Network Layer – Routing Protocol

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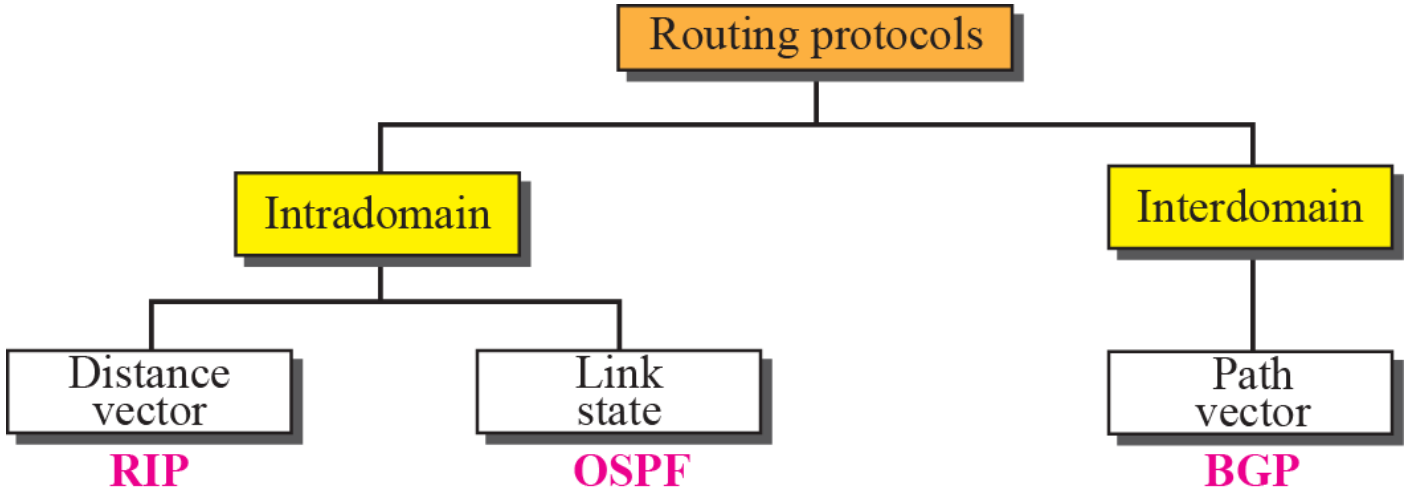
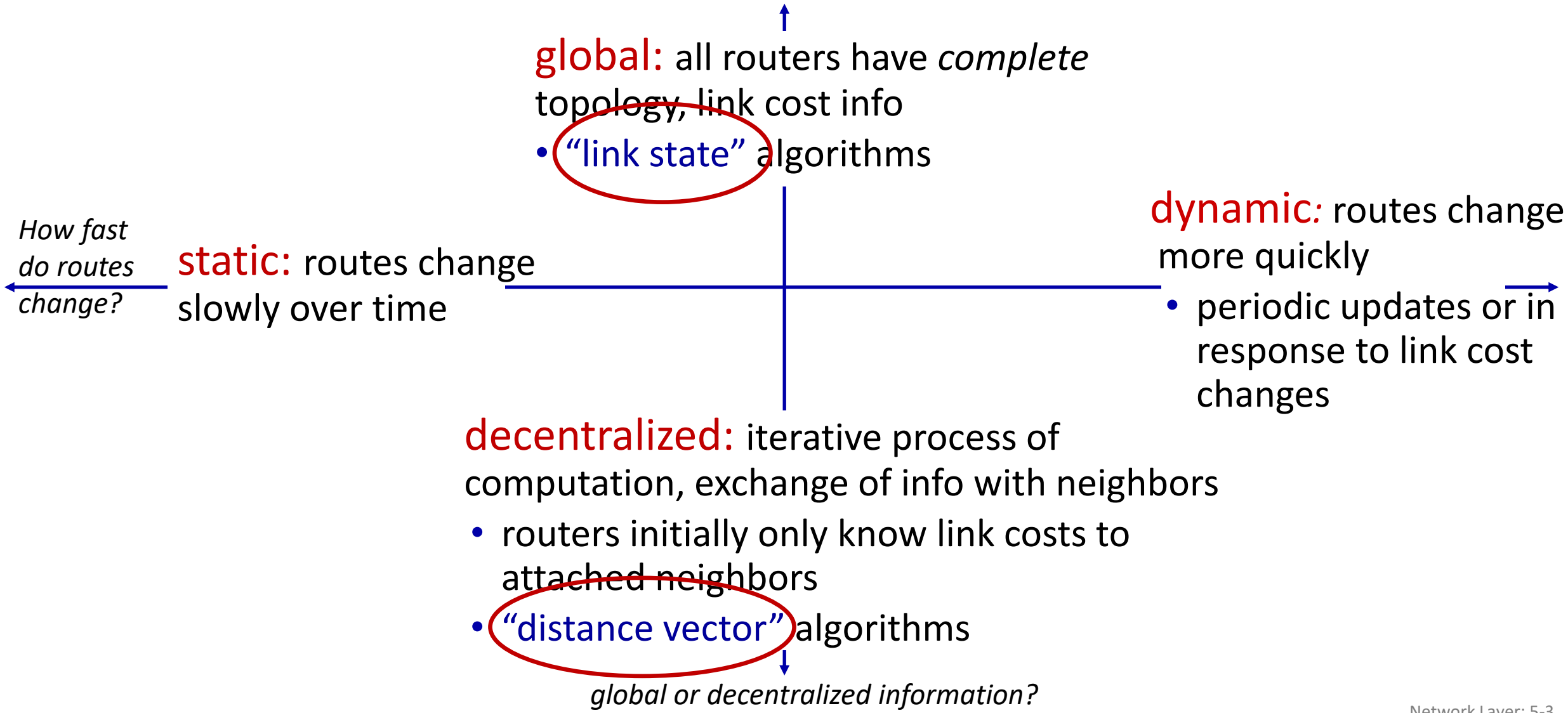
Popular routing protocols



Routing algorithm classification



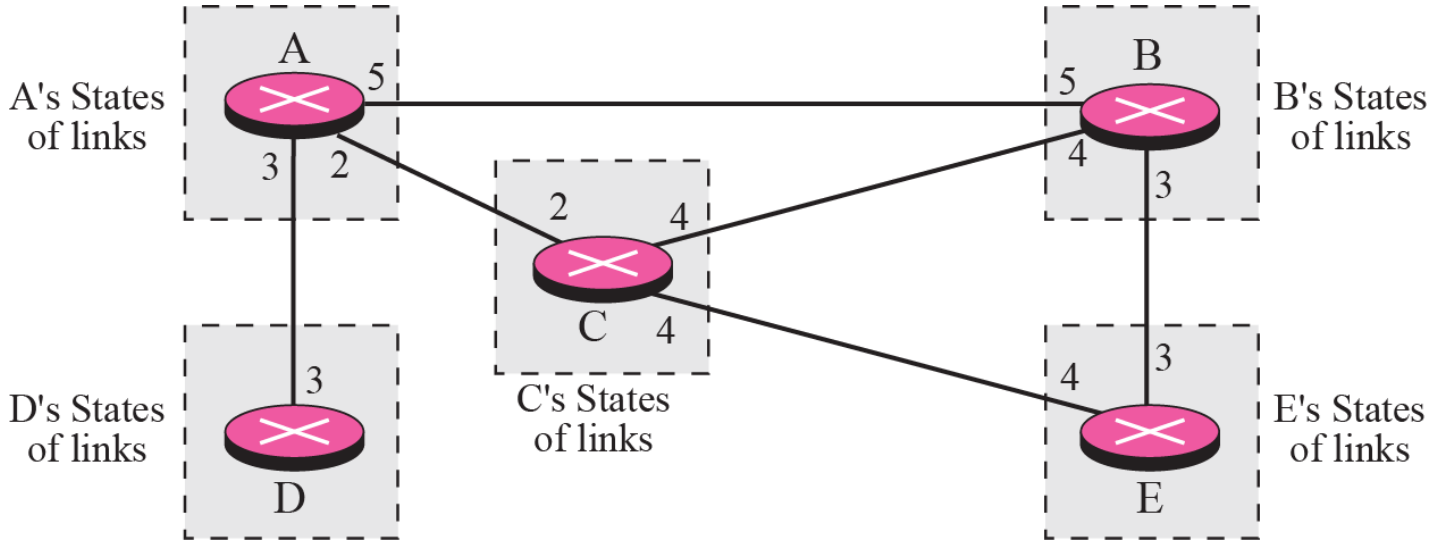
Link state routing

- Link state routing has a different philosophy from that of distance vector routing.
- In link state routing, each node in the domain has the entire topology of the domain—the list of nodes and links, how they are connected including the type, cost (metric), and the condition of the links (up or down)—the node can use the Dijkstra algorithm (single source shortest path) to build a routing table.
- OSPF (Open Shortest path First)

Basic Idea – LSR/OSPF

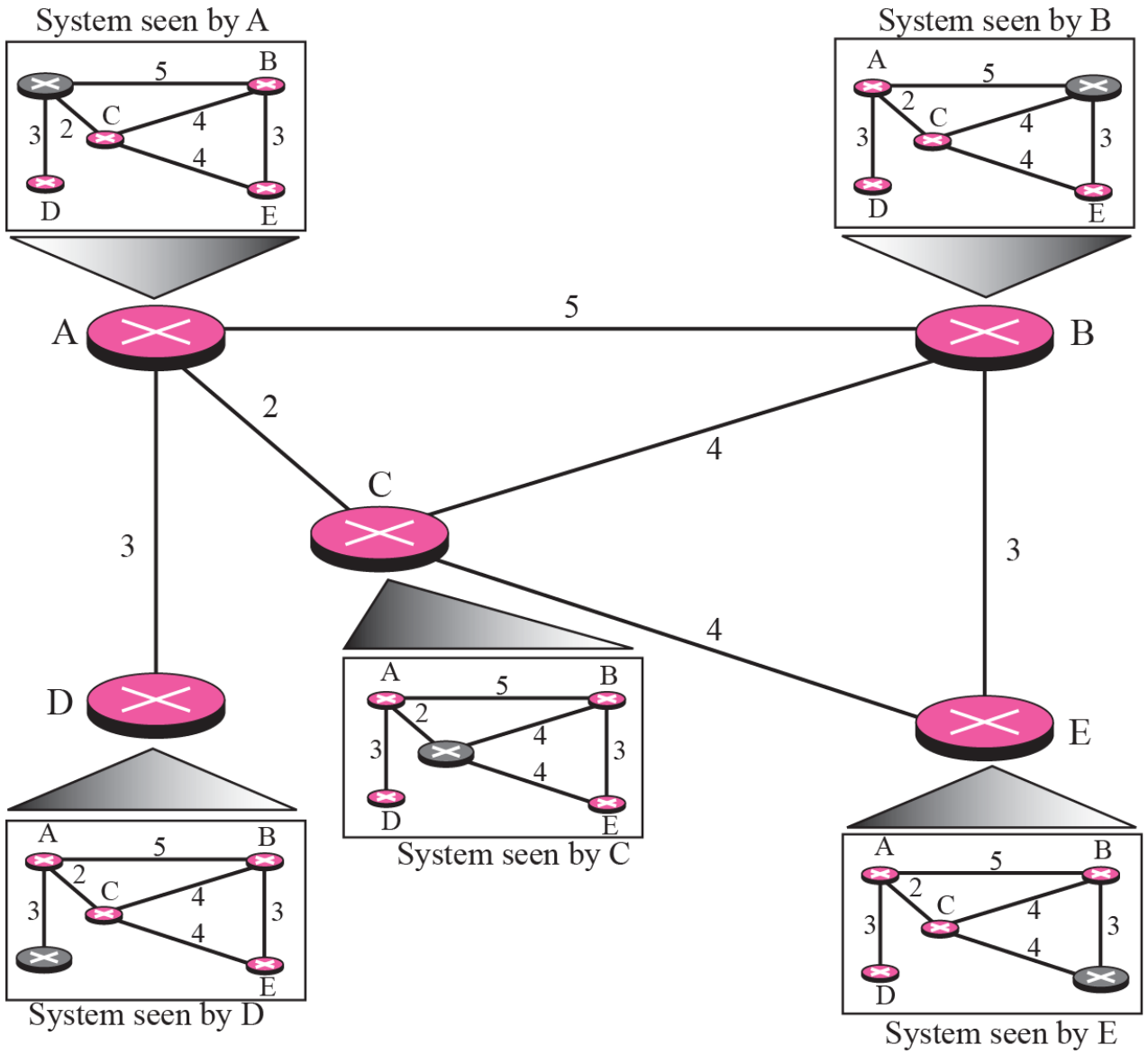
- Discover neighbors and learn their network addresses – Hello Message
- Set the distance or cost metric to each of the neighbors
- Construct a packet telling all it has learned [neighbor link state info]
- Broadcast this packet – every router periodically learns the **link state** of the network graph
- Compute the shortest path (using Dijkstra Algo) to every other routers

Link state knowledge and Link state packets



-> Each Node shares the link state packet to all the nodes in the network.

Concept of Link state routing



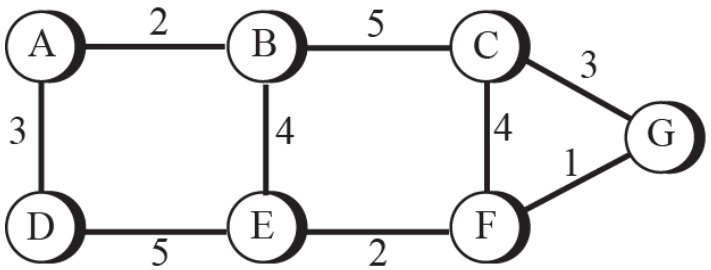
Building Routing Tables

- Creation of the states of the links by each node, called the link state packets (LSP)
- Spreading of LSPs to every other routers, called flooding (efficiently)
- Formation of a shortest path tree for each node
- Calculation of a routing table based on the shortest path tree

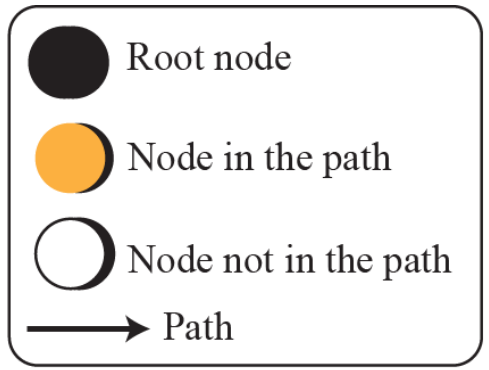
Creation of LSP

- LSP data: E.g. the node ID, the list of links, a sequence number, and age.
- LSP Generation
  - When there is a change in the topology of the domain
  - On a periodic basis

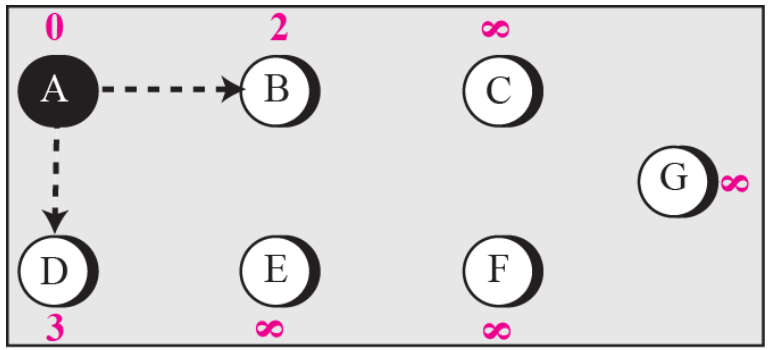
Forming shortest path tree for router A in a graph



Topology

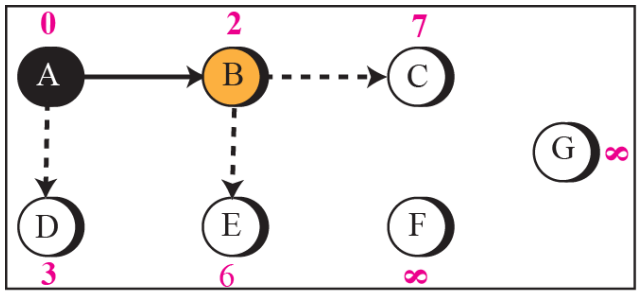


Legend

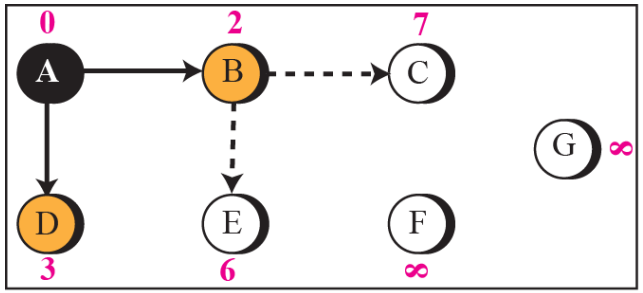


Initialization

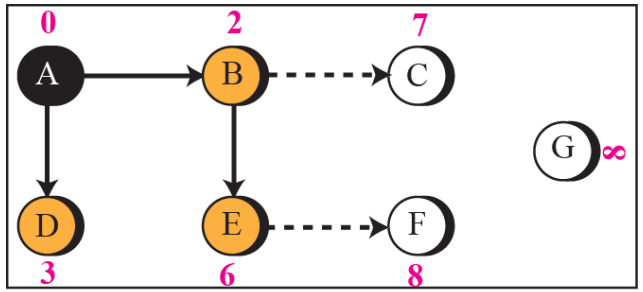
Continued



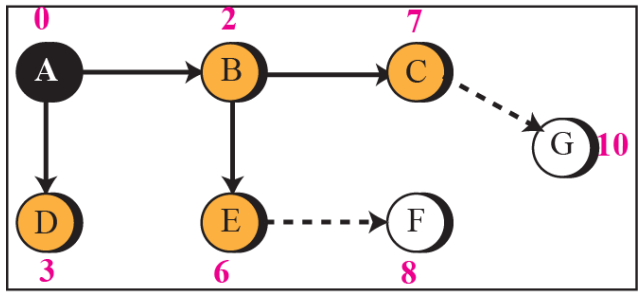
Iteration 1



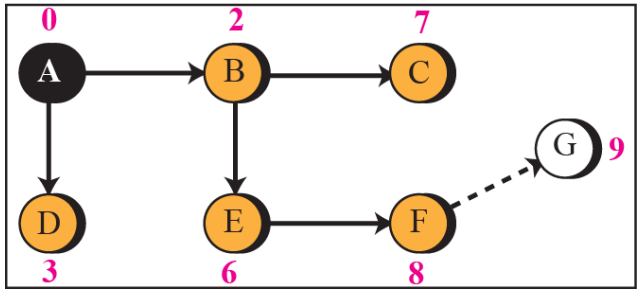
Iteration 2



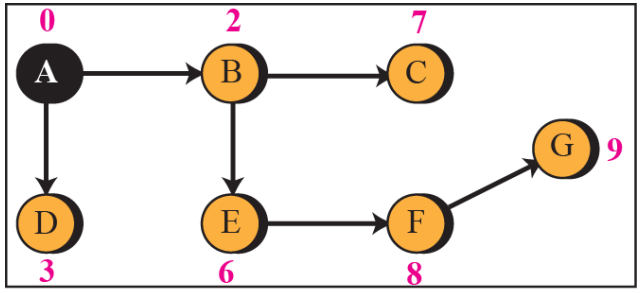
Iteration 3



Iteration 4



Iteration 5

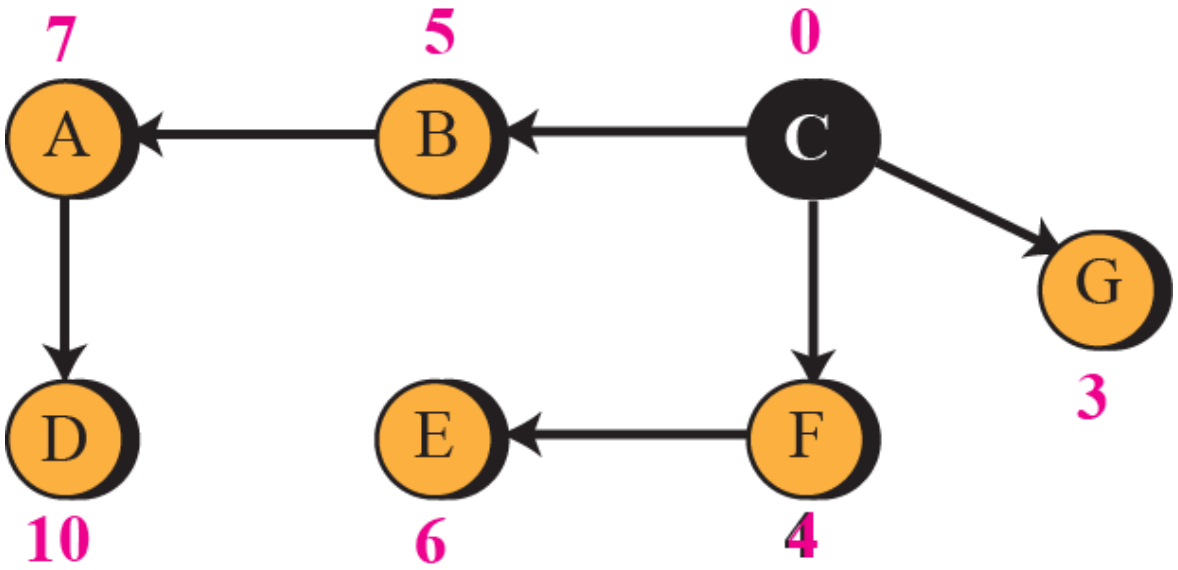


Iteration 6

Table 11.4 *Routing Table for Node A*

Destination	*Cost*	*Next Router*
A	0	—
B	2	—
C	7	B
D	3	—
E	6	B
F	8	B
G	9	B

shortest path tree for each node is different [Node C]



OSPF

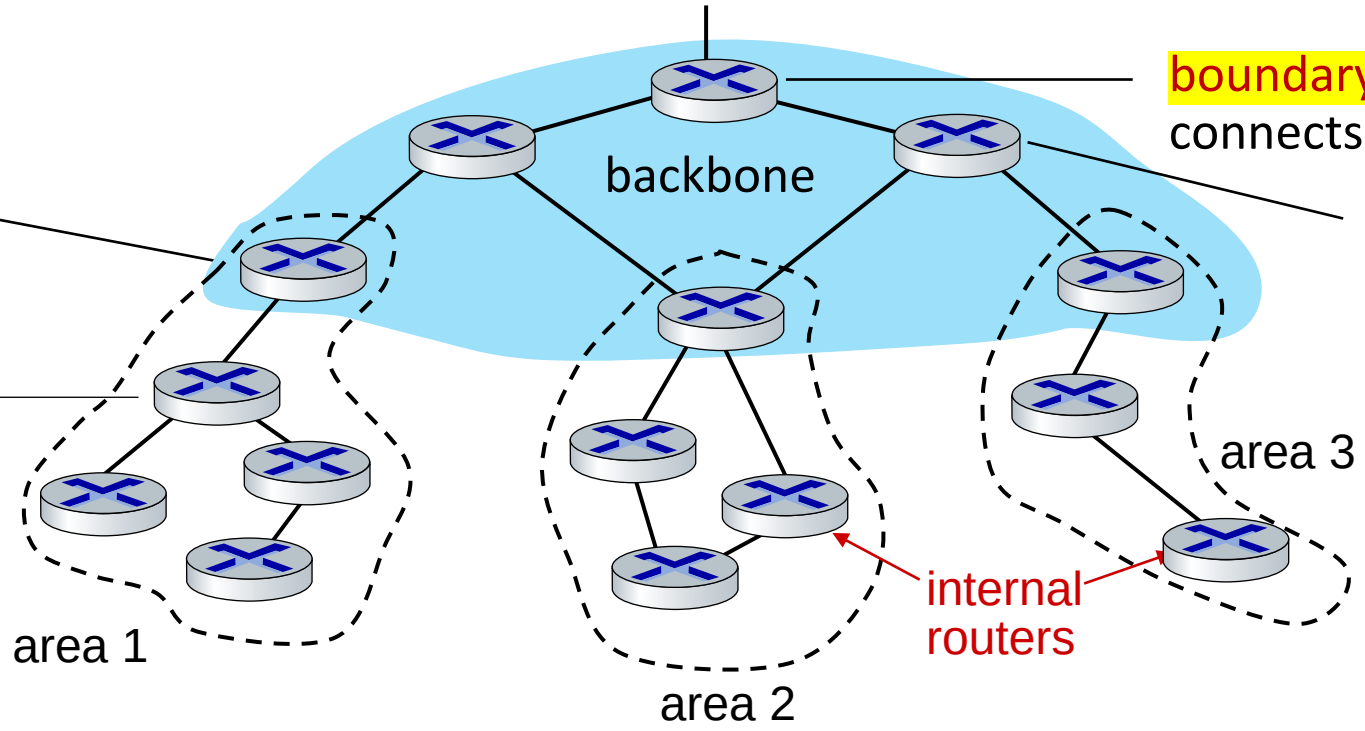
The Open Shortest Path First (OSPF) protocol is an intra-domain routing protocol based on link state routing.

Hierarchical OSPF

- two-level hierarchy: local area, backbone.
  - link-state advertisements flooded only in area, or backbone
  - each node has detailed area topology; only knows direction to reach other destinations

area border routers:
"summarize" distances to destinations in own area, advertise in backbone

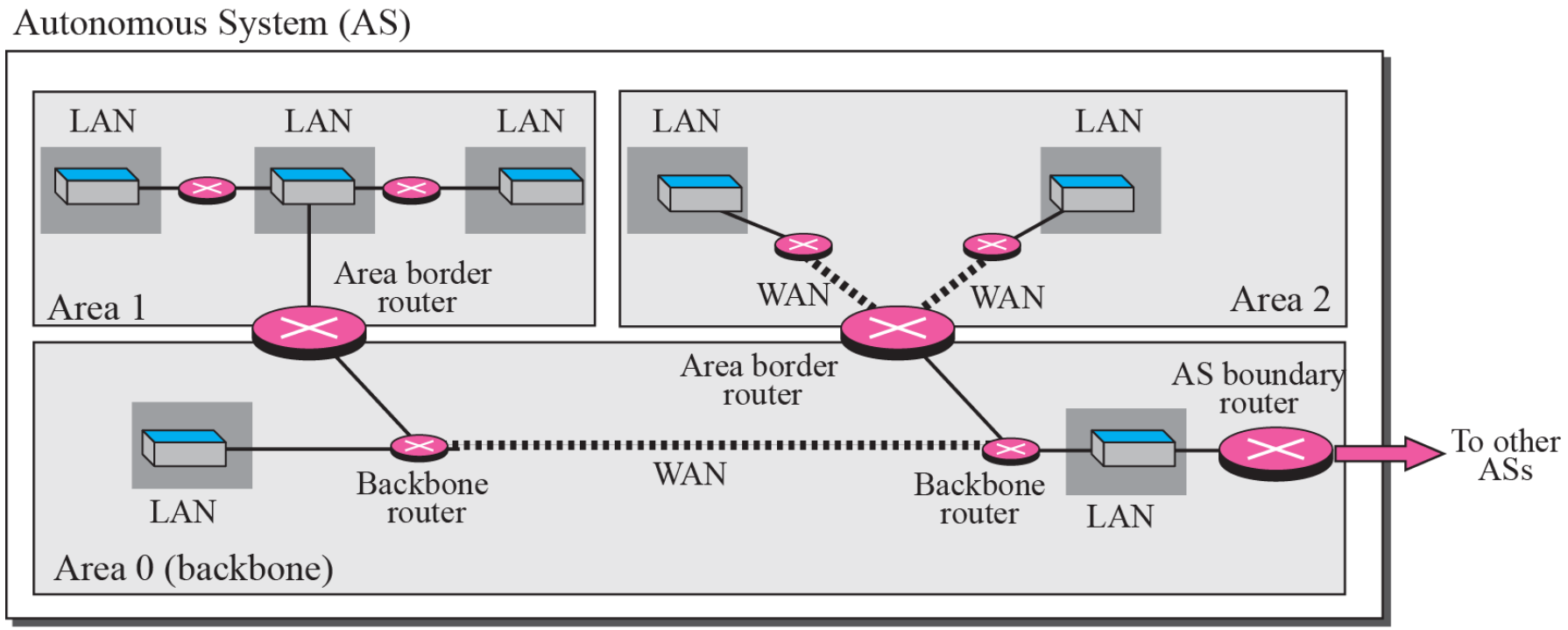
local routers:
- flood LS in area only
- compute routing within area
- forward packets to outside via area border router



boundary router:
connects to other ASes

backbone router:
runs OSPF limited to backbone

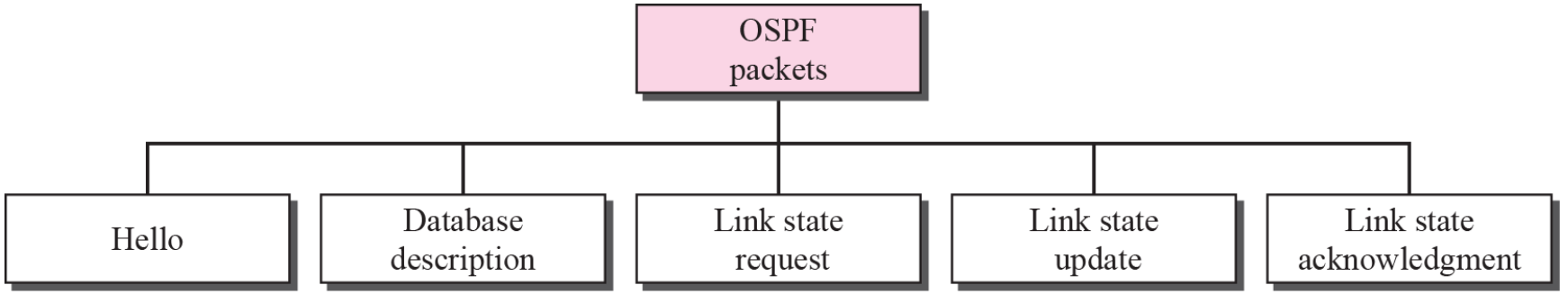
Areas in an autonomous system



Area in OSPF (1)

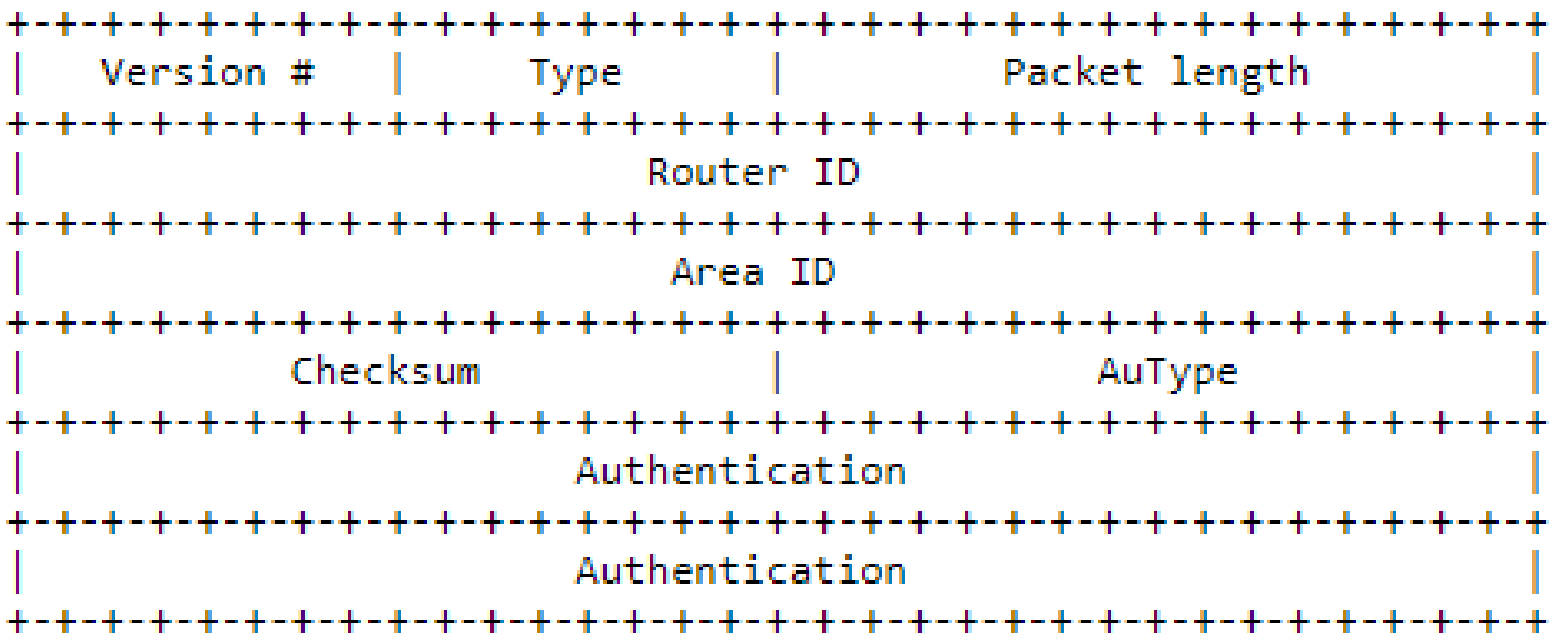
- A collection of networks with area ID
- Routers inside an area flood the area with routing information
- Area border routers summarize the information about the area and send it to other areas
- Backbone area and backbone routers
  - All of the area inside an AS must be connected to the backbone

Types of OSPF packet



OSPF packet type	Description
Type 1-Hello	Establishes and maintains adjacency information with neighbours
Type 2- Database Description Packet (DBD)	Describes the content of an OSPF routers link-state database
Type 3- Link state Request	Requests specific pieces of a routers link-state database
Type 4- Link state Update (LSU)	Transports link state advertisements (LSAs) to neighbour routers
Type 5- Link state Ack (LSACK)	Acknowledges receipt of a neighbours LSA

OSPF common header



Ref: https://sites.google.com/site/amitsciscozone/home/important-tips/ospf/ospf-packet-types

Packet Field Details

- **Version-** 2 (1-byte)
- **Type-** It specifies the type of OSPF packet. There are 5 different types of OSPF packets. (1-byte)
  1- Hello packet
  2- Database Descriptor packet
  3- Link State Request packet
  4- Link State Update packet
  5- Link State Acknowledgment packet
- **Packet Length-** Total length of the OSPF packet (2-bytes)
  Router ID- The Router ID of the advertising router
  Area ID- 32-bit Area ID assigned to the interface sending the OSPF packet (4-bytes)
  Checksum- Standard IP Checksum of OSPF packet excluding Authentication field (2-bytes)
  AuType- Authentication Type (2-bytes)

  0- No Password
  1- Plain-text password
  2- MD5 authentication

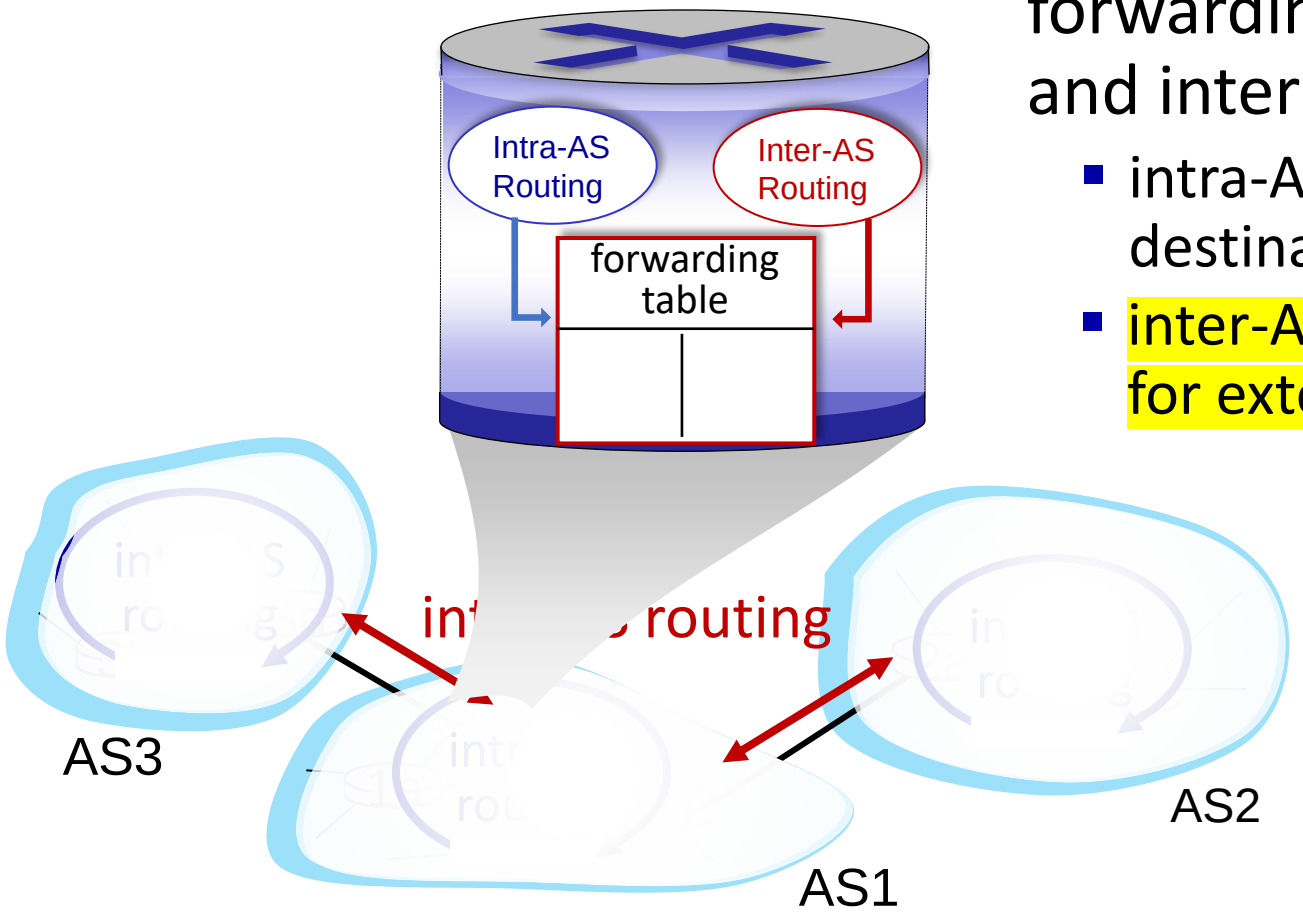
  Authentication- Authentication data to verify the packet's integrity (8-bytes)

Note

OSPF packets are encapsulated in IP datagrams.

Protocol number 89 for the IP Protocol field.

Interconnected ASes



forwarding table configured by intra- and inter-AS routing algorithms

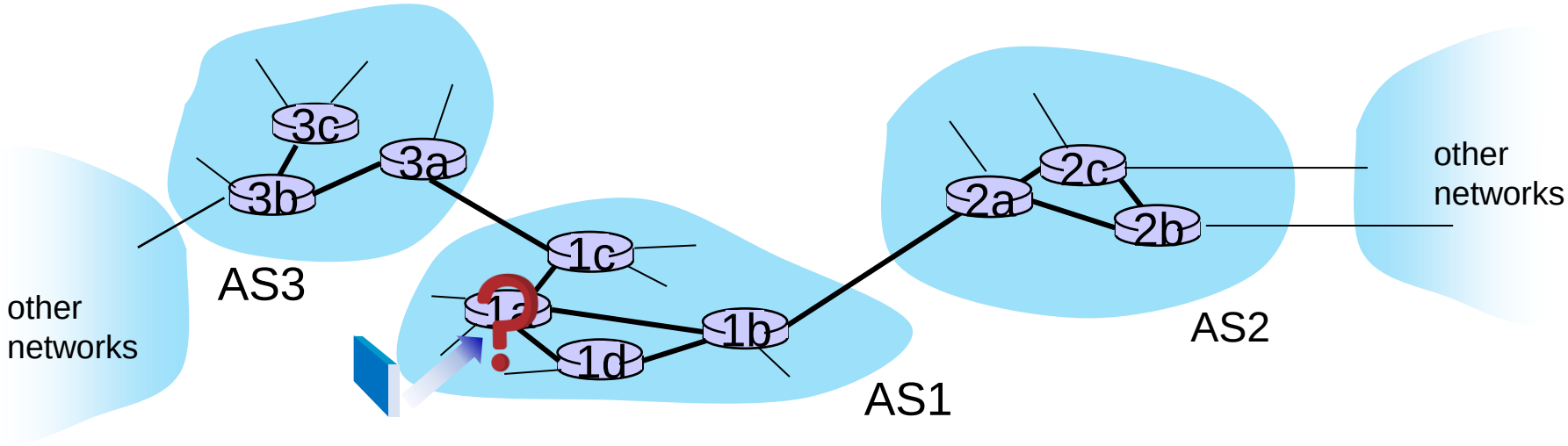
- intra-AS routing determine entries for destinations within AS
- inter-AS & intra-AS determine entries for external destinations

Inter-AS routing: a role in intradomain forwarding

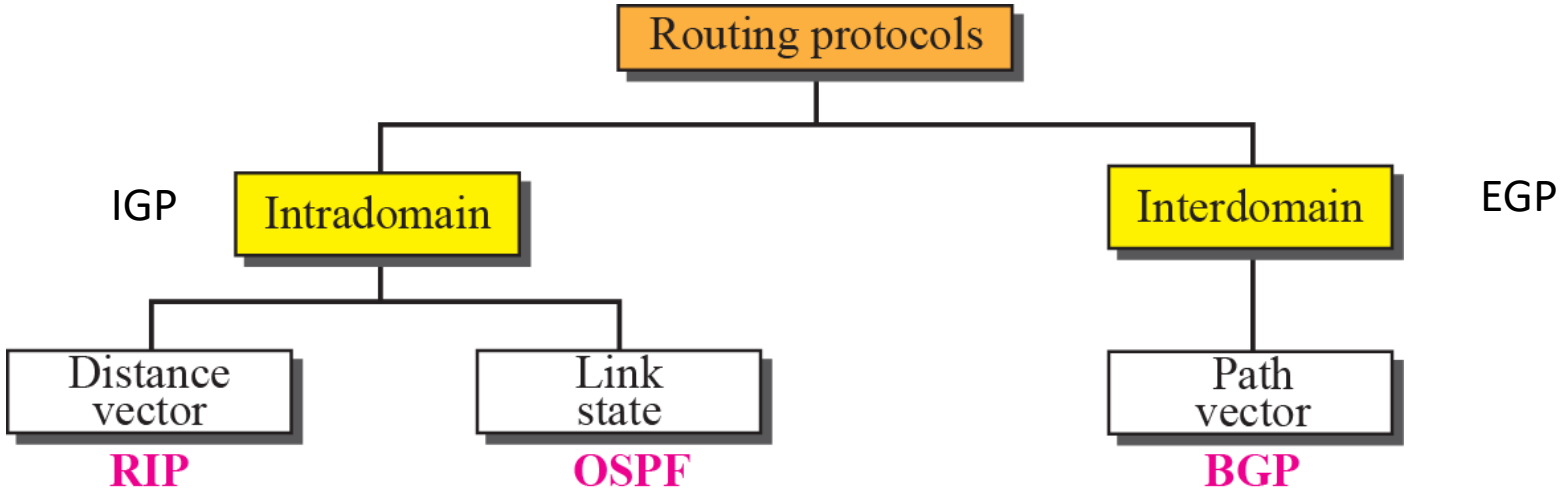
- suppose router in AS1 receives datagram destined outside of AS1:
  - router should forward packet to gateway router in AS1, but which one?

AS1 inter-domain routing must:

1. learn which destinations reachable through AS2, which through AS3
2. propagate this reachability info to all routers in AS1



Popular routing protocols



Types of AS

- Stub AS
  - Only one connection to another AS (only a source or sink for data traffic) – configure Default route as you have only one path
- Multihomed AS
  - More than one connection to other AS, but it is still only a source or sink for data traffic – BGP can be used for routing (path manipulation).
- Transit AS (ISPs)
  - Multihomed AS that also allows transient traffic – BGP for routing

Path Vector Routing

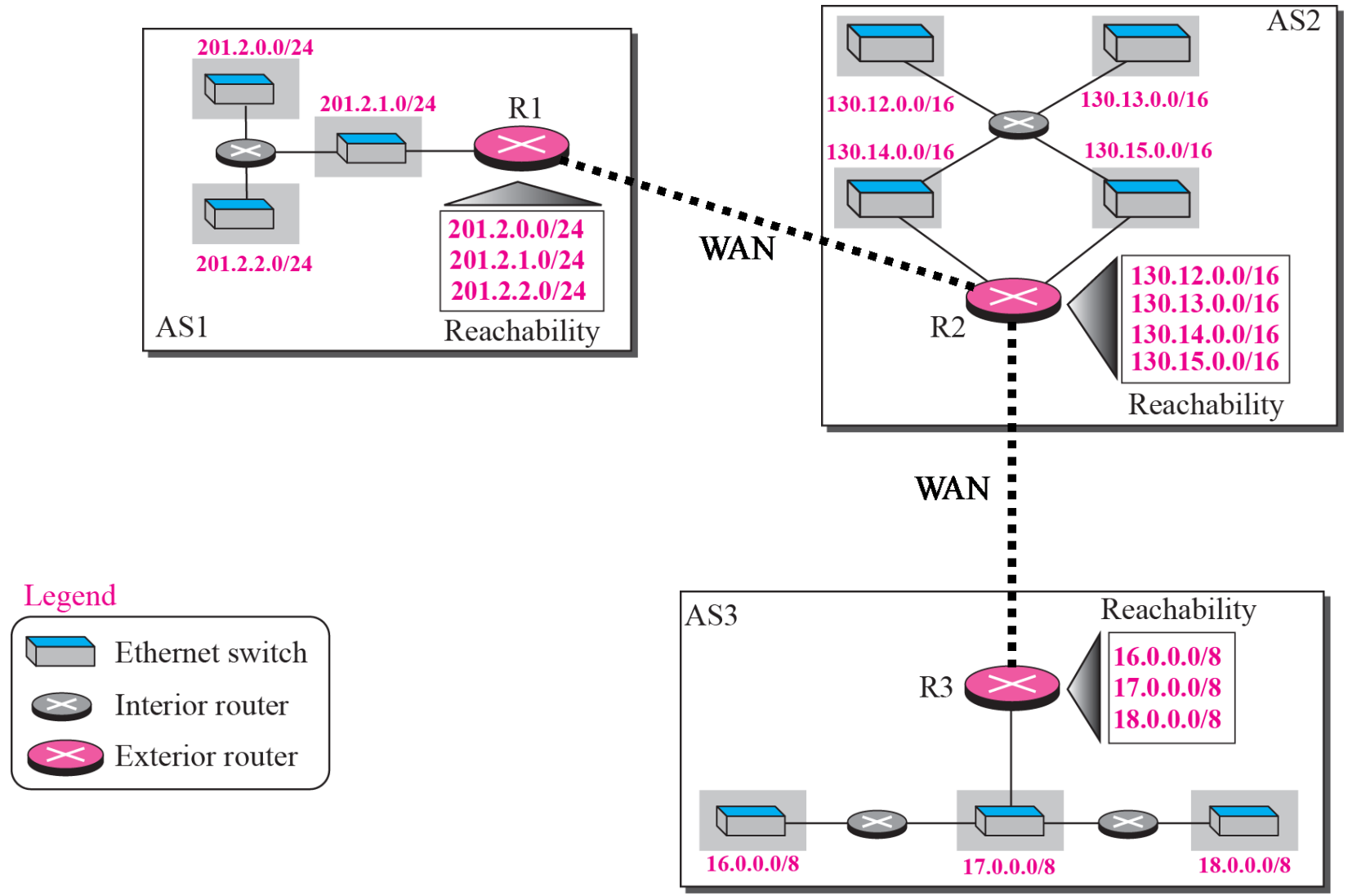
- Distance vector and link state routing are both interior routing protocols. They can be used inside an autonomous system.
- Both of these routing protocols become complex when the domain of operation becomes large.
- Distance vector routing is subject to instability if there is more than a few hops in the domain of operation.
- Link state routing needs a huge amount of resources to calculate routing tables. It also creates heavy traffic because of flooding.
- There is a need for a third routing protocol which we call path vector routing.

Path Vector Routing Cont..

- The difference between the distance vector routing and path vector routing can be compared to the difference between a national map and an international map.

- A national map can tell us the road to each city and the distance to be traveled if we choose a particular route; an international map can tell us which cities exist in each country and which countries should be passed before reaching that city.

Reachability



Stabilized table for three autonomous system

R1

Network	Path
201.2.0.0/24	**AS1** (This AS)
201.2.1.0/24	**AS1** (This AS)
201.2.2.0/24	**AS1** (This AS)
130.12.0.0/16	AS1, AS2
130.13.0.0/16	AS1, AS2
130.14.0.0/16	AS1, AS2
130.15.0.0/16	AS1, AS2
16.0.0.0/8	AS1, AS2, AS3
17.0.0.0/8	AS1, AS2, AS3
18.0.0.0/8	AS1, AS2, AS3

Path-Vector Routing Table

R2

Network	Path
201.2.0.0/24	AS2, AS1
201.2.1.0/24	AS2, AS1
201.2.2.0/24	AS2, AS1
130.12.0.0/16	**AS2** (This AS)
130.13.0.0/16	**AS2** (This AS)
130.14.0.0/16	**AS2** (This AS)
130.15.0.0/16	**AS2** (This AS)
16.0.0.0/8	AS2, AS3
17.0.0.0/8	AS2, AS3
18.0.0.0/8	AS2, AS3

Path-Vector Routing Table

R3

Network	Path
201.2.0.0/24	AS3, AS2, AS1
201.2.1.0/24	AS3, AS2, AS1
201.2.2.0/24	AS3, AS2, AS1
130.12.0.0/16	AS3, AS2
130.13.0.0/16	AS3, AS2
130.14.0.0/16	AS3, AS2
130.15.0.0/16	AS3, AS2
16.0.0.0/8	**AS3** (This AS)
17.0.0.0/8	**AS3** (This AS)
18.0.0.0/8	**AS3** (This AS)

Path-Vector Routing Table

Routing tables after aggregation

R1

Network	Path
201.2.0.0/22	**AS1** (This AS)
130.12.0.0/18	AS1, AS2
16.0.0.0/6	AS1, AS2, AS3

Path-Vector Routing Table

R2

Network	Path
201.2.0.0/22	AS2, AS1
130.12.0.0/18	**AS2** (This AS)
16.0.0.0/6	AS2, AS3

Path-Vector Routing Table

R3

Network	Path
201.2.0.0/22	AS3, AS2, AS1
130.12.0.0/18	AS3, AS2
16.0.0.0/6	**AS3** (This AS)

Path-Vector Routing Table