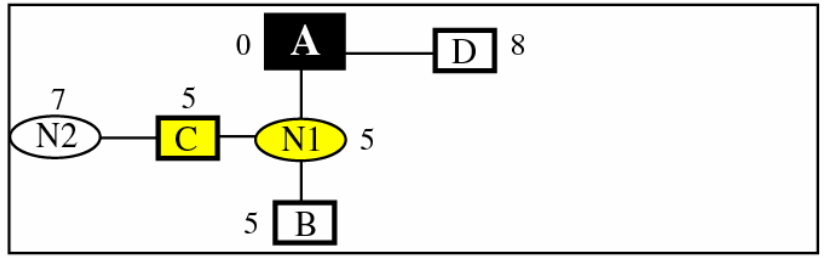
a. Start with A



b. Make A permanent, add its neighbors

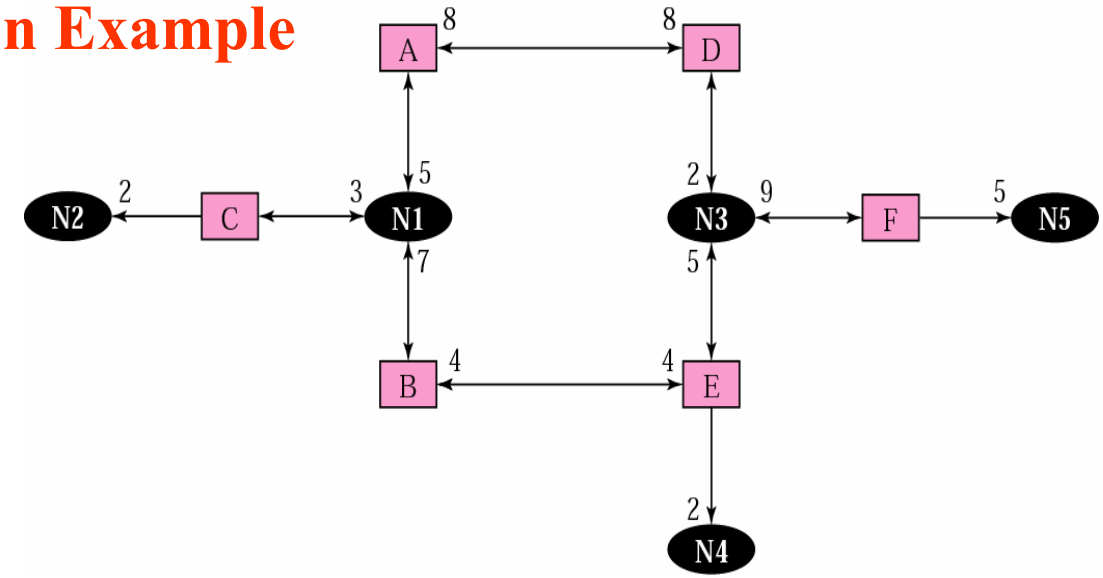


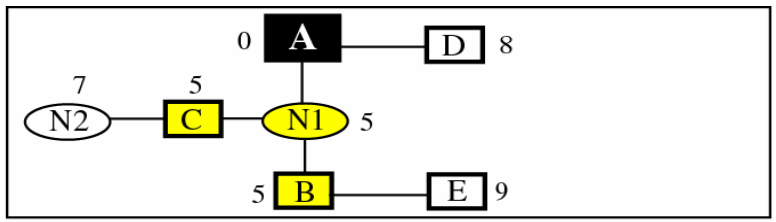
c. Make N1 permanent, add its neighbors



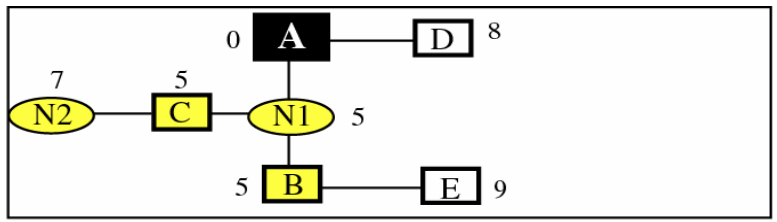
d. Make C permanent, add its neighbors

Shortest Path Calculation Example

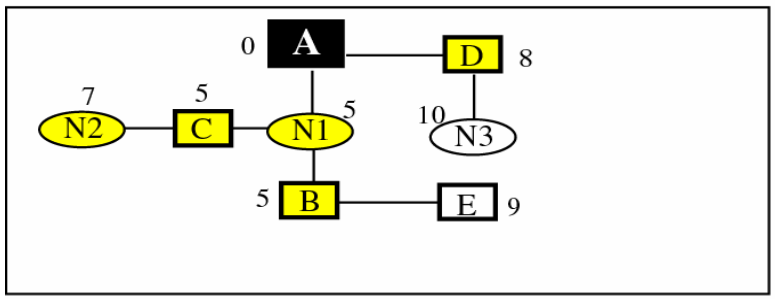




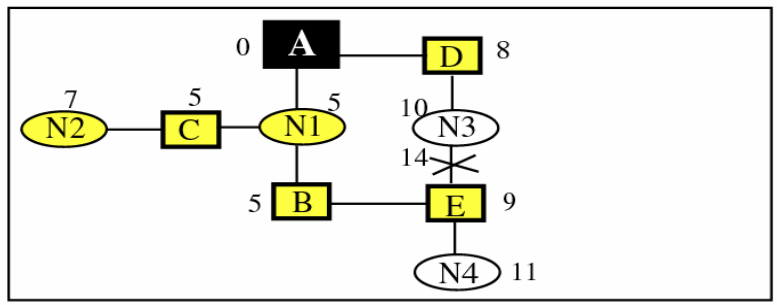
e. Make B permanent, add its neighbors



f. Make N2 permanent



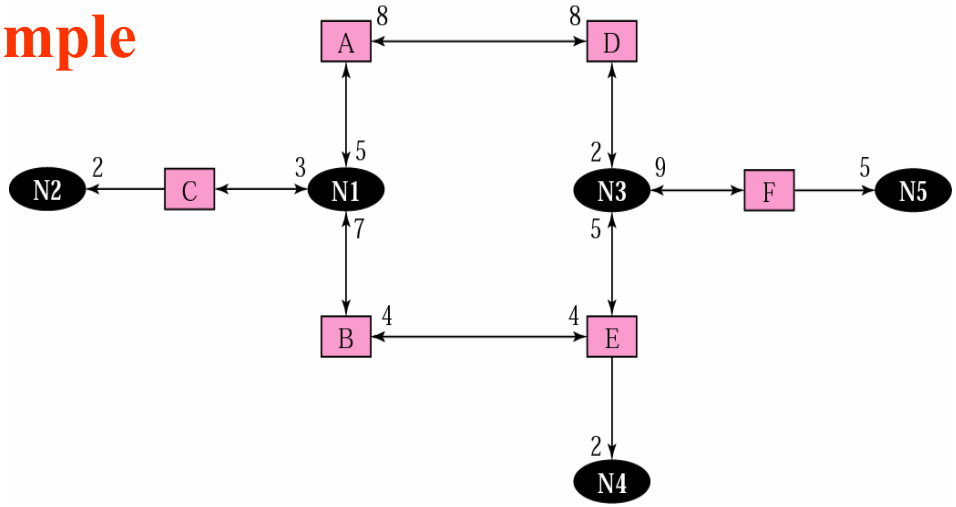
g. Make D permanent, add its neighbors

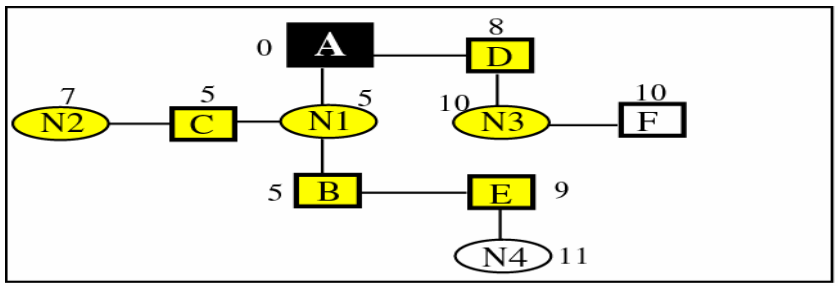


h. Make E permanent, add its neighbors

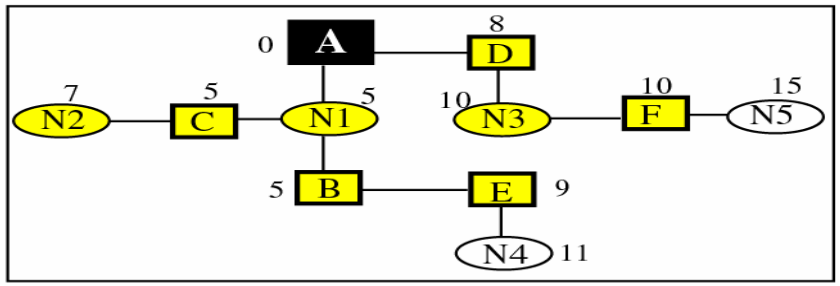
Shortest Path Calculation Example

Network	Cost	Next Router	Other Info
N1	5		
N2	7	C	
N3	10	D	
N4	11	B	
N5	15	D	

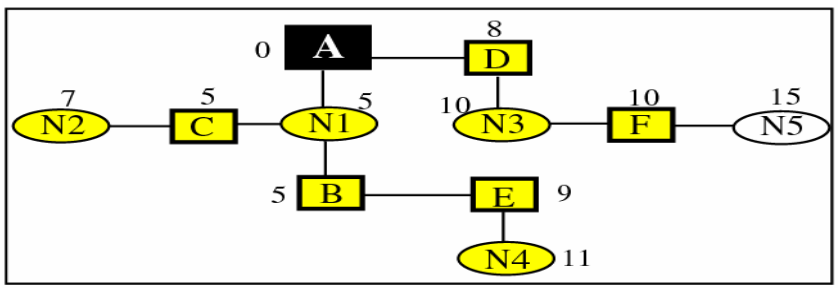




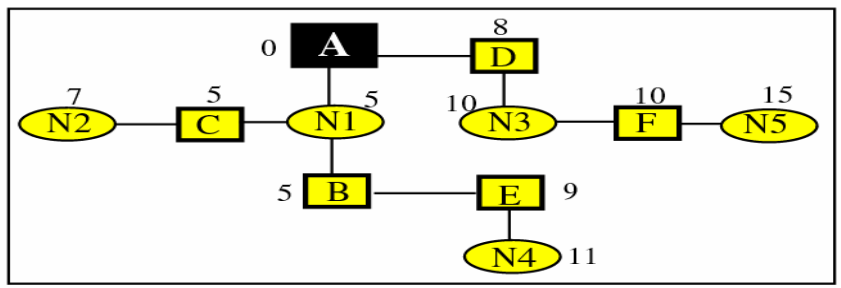
i. Make N3 permanent, add its neighbors



j. Make F permanent, add its neighbors



k. Make N4 permanent



l. Make N5 permanent