CS3103: Computer Networks Practice

Routing - OPSF (Open Shortest Path First)

- Link state routing
- OSPF

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Routing Protocols

- Distance Vector Routing
- Link State Routing

Let us start with a QUIZ:

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Make sure you LOGIN using your NUSNET ID.

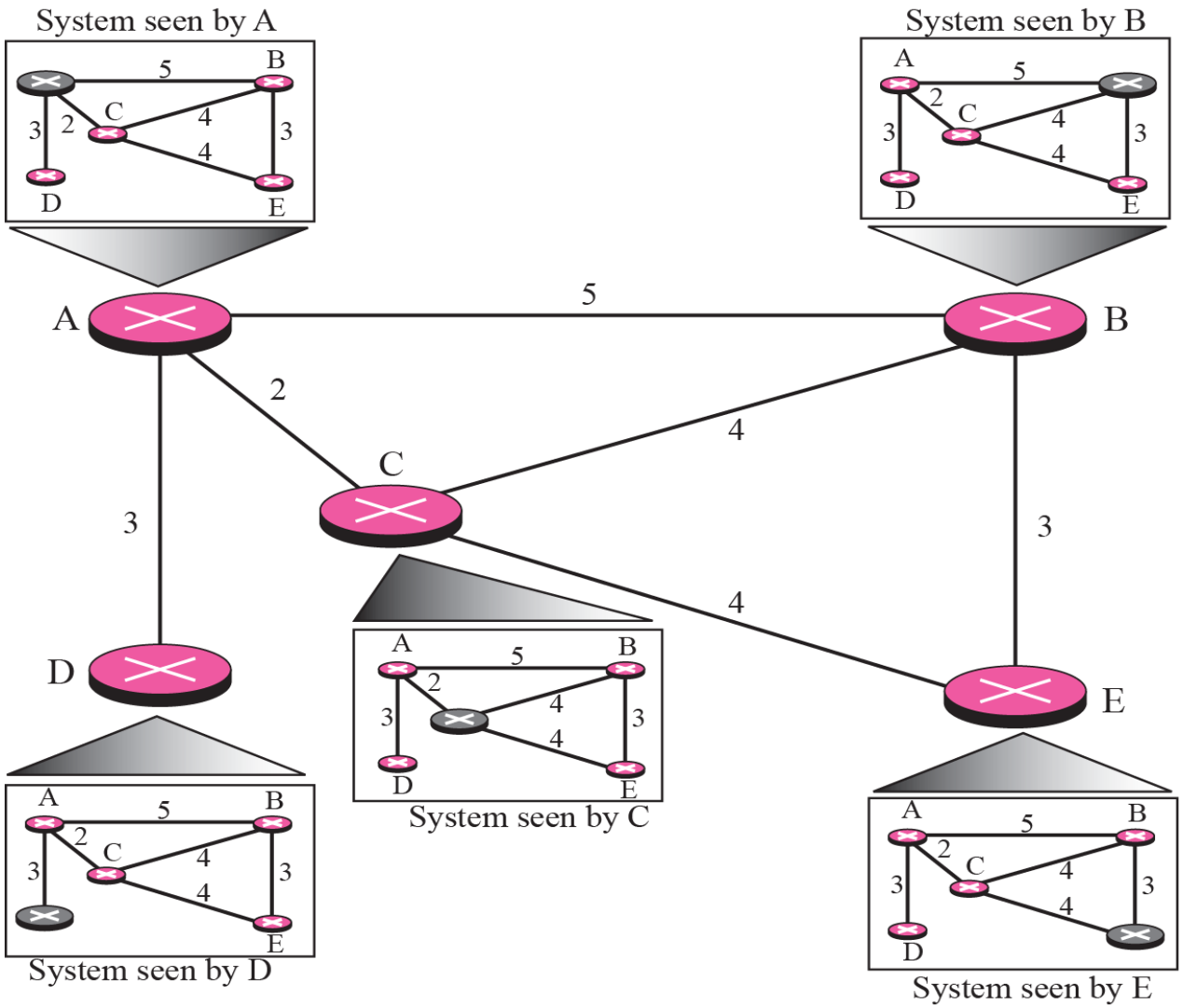
LINK STATE ROUTING

- In distance vector (DV) routing, router knows only *cost* to each destination
  - hides information, causing problems

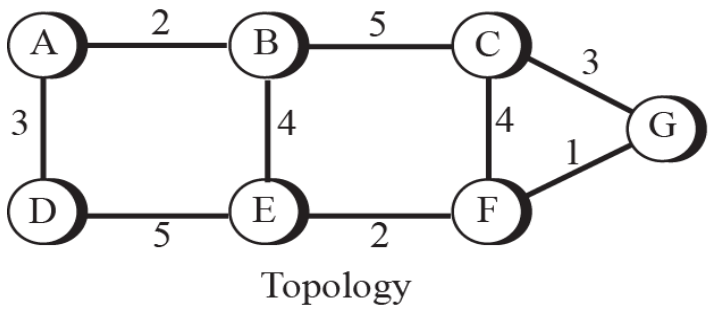
routers flood info about the state and cost of its own links to neighbors so every router is aware of the entire topology then dijsktra is performed.

- In link state (LS) routing, router knows entire network topology
  - computes shortest path by itself using well known algorithm - ***Dijkstra's algorithm***
  - independent computation of routes

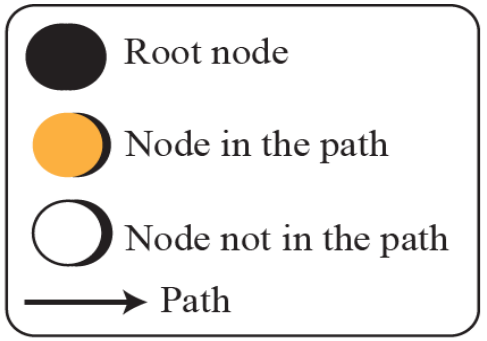
Concept of Link state routing



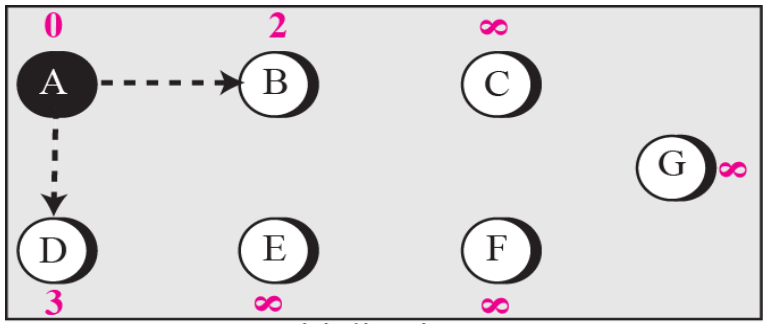
Forming shortest path tree for router A in a graph (Dijsktra's Algorithm)



Topology

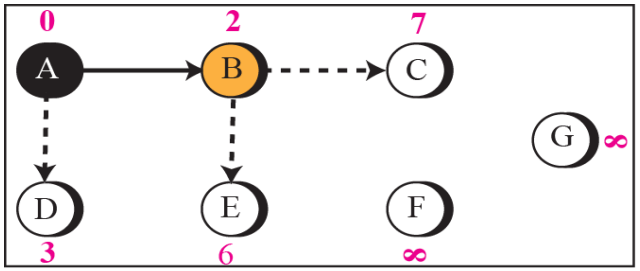


Legend

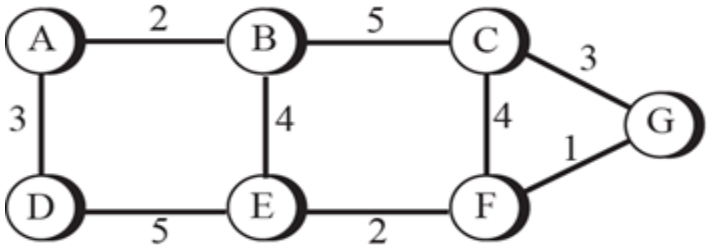


Initialization

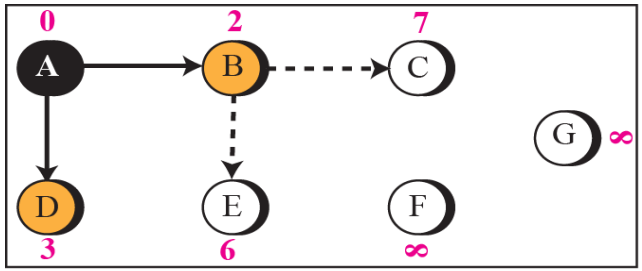
… Continued



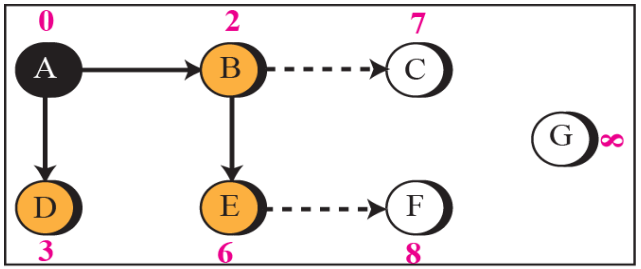
Iteration 1



Topology

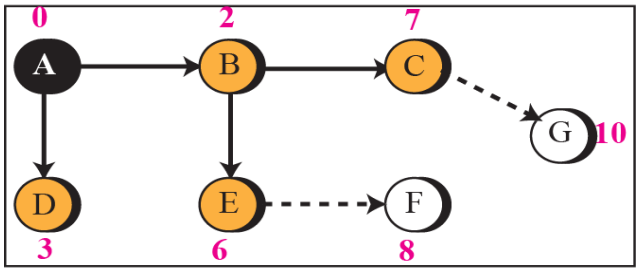


Iteration 2

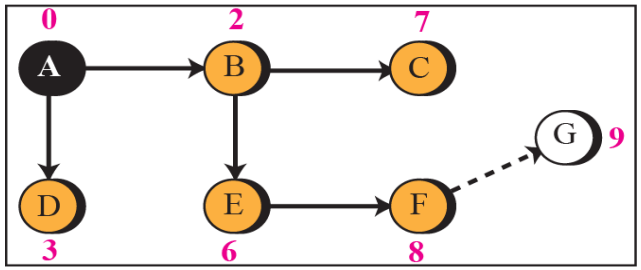


Iteration 3

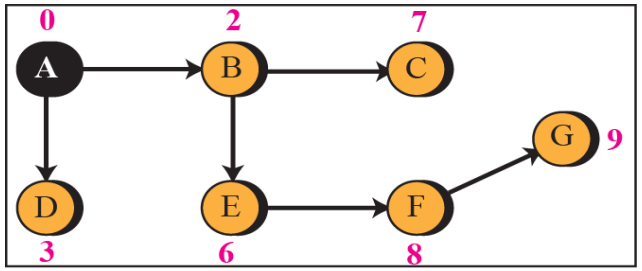
… Continued



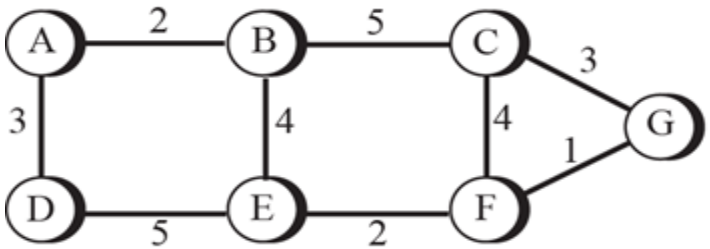
Iteration 4



Iteration 5



Iteration 6



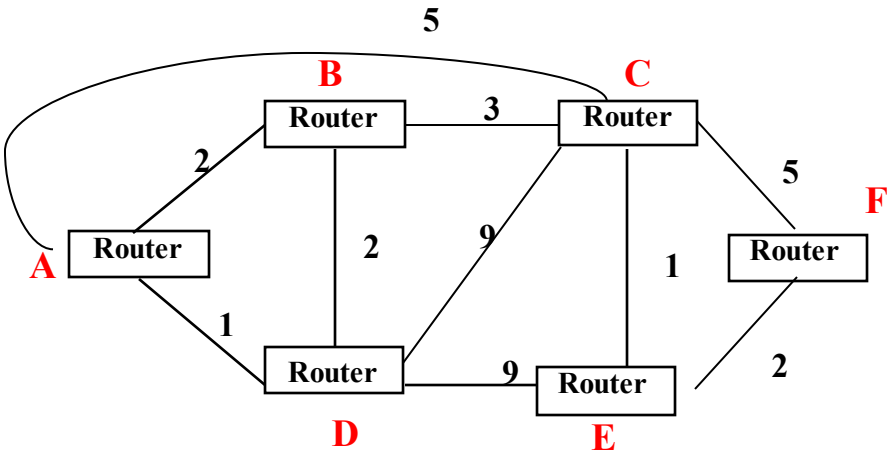
Topology

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

Iteration	Destination added to Shortest Path	Candiadte List Destination (cost, next hop)
1	A (0,A)	B (2,B)
		C(5,C)
		D(1,D)
2	A (0,A)	B(2,B,; 3, D-B)
	D(1,D)	C(5,C; 10, D-C)
		E(10, D-E)
3	A (0,A)	C(5,C; 10, D-C; 5,B-C)
	D(1,D)	E(10, D-E)
	B(2,B)	
4	A (0,A)	E(10, D-E; 6,C-E)
	D(1,D)	F(10,C-F)
	B(2,B)	
	C(5,C)	
5	A (0,A)	F(10,C-F; 8, C-E-F)
	D(1,D)	
	B(2,B)	
	C(5,C)	
	E(6, C-E)	
6	A (0,A)	
	D(1,D)	
	B(2,B)	
	C(5,C)	
	E(6, C-E)	
	F(8, C-E-F)	

(Another Example)



Shortest path (SP) to every destination in the network can be calculated using Dijsktra's SP Algorithm

Dijkstra's Algorithm

- *Let D_i be shortest path length from node i to node S where, S is start node. [Initially D_i 's are infinite (unknown)]*
- *Let c_{ij} be the cost of link (i,j); infinity if (i,j) is not an arc of the graph*

- Initialise $P_{(path)} = \{S\}$, $D_s = 0$, $D_j = c_{js}$ for j not equal to S
- Step 1 (Find closest node): Find i not in P such that
  - **$D_i = \min_{j \text{ not in } P} D_j$,** set P = P U {i}.
  - If P contains all nodes, END
- Step 2 (Update D_j): For all j not in P
  - **$D_j = \min [D_j, c_{ji}+D_i]$,** goto step 1

Q: The entire network topology should be known to compute shortest path & build routing table. How routers learn about the entire network topology?

OSPF

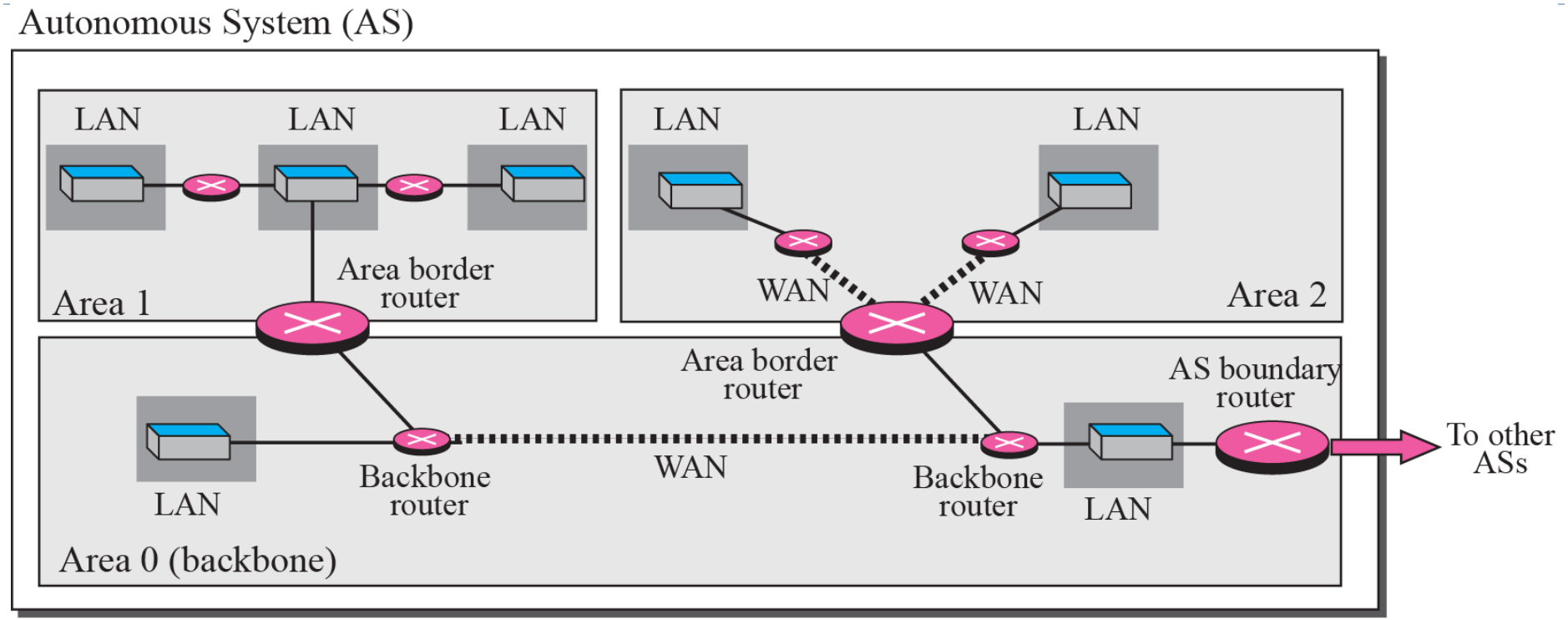
- **The Open Shortest Path First (OSPF) protocol is an intradomain routing protocol based on link state routing. Its domain is also an autonomous system (AS).**

- **Key elements**
  - **topology dissemination**
  - **uses link state routing to compute shortest routes**

Some additional materials from reference book:

- Computer Networking A Top Down Approach Featuring the Internet- by James Kurose and Keith Ross, Addison Wesley, 6rd Edition

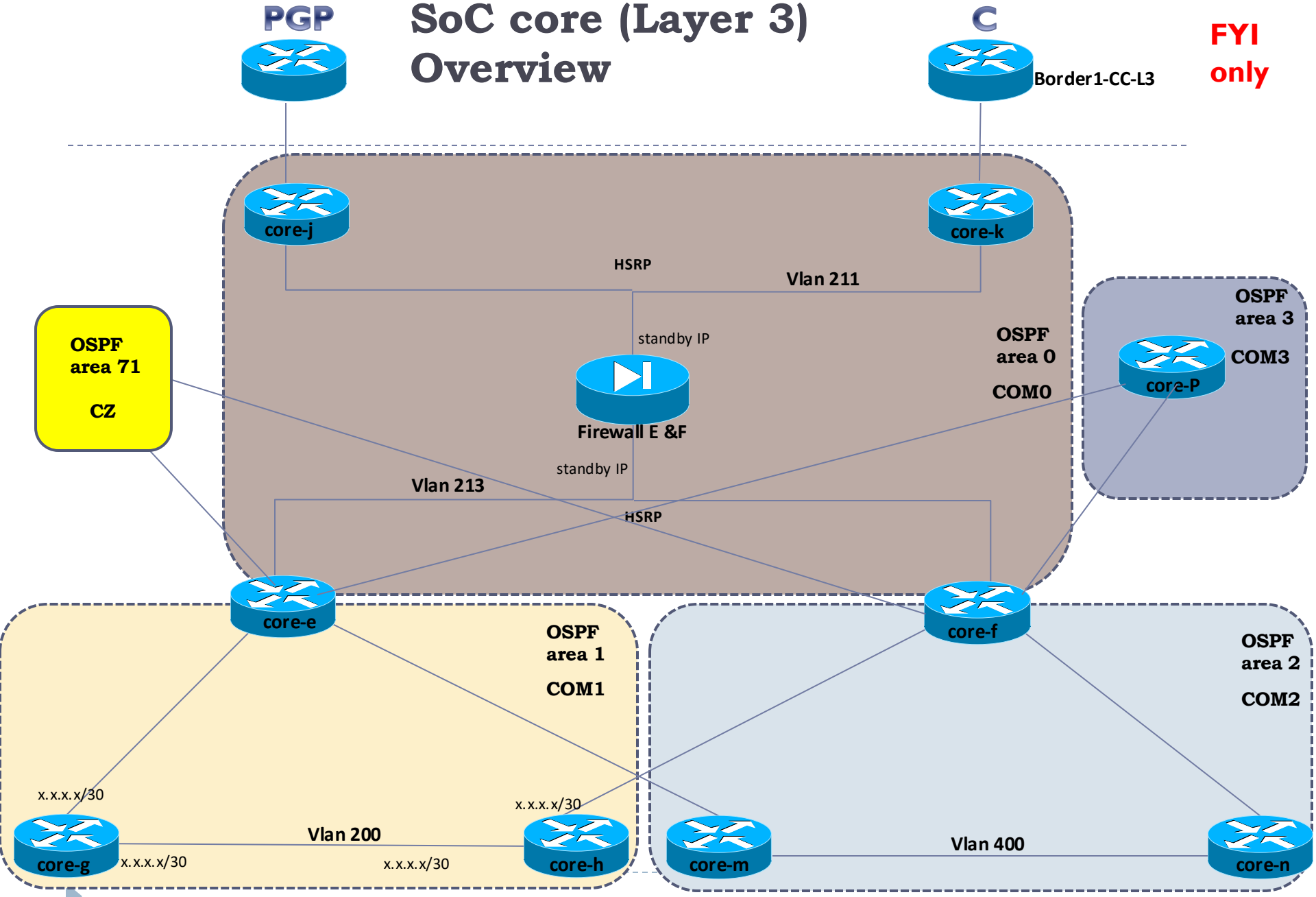
Areas in an autonomous system



- Within an OSPF area, all routers maintain the same link-state (topology) database and have no knowledge of the network topology outside their own area. Area Border Routers (ABRs) summarize and distribute information about their area to other areas. Autonomous System Boundary Routers (ASBRs) take routes learned from other routing domains (e.g., RIP, BGP, static routes) and redistribute them into OSPF domain as **external routes**.
- Area concept limits the amount of link-state info exchanged (flooded), size of database stored, and amount of processing carried out by each router.

SoC core (Layer 3) Overview

FYI only



OSPF *(cont)*

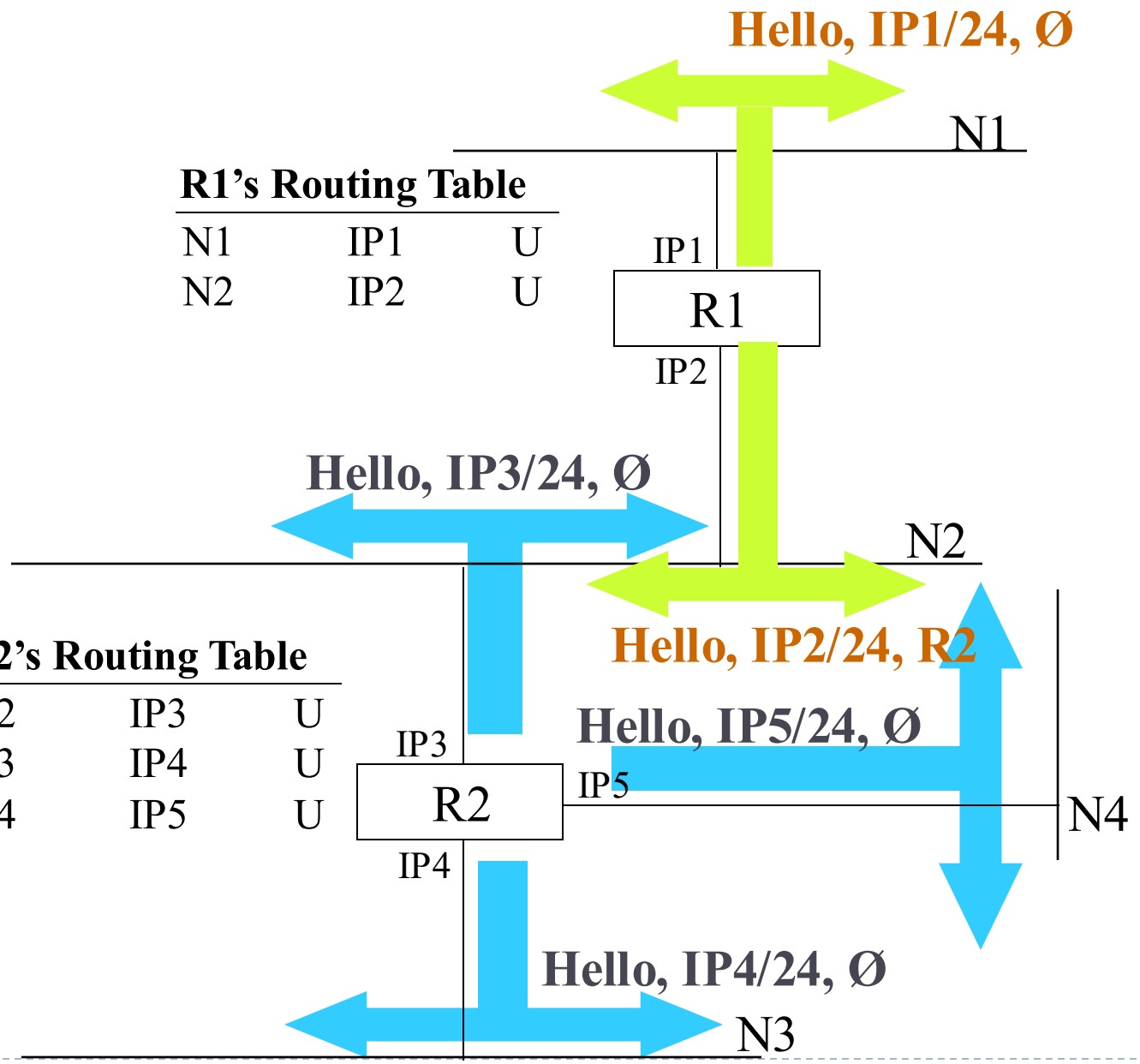
- Every Router in an area computes the shortest path to every other router
- **Two problems** in building OSPF routing table
  - **PROBLEM 1**: to determine a router's local environment
  - **PROBLEM 2:** to exchange information with the rest of the routers to maintain identical database that define the Network Topology

OSPF *(cont)*

- **Local environment information**:
  - neighboring routers
  - links to connected networks
  - cost of the links (metric) - delay, $ cost, transmission time, max throughput, etc.,
- **Link-state protocol:**
  - link-state packets are sent to all routers in the area.
  - they contain list of **network links (links to networks and routers)** and their associated **costs**
- RFC 2328

Prob. 1: Neighbour Discovery and Maintenance

- Who are the neighbors is found out by ***Hello*** messages.
- For every network interface a router has, *Hello* messages are generated. Content includes
  - router's IP address for that interface, subnet mask (a.b.c.d/n)
  - Hello interval
  - a list of neighbors whose *Hellos* the sender has already heard.
- Hellos are multicast to all OSPF routers using the address **224.0.0.5** every 10 secs. Tests the status of link to its neighbors.
- Failure to receive any Hellos from a neighbor for 40 secs - link to that neighbor failed or that neighbor crashed.


Hello, IP1/24, Ø
N1
R1's Routing Table
N1 IP1 U
N2 IP2 U
IP1
R1
IP2
Hello, IP3/24, Ø
N2
Hello, IP2/24, R2
R2's Routing Table
N2 IP3 U
N3 IP4 U
N4 IP5 U
Hello, IP5/24, Ø
IP3
IP5
R2
N4
IP4
Hello, IP4/24, Ø
N3

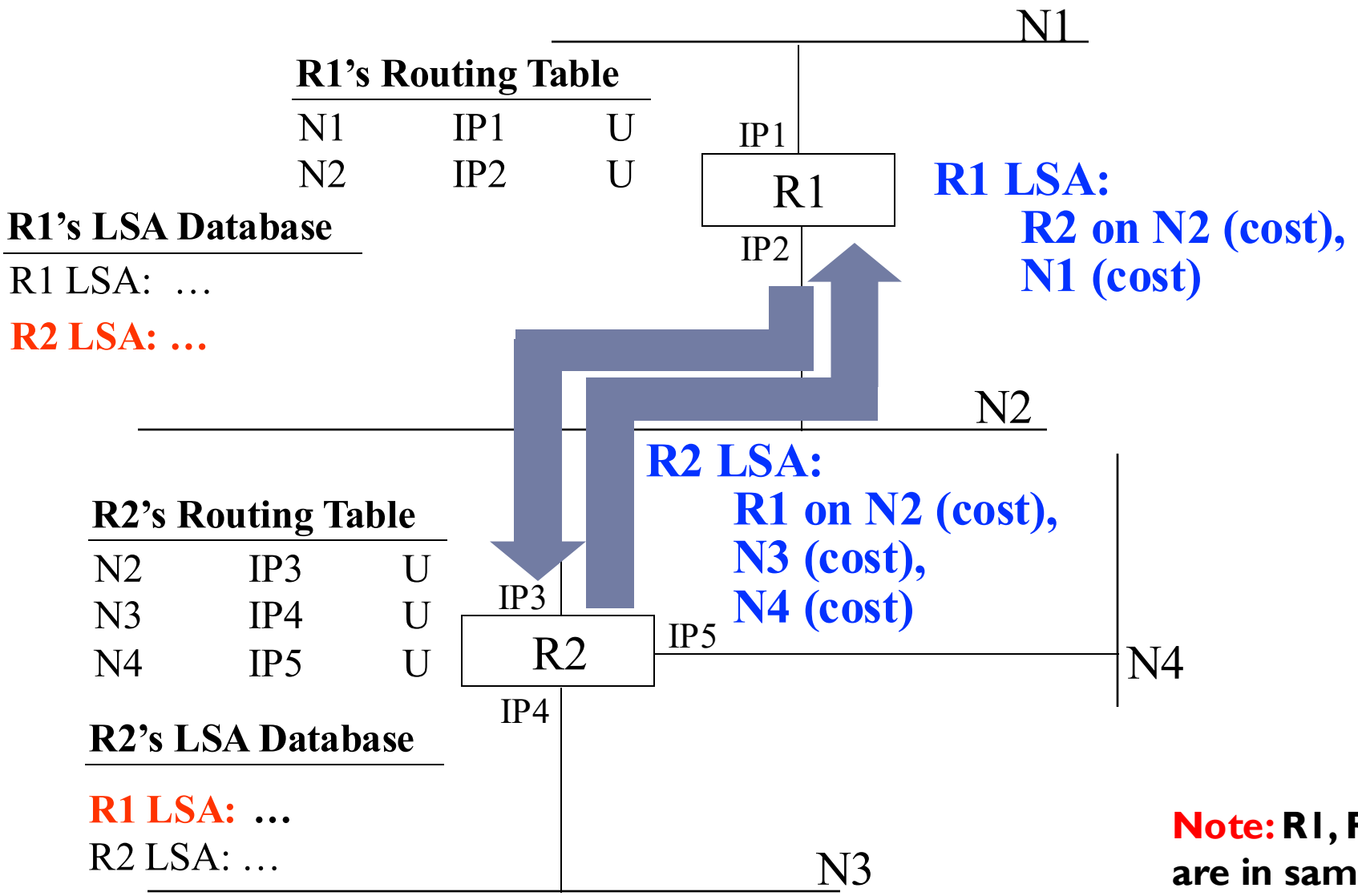
Prob. 2: Exchange of Link-state Information

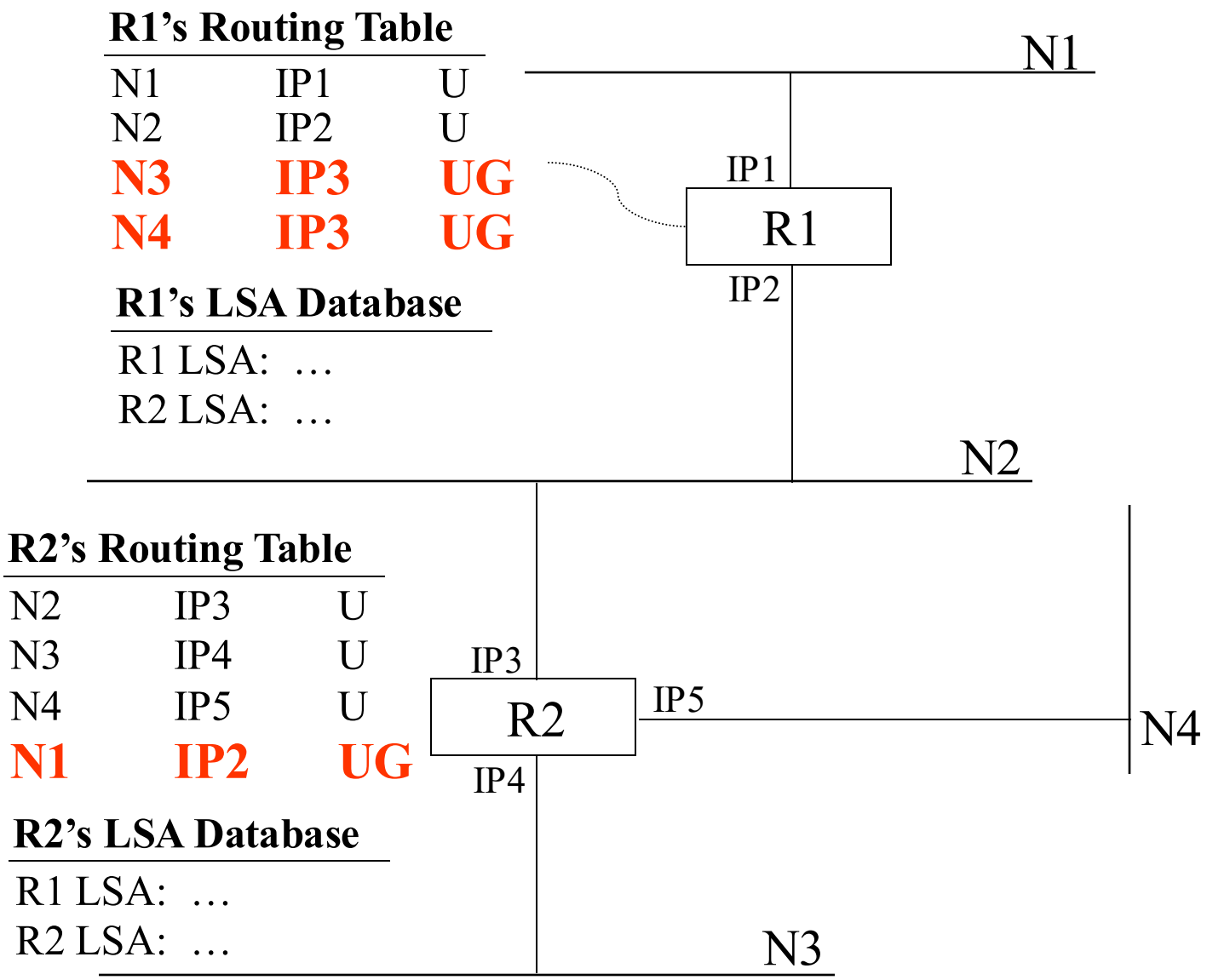
- Each entity in an area (eg., a router, a broadcast network/ ABR) distributes information about its local environment in packets called ***Link State Advertisements* (LSAs)**.

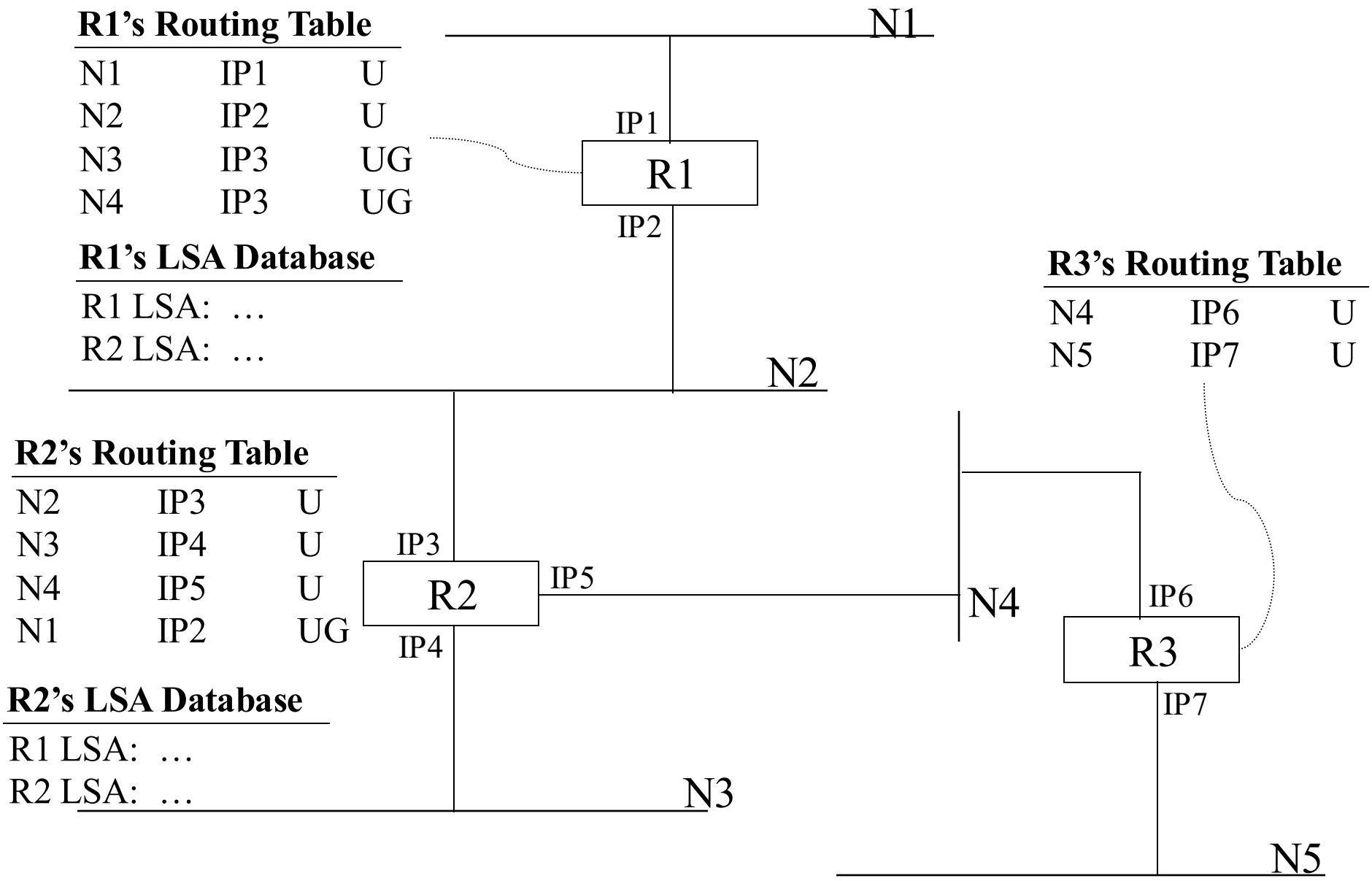
Prob. 2: Exchange of Link-state Information

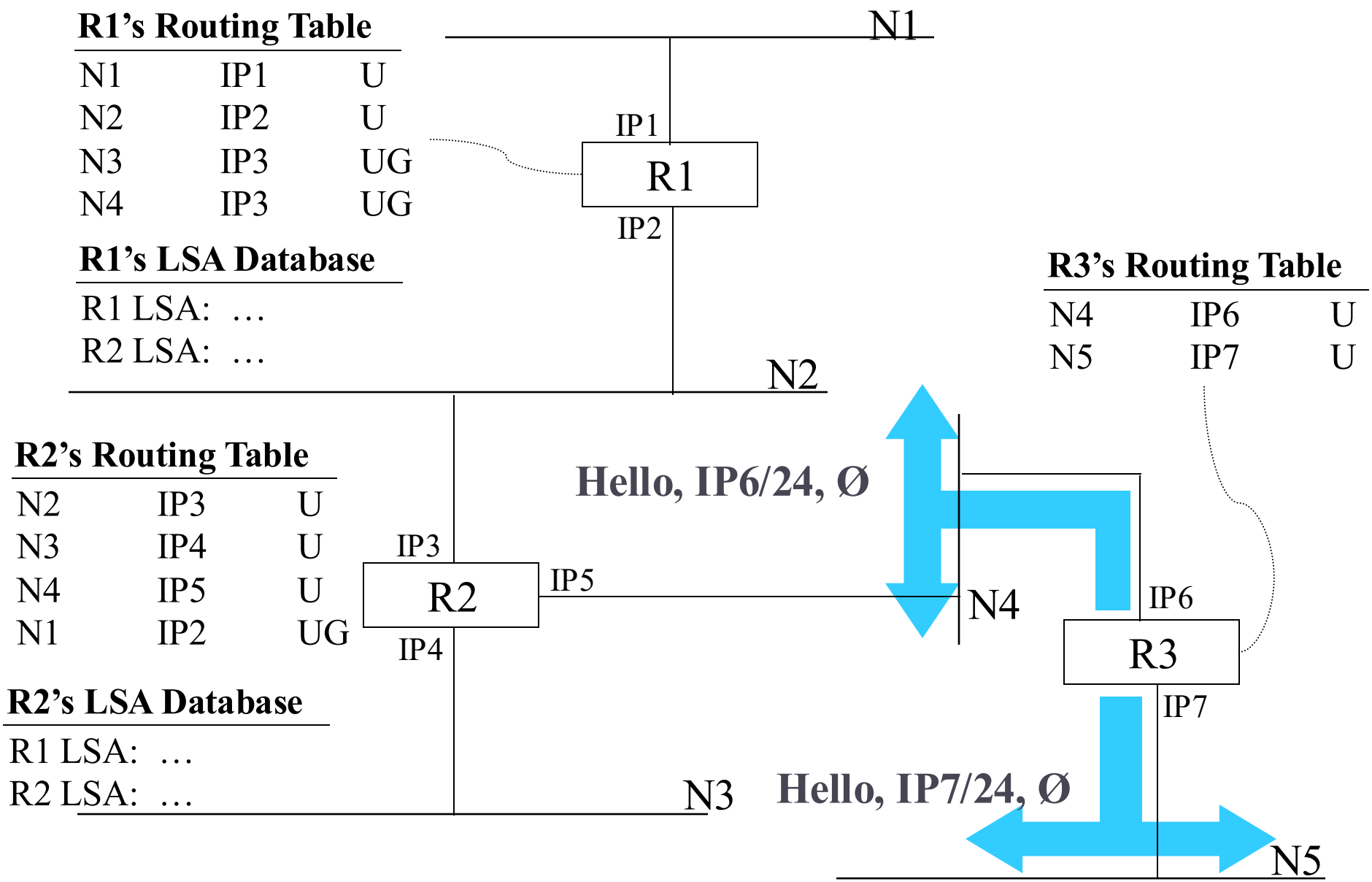
- LSA's are normally sent only under the following circumstances:
  - a router discovers a new neighbor
  - a link to a neighbor goes down
  - cost of a link changes
  - basic refresh packets are sent every 30min
- LSAs are distributed to all routers in the area by **reliable flooding - to synchronize**
  - explicitly ACKed, sequenced, and time-stamped

Example *(Cont'd)*




R1's Routing Table
N1 IP1 U
N2 IP2 U
N3 IP3 UG
N4 IP3 UG
R1's LSA Database
R1 LSA: …
R2 LSA: …
N1
IP1
R1
IP2
N2
R2's Routing Table
N2 IP3 U
N3 IP4 U
N4 IP5 U
N1 IP2 UG
R2's LSA Database
R1 LSA: …
R2 LSA: …
IP3
R2
IP4
IP5
N4
N3


R1's Routing Table
N1 IP1 U
N2 IP2 U
N3 IP3 UG
N4 IP3 UG
R1's LSA Database
R1 LSA: …
R2 LSA: …
N1
IP1
R1
IP2
N2
R3's Routing Table
N4 IP6 U
N5 IP7 U
R2's Routing Table
N2 IP3 U
N3 IP4 U
N4 IP5 U
N1 IP2 UG
IP3
R2
IP4
IP5
N4
IP6
R3
IP7
R2's LSA Database
R1 LSA: …
R2 LSA: …
N3
N5


R1's Routing Table
N1 IP1 U
N2 IP2 U
N3 IP3 UG
N4 IP3 UG
R1's LSA Database
R1 LSA: …
R2 LSA: …
N1
IP1
R1
IP2
N2
R2's Routing Table
N2 IP3 U
N3 IP4 U
N4 IP5 U
N1 IP2 UG
R2's LSA Database
R1 LSA: …
R2 LSA: …
IP3
R2
IP4
IP5
N3
Hello, IP6/24, Ø
N4
R3's Routing Table
N4 IP6 U
N5 IP7 U
IP6
R3
IP7
Hello, IP7/24, Ø
N5

R1's Routing Table

N1	IP1	U
N2	IP2	U
N3	IP3	UG
N4	IP3	UG
N5	**IP3**	**UG**

R1's LSA Database

R1 LSA: …
R2 LSA: …
R3 LSA: …

R2's Routing Table

N2	IP3	U
N3	IP4	U
N4	IP5	U
N1	IP2	UG
N5	**IP6**	**UG**

R2's LSA Database

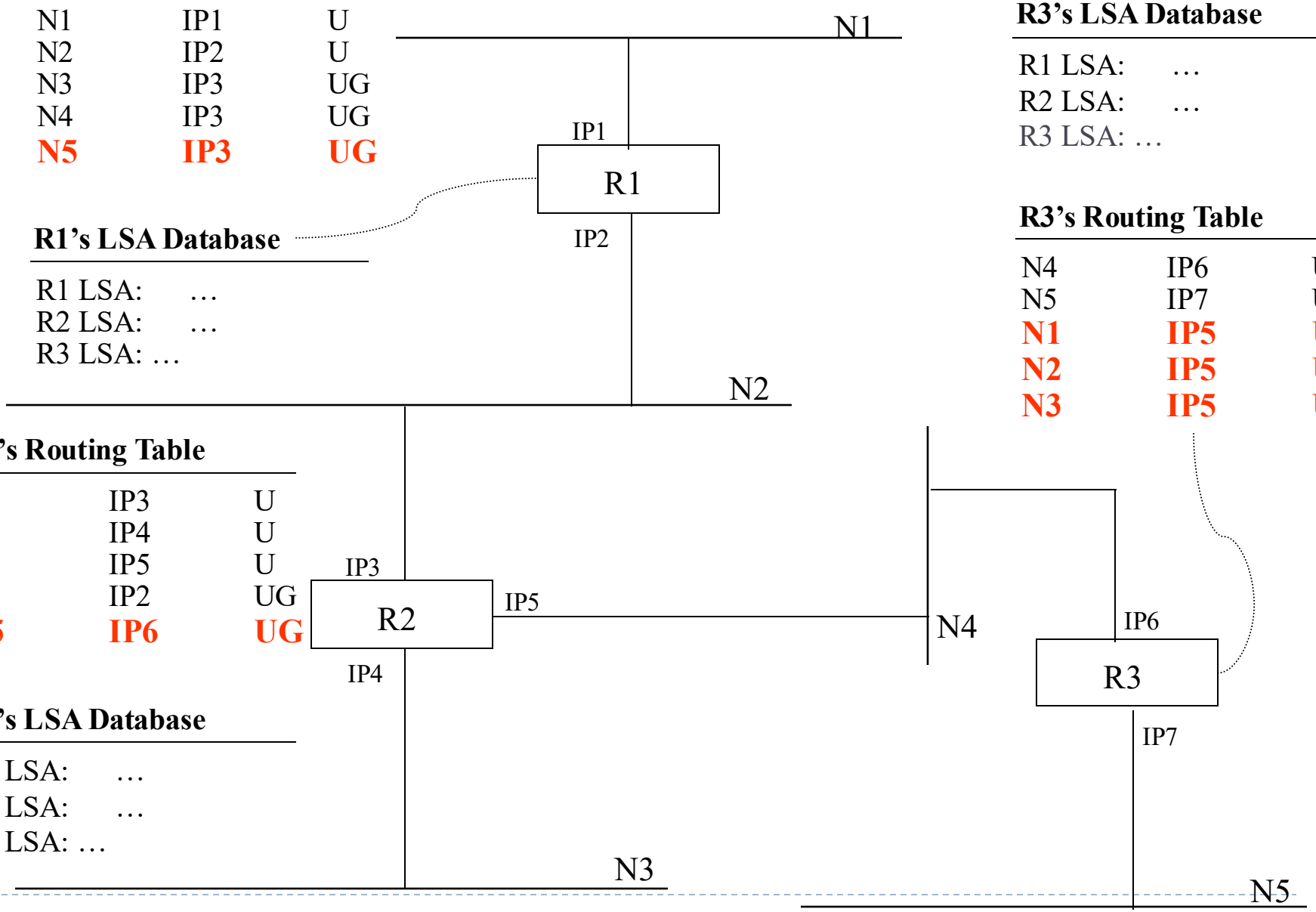
R1 LSA: …
R2 LSA: …
R3 LSA: …

R3's LSA Database

R1 LSA: …
R2 LSA: …
R3 LSA: …

R3's Routing Table

N4	IP6	U
N5	IP7	U
N1	**IP5**	**UG**
N2	**IP5**	**UG**
N3	**IP5**	**UG**



Quiz

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Make sure you
LOGIN
using your
NUSNET ID.

OSPF *(cont)*

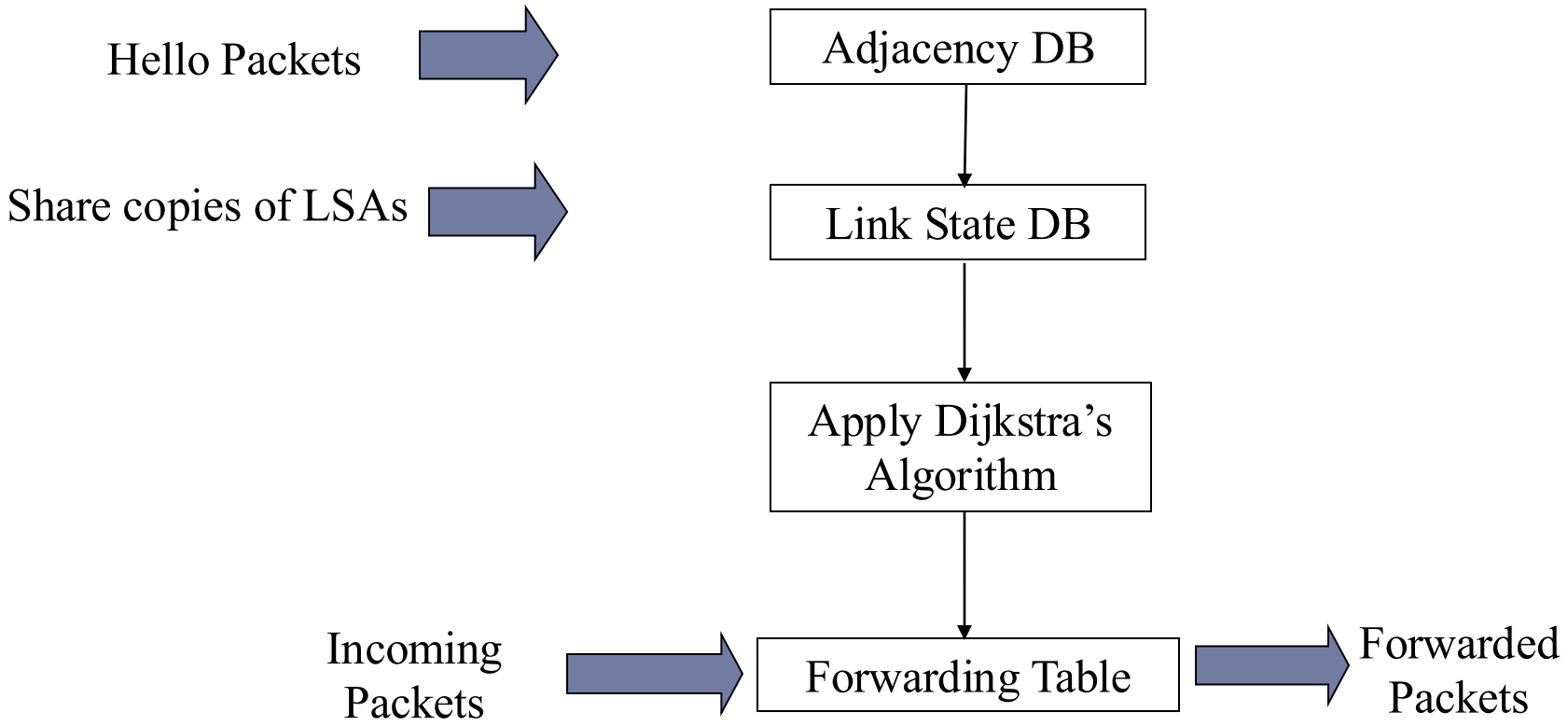
For your own reading

- Every router in an area receives the LSAs generated by other routers in the area (that contain the respective router's local environment information) and builds a database of LSAs that describes the topology of the area.
- The database of LSAs maintained by all routers in an area are identical.
- Each router then constructs the shortest path with itself as the root and using metric as the cost, to build its routing table.

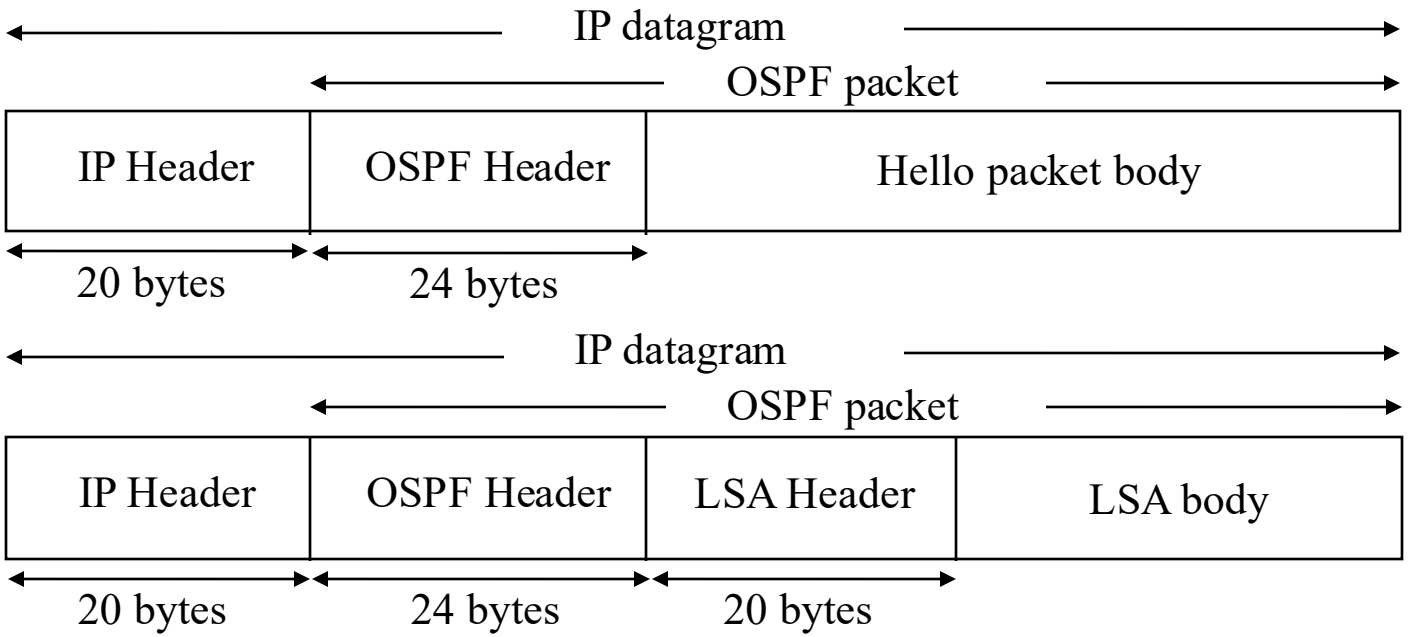
so step 1: hello multicasts to a single ip address to discover neighbours
step 2: USE LSAs and if possible designate the DR on a multi access network .
Step 3 build the shortest path

but why is stage 2 needed when u do multicast? thats because hello packets are very small and contains a list of neighbors and doesnt contain link costs to other networks or the full topology
SO WAHT DOES THE MULTICAST MEAN? DIFFERENT NETWORKS!! mutlicasts do not cross routers,
explore more!

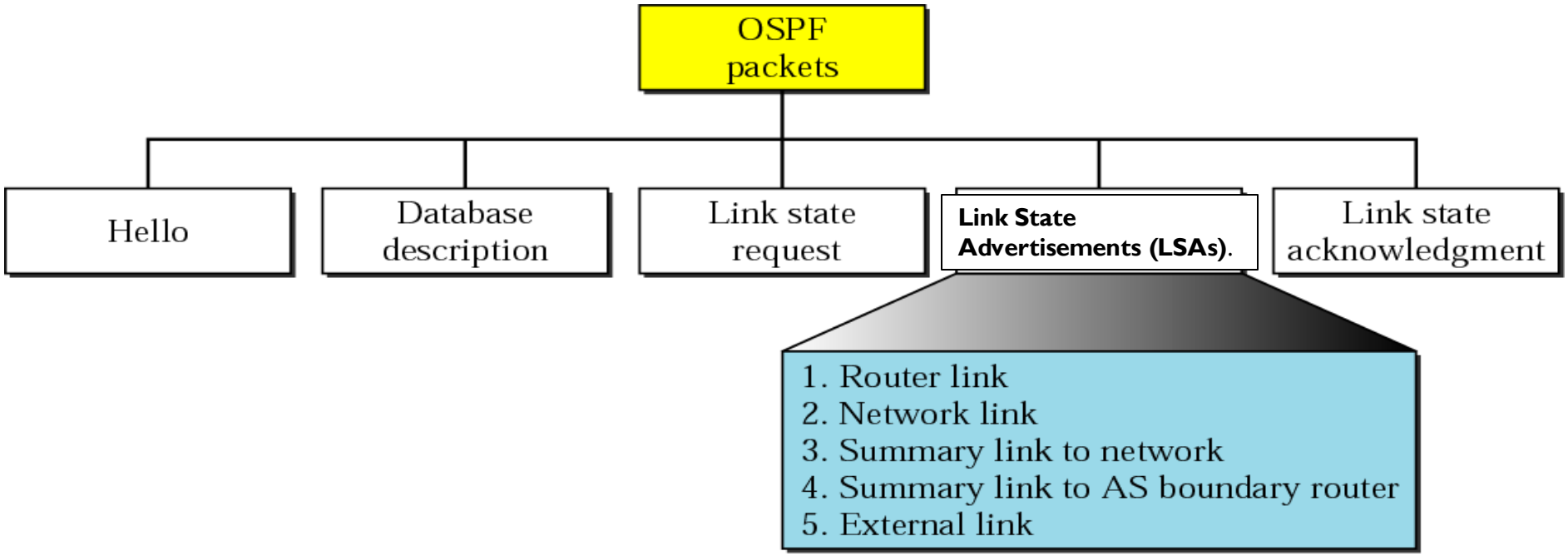
OSPF (cont)


Hello Packets
Share copies of LSAs
Adjacency DB
Link State DB
Apply Dijkstra's Algorithm
Incoming Packets
Forwarding Table
Forwarded Packets

OSPF uses IP directly



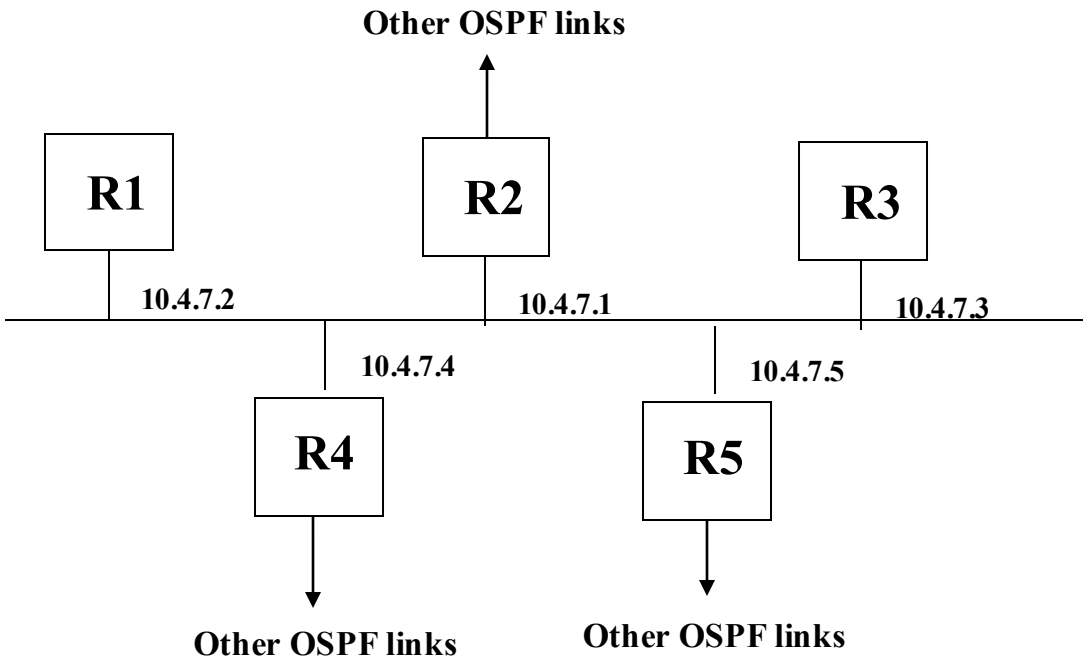
Types of OSPF packets



- Hello messages and LSAs are encapsulated in OSPF packets for transmission

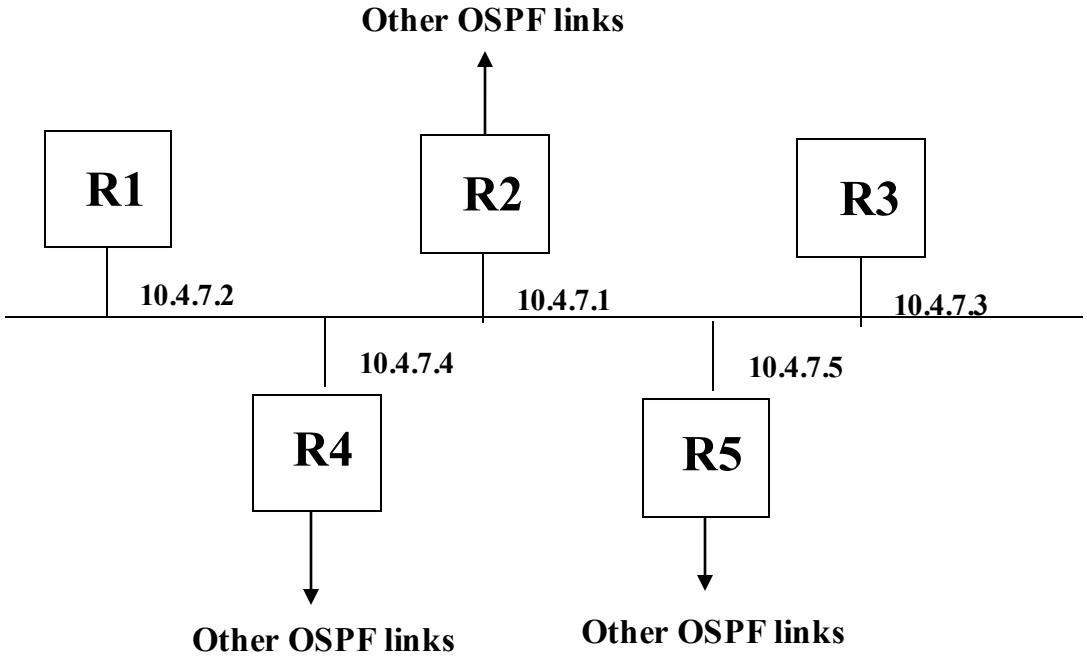
Transient Link

- In a Transient link (Network with multiple routers) lots of LSAs messages are flooded to synchronize the LSA databases.
  - Q: Can we minimize this traffic?

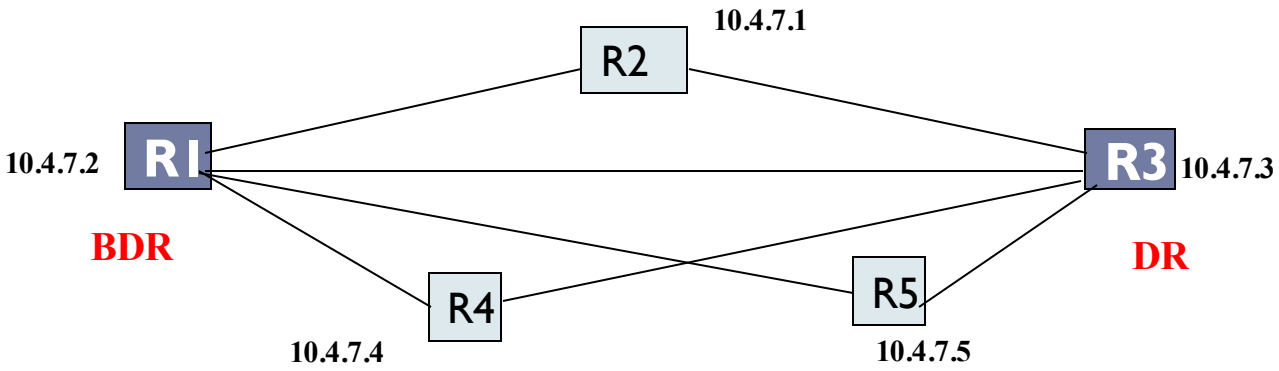


Transient link

Transient Link



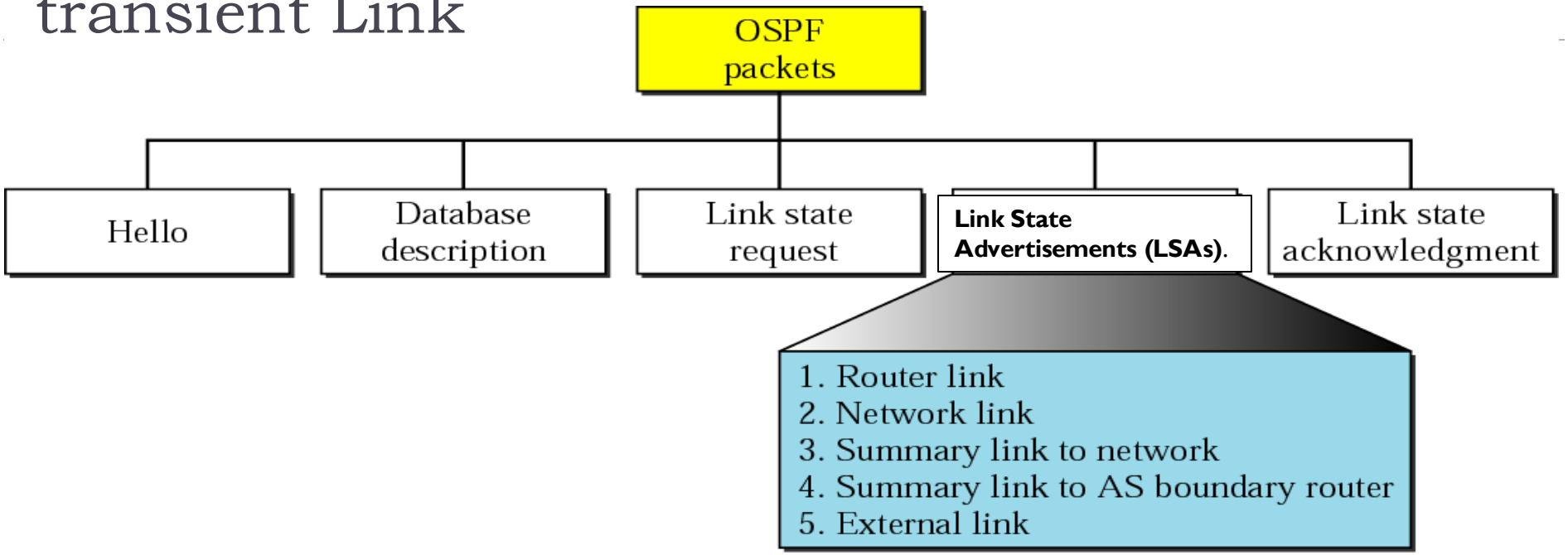
- *In a Transient link (network with several routers attached to it), Instead of each router flooding the entire network with **LSAs**, they only send it to the DR and BDR.*
- *That is, each router will have only DR and BDR as neighbor. The DR and BDR will have all routers in the network as neighbors.*



Eg. If R5 receives a LSA from other OSPF link then it conveys the same to DR and BDR using 224.0.0.6 multicast address

Q: DR/BDR election policy?

Initialising DB for a Newly Joining Router in transient Link



1. DR sends a summary of its database of LSAs to the new router - **database description packets**
2. The new router responds with a list of LSAs that it does not have or that are outdated **- link-state request packet**
3. DR forwards the full LSAs in the list to the new router - **link-state update (or Network Link Advertisement) packet**
4. New router responds with **link-state-ACK packet**
5. After initialisation, the newly joined router's new LSA should be sent to all routers in the area. First the new router sends its LSA to DR and BDR. Then, DR, DBR multicasts them to other routers.

Other LSAs

LSAs

- In general, it is Router Link LSA or Network Link LSA
  - Router Link LSA is sent by every router in the area
    - In this LSA you will find a list with all the directly connected links of **this** router.
  - Network Link LSA is sent by DR or BDR only in a *Transient link*
    - In this LSA we will find all the routers that are connected to the *Transient link*.

OTHER LSAs

usually when they are connected to a multi access network which is a

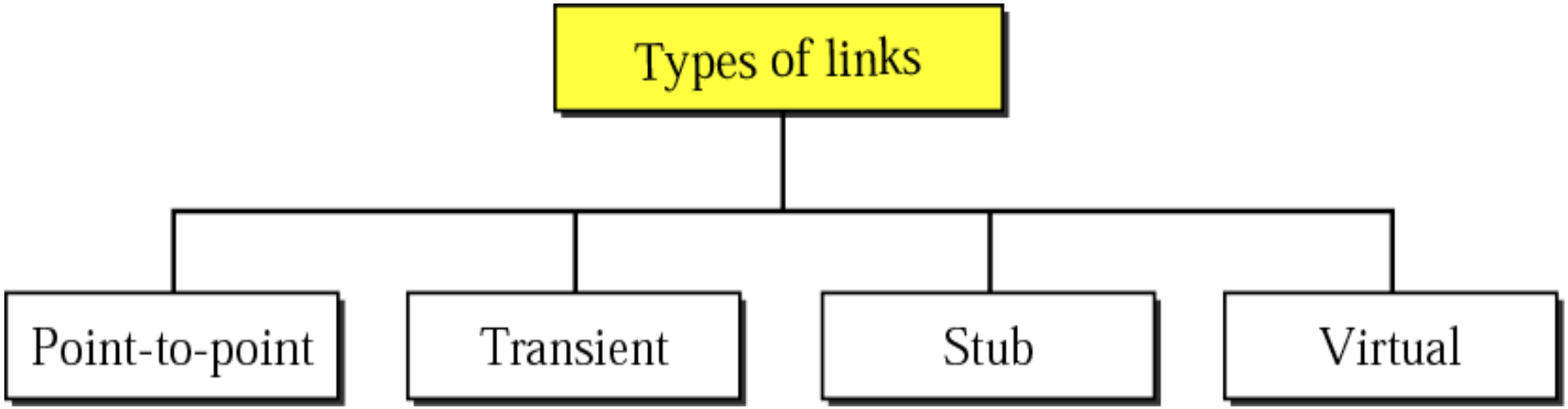
- Summary Link to Network

  Provide information on routers/networks outside the area, provided by ABR. [Note: within same AS]
- Summary Link to AS Boundary Router

  What is this for? (Flooded to all routers by ABR)
- External Link

  An **ASBR** redistributes routes learned from non-OSPF routing domains (such as RIP, BGP, or static routes) into the OSPF domain, advertising them as **external routes using Type 5 LSAs**.

Types of links



Link Type	Description	Link ID
1 – Point-to-Point	Point-to-point connection to another router.	Neighbor router ID
2 – Transient	Connection to transit network.	IP address of DR
3 – Stub	Connection to stub network.	IP Network
4 – Virtual	Virtual Link	Neighbor router ID

Q: What is the use of Virtual Link?

Routing Information maintained at Router

- Router maintains much more information than a host system.
  - The routing table on the following page is that of router 137.132.90.1.
  - Only a part of the table is given below.
  - Please note some sub-subnet destination network addresses.
  - Observe that network mask is stored as part of the information.

----------IP Routing Table----------

Total Routes = 185, Total Direct Networks = 5

Destination	Mask	Gateway	Metric	Status	TTL	Source
137.132.1.0	255.255.255.0	137.132.90.253	2	Up	--	OSPF-Inter-*
137.132.2.0	255.255.255.224	137.132.90.253	12	Up	--	OSPF-Inter-*
137.132.2.32	255.255.255.224	137.132.90.253	22	Up	--	OSPF-Inter-*
137.132.2.64	255.255.255.224	137.132.90.253	7	Up	--	OSPF-Inter-*
137.132.4.0	255.255.255.0	137.132.90.253	12	Up	--	OSPF-Inter-*
137.132.84.0	255.255.255.0	137.132.90.253	12	Up	--	OSPF-Inter-*
137.132.85.0	**255.255.255.0**	**137.132.90.254**	**11**	**Up**	**--**	**OSPF-Intra-***
		137.132.90.253	**11**	**Up**	**--**	**OSPF-Intra-***
137.132.86.0	**255.255.255.0**	**137.132.90.254**	**11**	**Up**	**--**	**OSPF-Intra-***
		137.132.90.253	**11**	**Up**	**--**	**OSPF-Intra-***
137.132.87.0	**255.255.255.0**	**137.132.90.254**	**11**	**Up**	**--**	**OSPF-Intra-***
		137.132.90.253	**11**	**Up**	**--**	**OSPF-Intra-***
37.132.88.0	**255.255.255.0**	**137.132.88.1**	**0**	**Up**	**--**	**Connected**
137.132.89.0	**255.255.255.224**	**137.132.89.1**	**0**	**Down**	**--**	**Connected**
137.132.89.64	**255.255.255.224**	**137.132.89.65**	**0**	**Down**	**--**	**Connected**
137.132.90.0	**255.255.255.0**	**137.132.90.1**	**0**	**Up**	**--**	**Connected**
137.132.91.0	**255.255.255.0**	**137.132.91.1**	**0**	**Up**	**--**	**Connected**
137.132.92.0	255.255.255.0	137.132.90.253	12	Up	--	OSPF-Inter-*
137.132.98.0	255.255.255.0	137.132.90.253	2	Up	--	OSPF-Inter-*

Administrative Distance (AD)

- When a router learns about the same network from multiple routing protocols, it uses the AD to **choose the "best" route** to install in the routing table.
  - Lower AD = more trusted route
  - Higher AD = less trusted route

```
Router# show ip route
O   10.0.0.0/24 [110/10] via 192.168.1.2, FastEthernet0/0
R   10.0.0.0/24 [120/5] via 192.168.1.3, FastEthernet0/1
```

- `O` = OSPF, metric 10, AD 110
- `R` = RIP, metric 5, AD 120

Quiz

https://pollev.com/banand

Make sure you
LOGIN
using your
NUSNET ID.

Summary

- OSPF Uses Dijkestra's Algorithm to find SP from Source to All nodes
- To use Dijkestra's algorithm, the Network Topology should be known.
  - Hello to Discover Neighbours
  - Link-State Protocol is used to share the Link States
  - Database of Link States (LSAs), describes the Topology
- In transient networks, normal routers send LSAs to only DR and BDR. DR/BDR sends LSAs to all Routers.

Reminder:

Assignment 4 will be released soon!
Group Work

END