CS 540
Computer Networks II

Sandy Wang
sandy.w@svuca.edu

9. ROUTING PROTOCOLS – ISIS

Topics

1. Overview
2. LAN Switching
3. IPv4
4. IPv6
5. Tunnels
6. Routing Protocols -- RIP, RIPng
7. Routing Protocols -- OSPF
8. Midterm Exam
9. **IS-IS**
10. BGP
11. MPLS
12. Transport Layer -- TCP/UDP
13. Congestion Control & Quality of Service (QoS)
14. Access Control List (ACL)
15. Final Exam

Reference Books

- **Routing TCP/IP Volume I, 2nd Edition** by Jeff Doyle and Jennifer Carroll

  ISBN: 1-57870-089-2
- **Routing TCP/IP Volume II** by Jeff Doyle and Jennifer DeHaven
  ISBN: 1-57870-089-2
- **Cisco CCNA Routing and Switching ICND2 200-101 Official Cert Guide, Academic Edition** by Wendel Odom -- July 10, 2013**.**
  ISBN-13: 978-1587144882
- **The TCP/IP Guide: A Comprehensive, Illustrated Internet Protocols Reference** by Charles M. Kozierok – October 1, 2005.
  ISBN-13: 978-1593270476
- **CCNA Routing and Switching 200-120 Network Simulator.** By Wendell Odom, Sean Wilkins. Published by Pearson IT Certification.
- http://class.svuca.edu/~sandy/class/CS540/

Interior and Exterior Gateway Protocols

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		**Link State Routing Protocols**		**Path Vector**
Classful	**RIPv1** (1982/1988)	**IGRP** (1985)			**EGP** (1982)
Classless	**RIPv2** (1994)	**EIGRP** (1992)	**OSPFv2** (1991)	**IS-IS** (1990)	**BGPv4** (1995)
IPv6	**RIPng** (1997)	**EIGRP for IPv6** (not yet released)	**OSPFv3** (1999)	**IS-IS for IPv6** (2000)	**BGPv4 for IPv6** (1999)

- **Note**: IGRP and EIGRP are Cisco proprietary protocols. They are meant as an alternative between the limited RIP routing protocol and the more complicated and resource intensive OSPF and IS-IS routing protocols. IGRP was discontinued with IOS 12.2 in 2005.
- The dates shown are when the RFC or other document was finalized. The protocol may have been implemented earlier than this date.

History

- IS-IS: Intermediate System to Intermediate System
- Described in ISO 10589, 1992
- First production developed by Digital Equipment Corporation
- Integrated IS-IS was proposed RFC 1195. Routing both ISO's Connectionless-Mode Network Service (CLNS) and IP.

Similarities between OSPF & IS-IS

- Link-state routing protocol and use a Dijkstra-based SPF algorithm to calculate shortest-path tree
- Hellos to maintain adjacencies
- Hierarchical
- Provide address summarization
- Classless
- Elect Designated Router for broadcast networks
- Authentication Capabilities

point-to-multipoints or broadcast

LAN

IS-IS versus OSPF - Terminology

IS-IS	OSPF	Comments
ES (End System)	Host send/receive but not fwd.	
IS (Intermediate System)	Router	
Circuit	Link	
SNPA (Subnetwork Point of Attachment)	Datalink Address	MAC address
PDU (Protocol Data Unit)	Packet	
DIS (Designated Intermediate System)	DR (Designated Router)	
N/A ← no back up router	BDR	Backup designated router
IIH (IS-to-IS Hello Packet)	Hello packet	

IS-IS versus OSPF - Terminology

IS-IS	OSPF	Comments
LSP (Link-State Packet)	LSA (Link -State Advertisement)	LSAs are actually comparable to TLVs used in LSPs.
CSNP (Complete Sequence Number PDU or Packet)	DBD (Data Base Description Packet)	the summary (title/ID) of the data.
PSNP (Partial Sequence Number PDU or Packet)	LSAck or LSR (Link State Request)	
Routing Domain	AS	The term routing domain is also used with OSPF.
Level 1 Area ← within your area	Area (non-backbone)	
Level 2 Area ← talk to ppl outside ur area	Backbone area (Area 0)	IS-IS uses a backbone path connected by contiguous L2 routers. There is no backbone area in IS-IS

IS-IS versus OSPF – ISs (Routers)

IS-IS	OSPF	Comments
Level 1 IS (router)	Internal Non-backbone Router	Internal, non-backbone router in a Totally Stubby Area
Level 2 IS (router)	Internal Backbone Router or ASBR	Any Level 2 router can distribute externals into the domain. No special name. (Cisco IOS allows Level 1 routers to distribute externals.)
Level 1-2 IS (router)	ABR	
System ID	Router ID	The System ID is the key for SPF calculations. Sometimes the NET address is thought of as the Router ID.
AFI = 49	RFC 1918 Addresses	AFI is part of the NSAP.

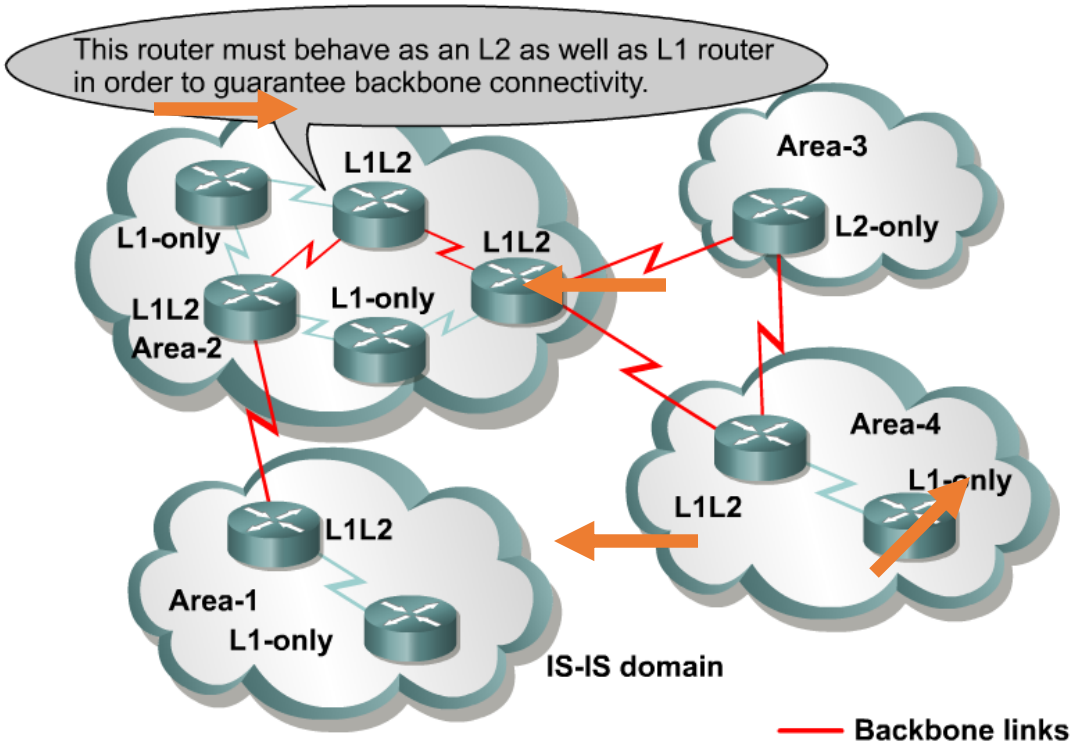
talk to both

IS-IS versus OSPF - Timers

Interface	**IS-IS**	**OSPF**
Point-to-Point	Hello – 10 sec Holdtime – 30 sec	Hello – 10 sec Dead – 40 sec
Broadcast	Hello – 10 sec Holdtime – 30 sec	Hello – 10 sec Dead – 40 sec
NBMA	N/A	Hello – 30 sec Dead – 120 sec

Other	**IS-IS**	**OSPF**
LS Aging	1,200 sec or 20 min (counts down)	3,600 sec or 60 min (counts up)
LS Refresh	Every 15 min	Every 30 min
NBMA	N/A	Hello – 30 sec Dead – 120 sec
SPF Delay/Holdtime	5.5 sec / 10 sec	5 sec / 10 sec

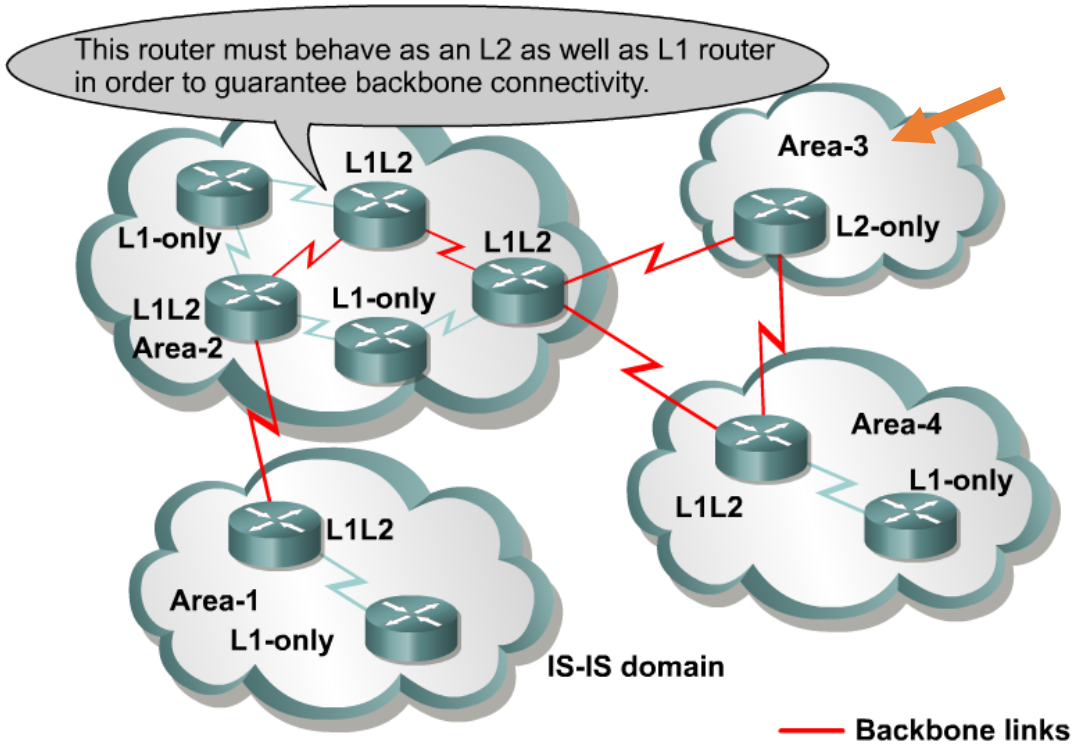
Level 1 Router



- **Level 1 IS (L1 IS, router)**
  - Analogous to OSPF Internal non-backbone router (Totally Stubby)
  - Responsible for only routing to ESs inside an area.
- Level 1 routers maintain the Level 1 database for the area and exit points to neighboring areas.

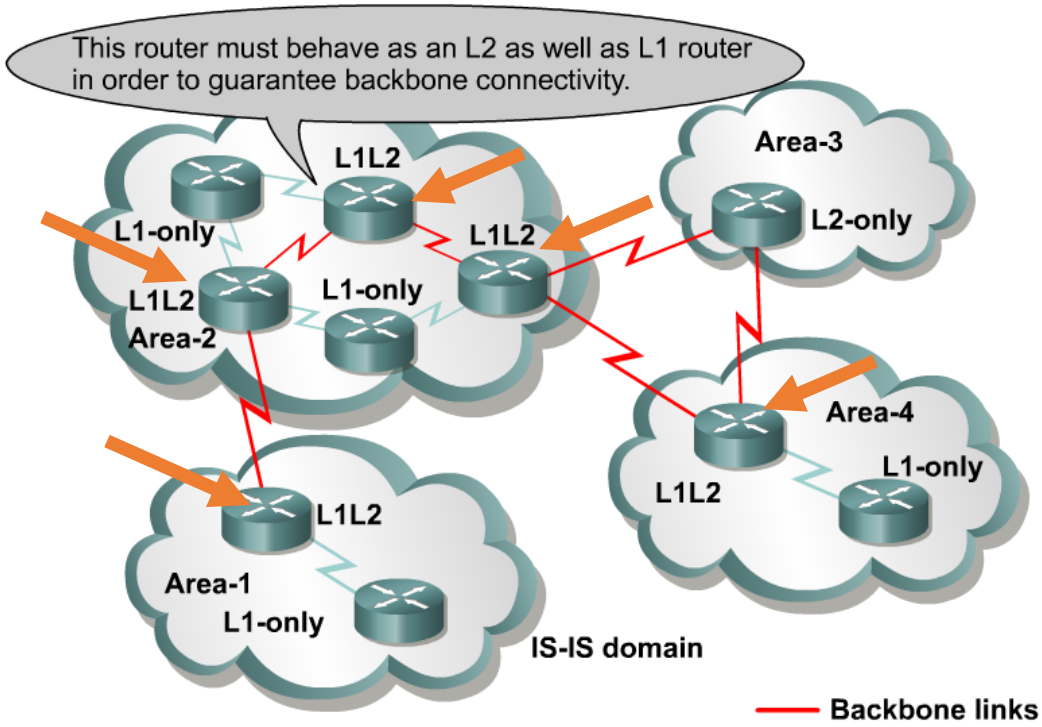
- ISIS does not have strict restriction of Area 0 as OSPF
- L1 & L2 are separate databases

Level 2 Router



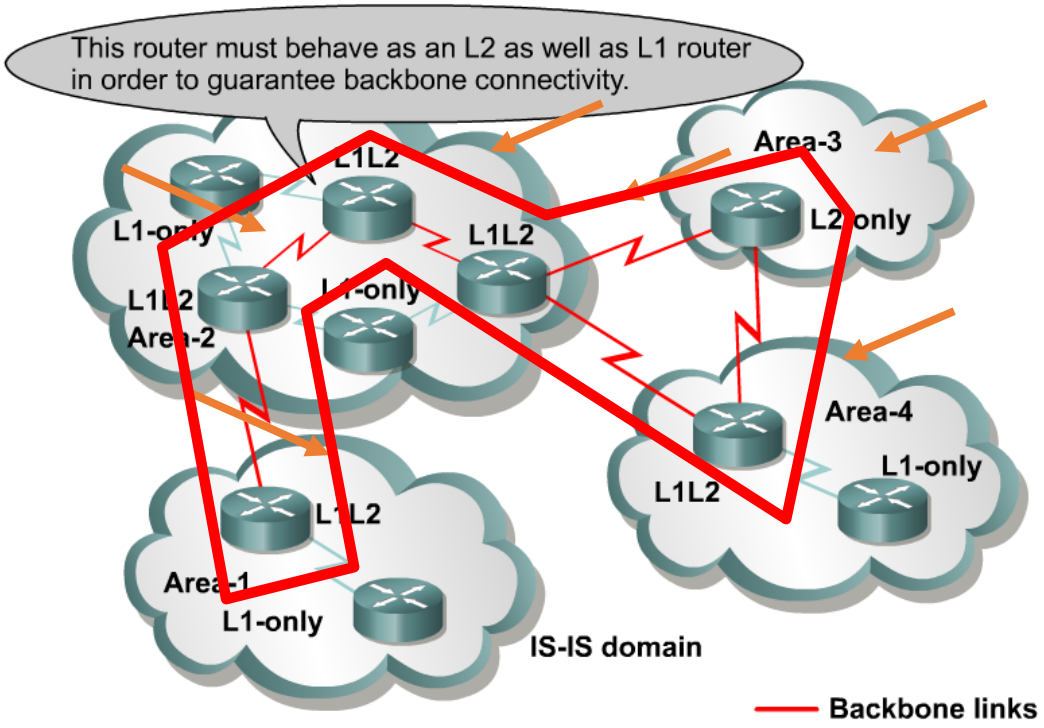
- **Level 2 IS (L2 IS, router)**
  - Analogous to OSPF Internal Backbone router
  - Responsible for routing between areas
- Also referred to as area routers.
- Interconnects the Level 1 areas
- Store separate database of only inter-area topology

Level 1 – Level 2 Router



- **Level 1 and Level 2 IS (L1-L2 IS, router)**
  - Analogous to OSPF ABR router
  - Participate in both L1 intra-area routing and L2 inter-area routing.
- Maintain both Level 1 and Level 2 LSDB
- Support Level 1 function communicating with other Level 1 routers in their area
  - Inform other Level 1 routers that they are the exit point (default route) from the area.
- Support Level 2 function communicating with the rest of the backbone path.

IS-IS Backbone



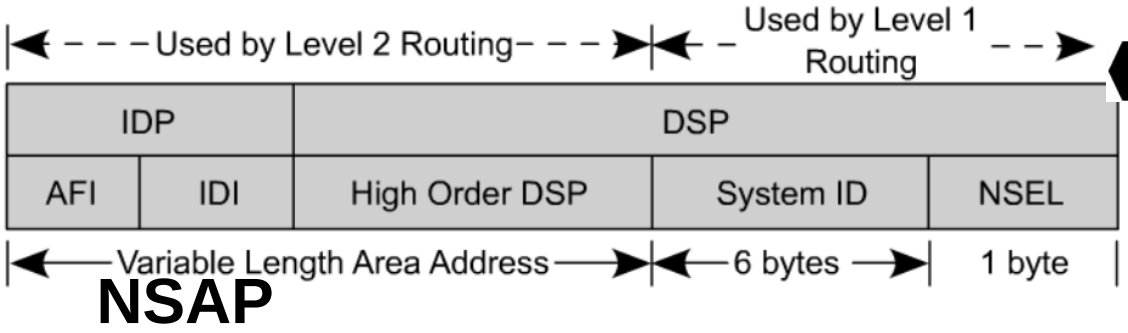
- IS-IS does **not** share the concept of a backbone area 0 with OSPF.
- **IS-IS backbone** a set of distinct areas interconnected by a chain of Level 2 routers, weaving their way through and between the Level 1 Areas.
- The **IS-IS backbone (path)** consists of a contiguous set of Level 1-2 and Level 2 routers.
- **Where is the backbone (path)?**

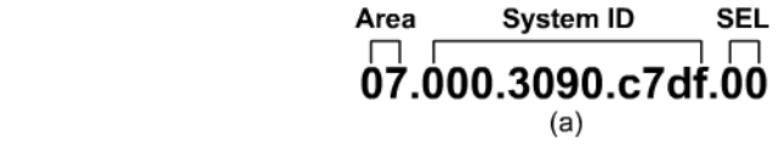
ISO Addressing

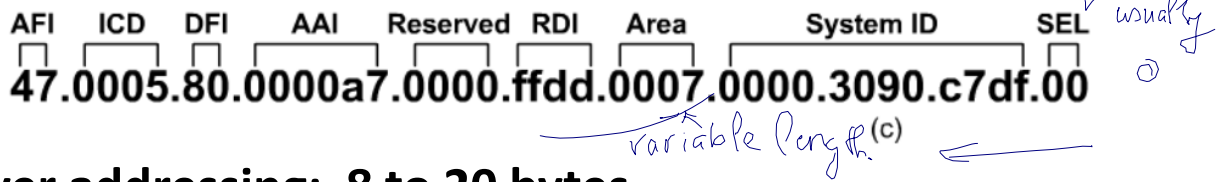
NSAP (Area, System ID, NSEL)

SNAP

ISO Address





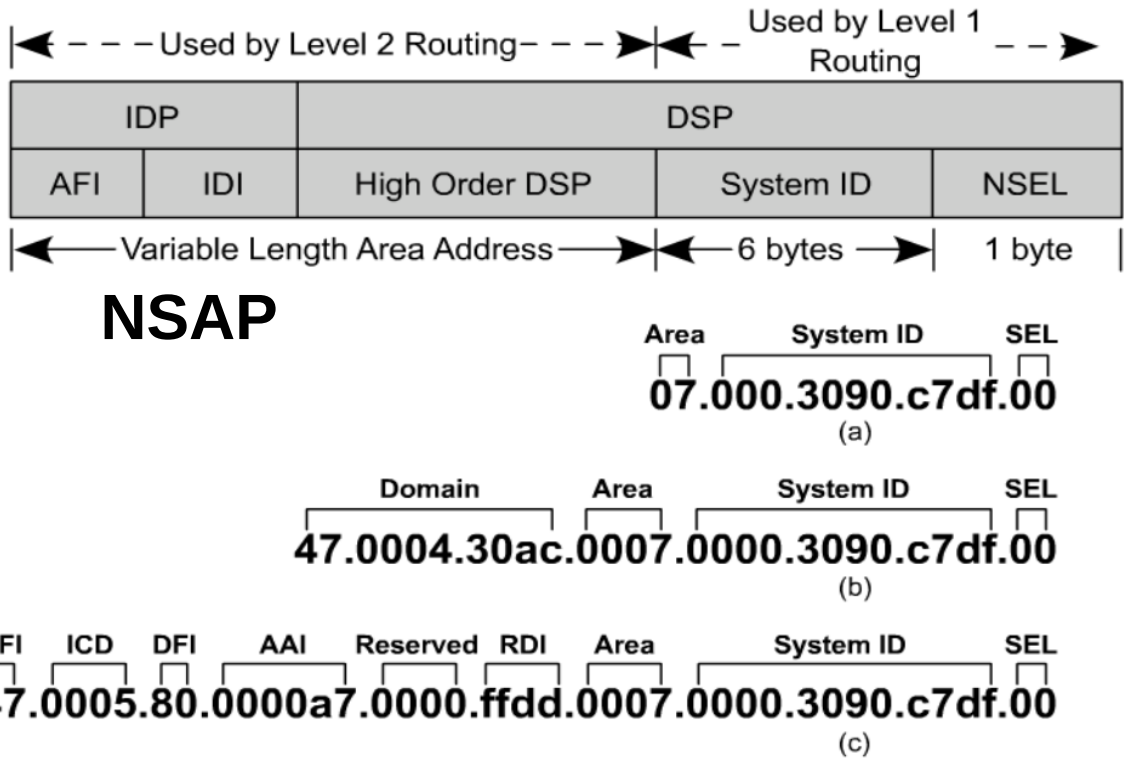


- IS-IS uses **OSI network layer addressing: 8 to 20 bytes**
- Network Entity Title (NET) Described in ISO 8348
- A variety of NSAP formats exist, which we will not go into.
- Represented in hexadecimal (up to 40 hex digits)
- Cisco format: Area – System ID – NSEL (always 00 on ISs)

49.0001.2222.2222.2222.00

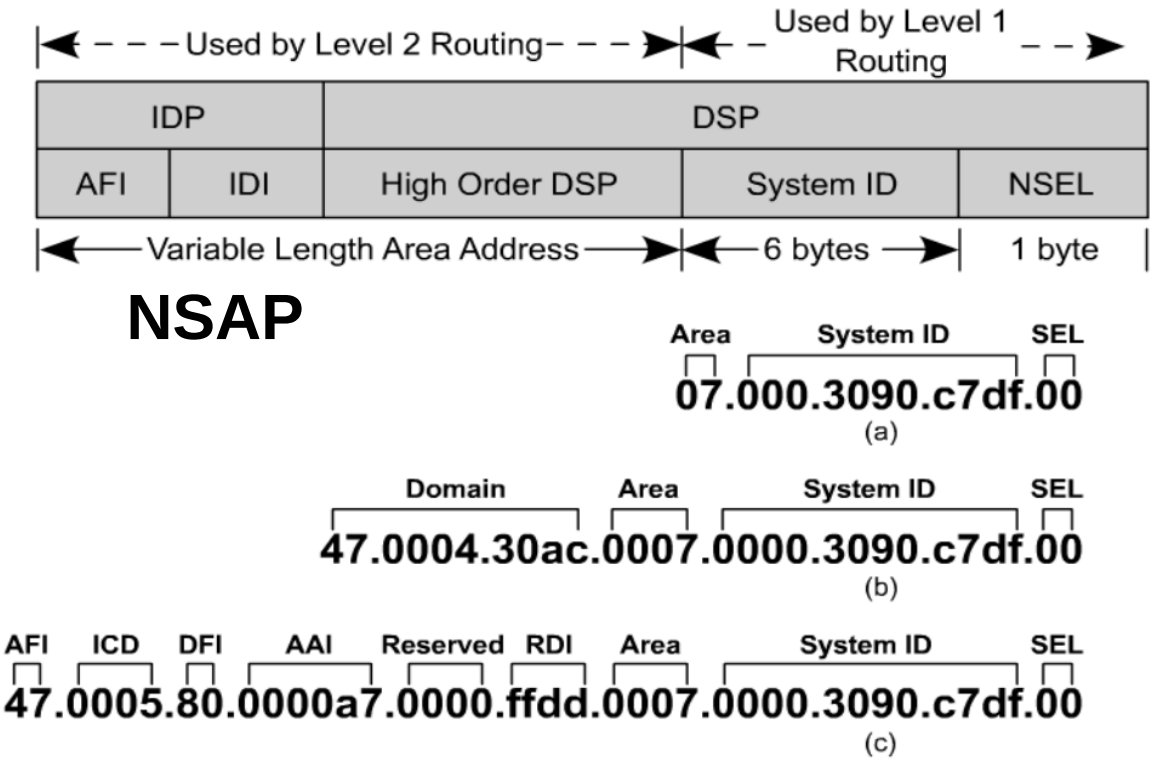
Cisco Area System ID 6 bytes usually MAC addr

OSI Addressing



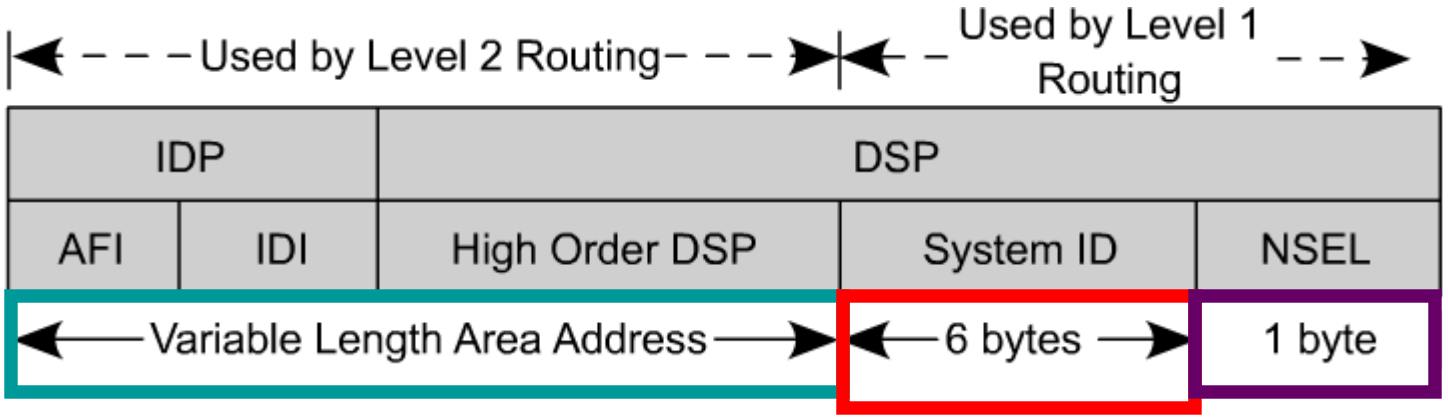
- (a) Simple Area ID/System ID Format
- (b) An OSI NSAP Format
- (c) a GOSIP NSAP Format (Government Open System Interconnection Profile)
  - AFI – Authority and Format identifier
  - ICD – International Code Designator
  - DFI – Domain Specific Part (DSP) Format identifier
  - AAI – Administrative Authority identifier
  - RDI – Routing Domain Identifier (Autonomous system number)
  - SEL: Network Service Access Point (NSAP) Selector

OSI Addressing



- Must begin with single octet (47.xxxx….)
- Must end with single octet

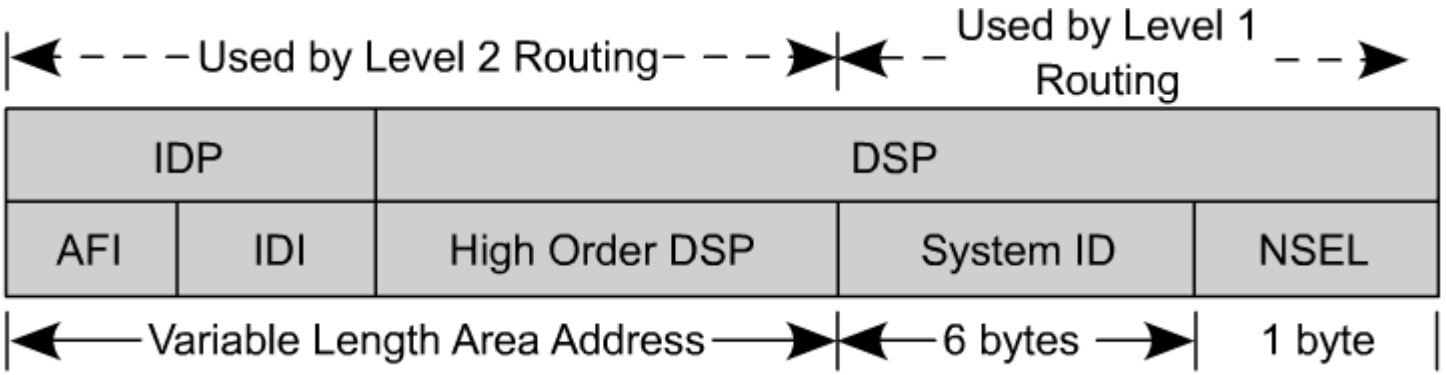
NSAPs



- Format of the Cisco NSAP address consists of three parts.
  1. Area address
  2. System ID
  3. NSAP selector byte

- **Area address** is a variable length field
- The **system ID** is the ES or IS identifier in an area, ***similar to the OSPF router ID***.
  - The system ID has a fixed length of six bytes as engineered in the Cisco IOS.
- The **NSAP selector byte** is a service identifier.
  - Analogous to that of a ***port or socket in TCP/IP***.

NSAPs – Cisco Format



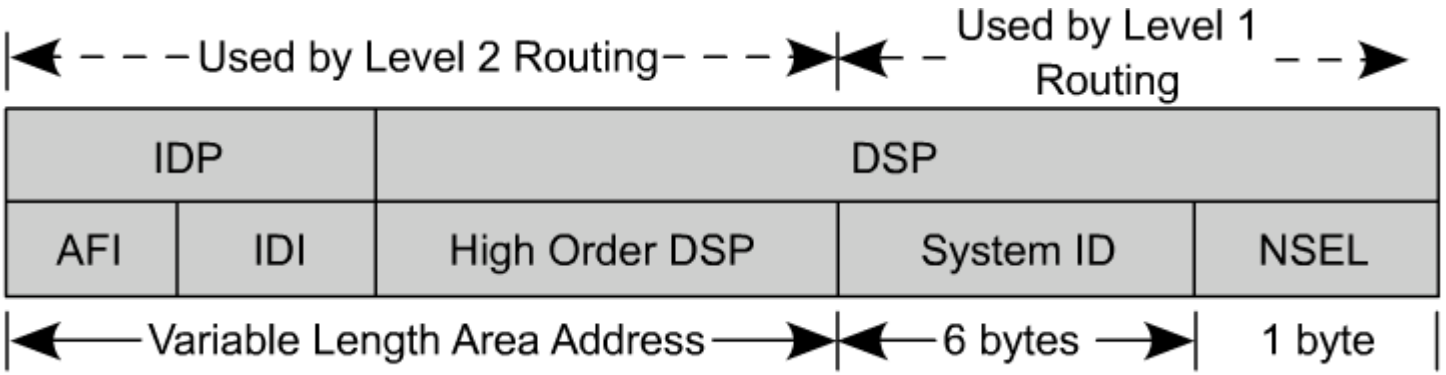
Area – System ID – NSEL

49.0001.2222.2222.2222.00

Area

- Addresses starting with 49 (AFI=49) are considered private IP address, analogous to RFC 1918.
  - Routed by IS-IS
  - Should not be advertised to other CLNS networks (outside this IS-IS domain)
- Additional 2 bytes (**0001**) added for the **area ID**
- All routers in the same are must have the same area address

NSAPs – Cisco Format



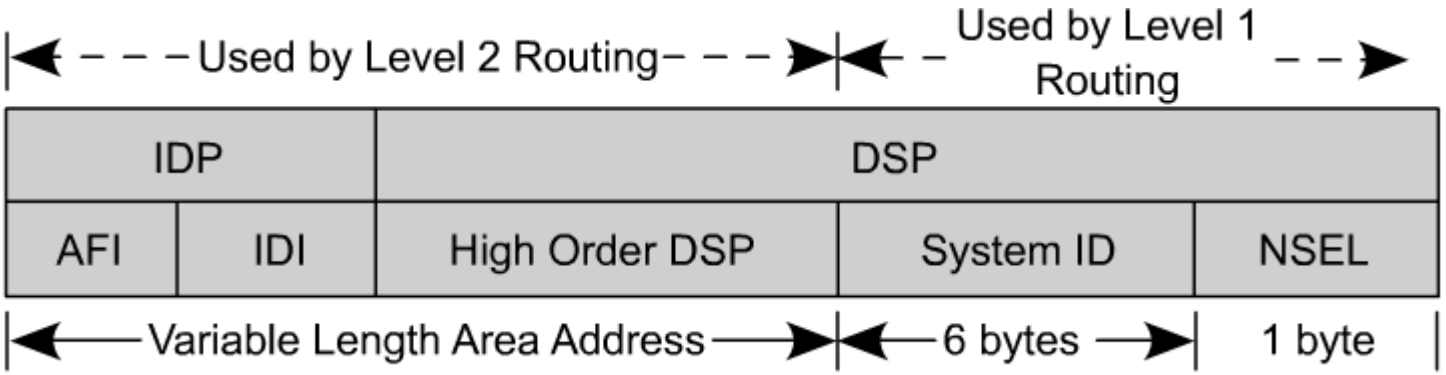
Area – System ID – NSEL

49.0001.2222.2222.2222.00

System ID

- Cisco fixes the System ID at 6 bytes.
- Customary to use one of the following:
  - MAC address from the router
  - IP address of loopback interface
    - 192.168.111.3 -> 192.168.111.003 -> 1921.6811.1003
- Each device (IS and ES) must have a unique System ID within the area. (Recommended to make them unique within the domain.)

NSAPs – Cisco Format



Area – System ID – NSEL

49.0001.2222.2222.2222.00

NSEL (NSAP Selector)

- NSEL is a service identifier.
- Loosely equivalent to that of a ***port or socket in TCP/IP***.
- Not used in routing decisions.

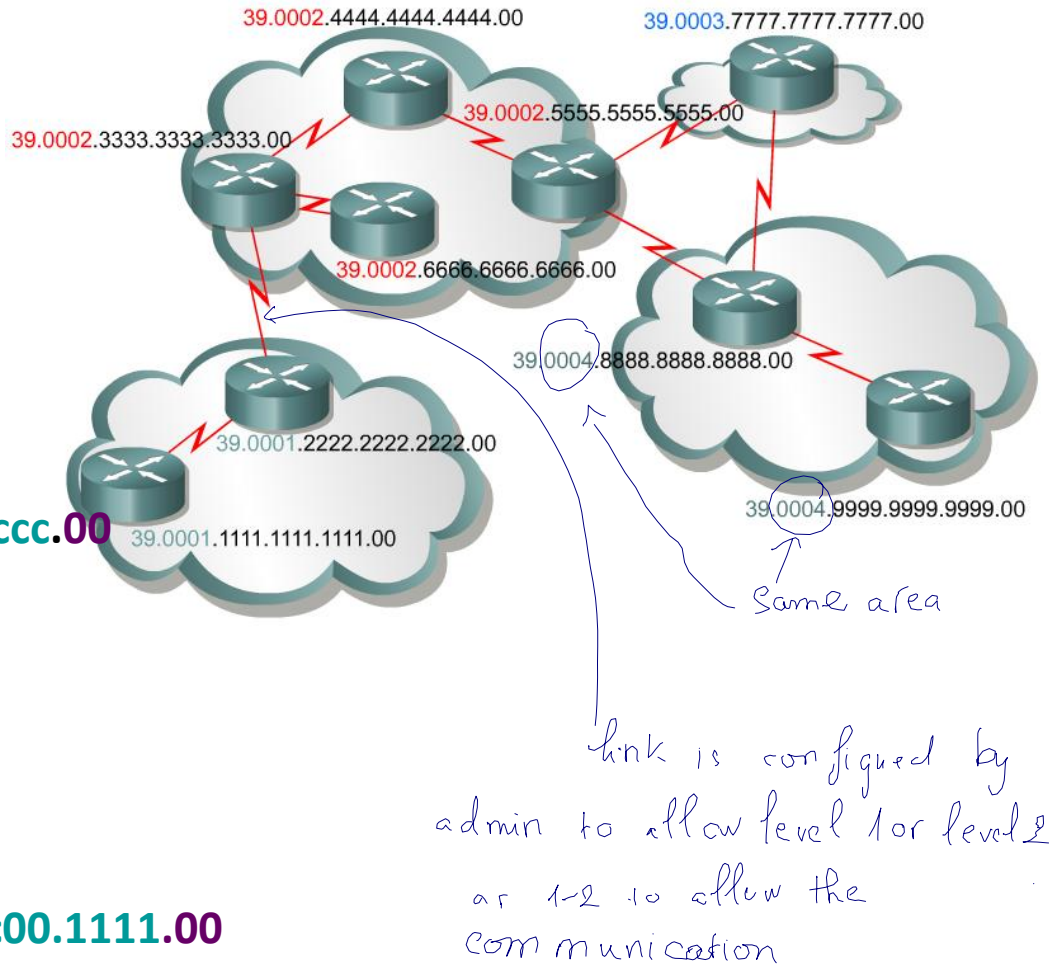
NET (Network Entity Title)

- When NSEL = **00**, it identifies the device itself, the network level address.
- The NSAP with a NSEL = 00 is known as a Network Entity Title (NET)
  - A NET is an NSAP with the NSEL set to (00)

NSAP (NETs)

Area – System ID – NSEL

49.0001.2222.2222.2222.00



Other Examples

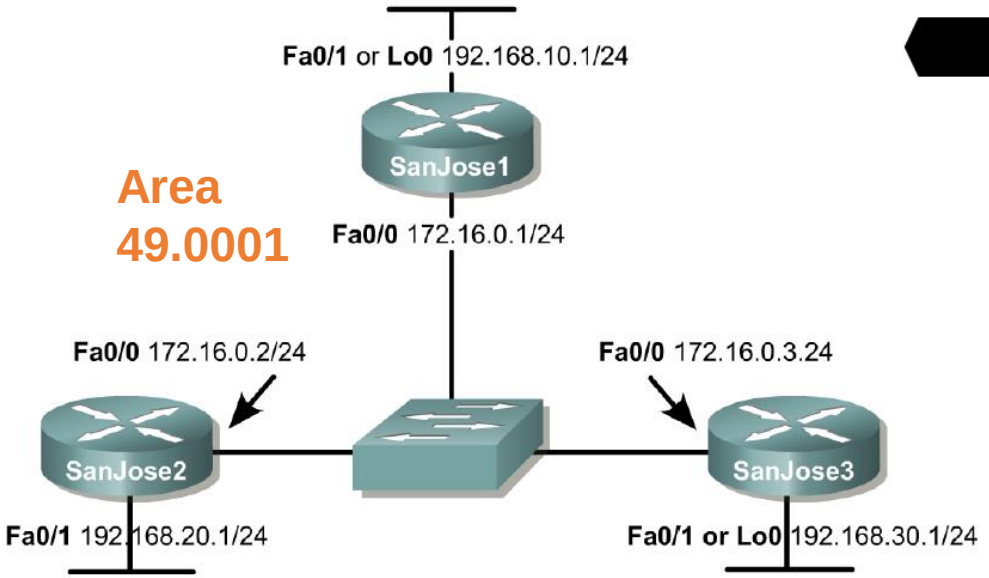
Example 1: NSAP **47.0001.aaaa.bbbb.cccc.00**

- Area ID is:
  - **47.0001**
- System ID is:
  - **aaaa.bbbb.cccc**
- NSAP selector byte is:
  - **00**

Example 2: NSAP **39.0f01.0002.0000.0c00.1111.00**

- Area ID is:
  - **39.0f01.0002**
- System ID is:
  - **0000.0c00.1111**
- NSAP selector byte is:
  - **00**

Configuring IS-IS (so far)



SanJose1

```
interface FastEthernet0/0
 ip address 172.16.0.1 255.255.255.0
 ip router isis
 isis priority 100
router isis
 net 49.0001.1111.1111.1111.00
```

SanJose2

```
interface FastEthernet0/0
 ip address 172.16.0.2 255.255.255.0
 ip router isis
router isis
 net 49.0001.2222.2222.2222.00
```

Administrator

Area . System ID . NSEL

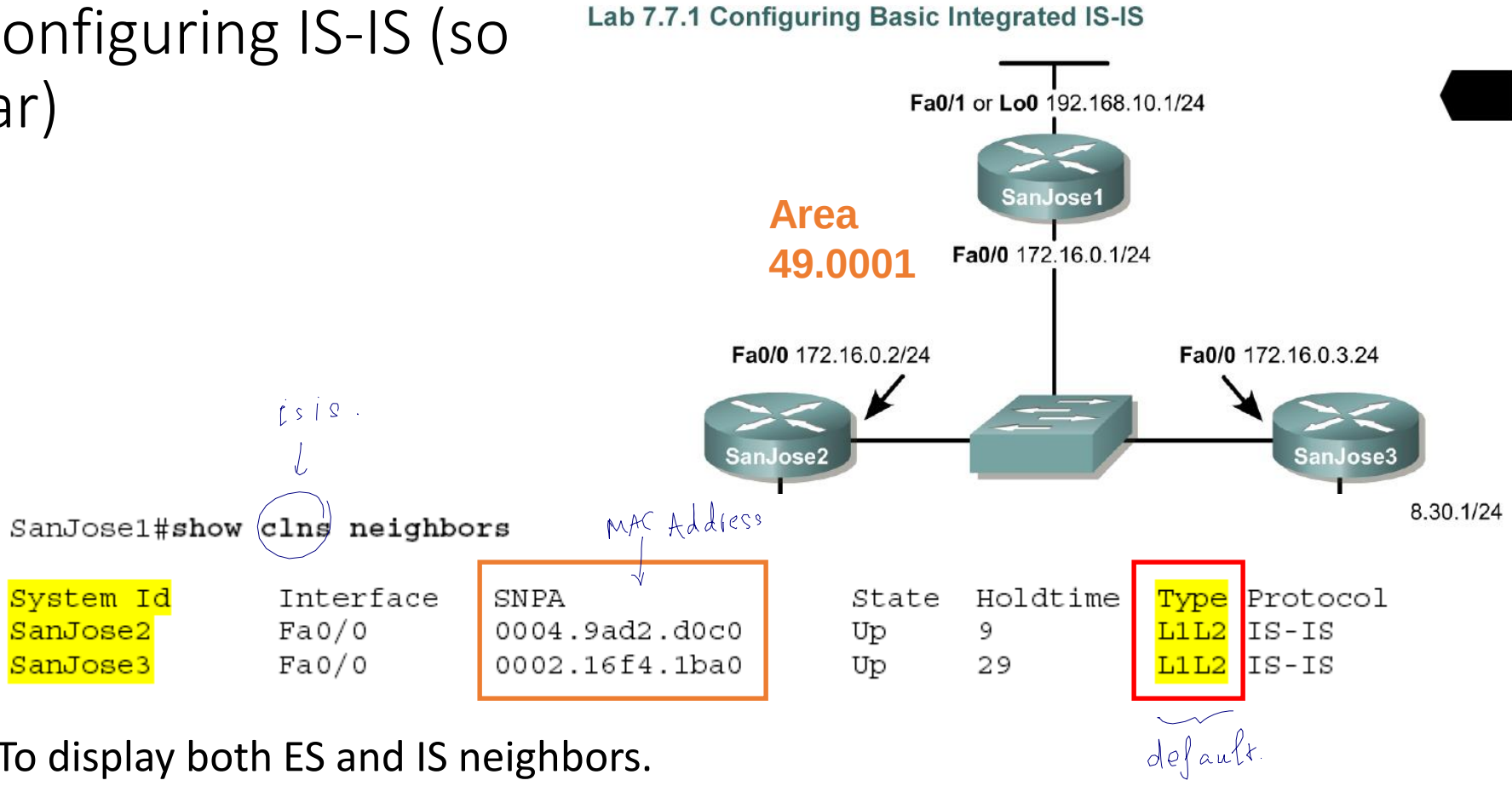
SanJose3

```
interface FastEthernet0/0
 ip address 172.16.0.3 255.255.255.0
 ip router isis
router isis
 net 49.0001.3333.3333.3333.00
```

if not enter level = 1&2.

- **`ip router isis`**: IS-IS must be enabled on the interface
- **Note:** IS-IS routing cannot be enabled on an interface until an IP address has been configured on the interface.
- **IOS:** Cisco IOS 12.2(12) with Enterprise Plus (16 MB Flash/48 MB RAM) or Enter Plus IPSec56 (16 MB Flash/64 MB RAM)

Configuring IS-IS (so far)



- To display both ES and IS neighbors.
- **SNPA** (Subnetwork Point of Attachment) address is the interface circuit ID.
  - Ethernet: MAC address of the remote router.
  - Serial, would show encapsulation, I.e. HDLC
- **Type**: Cisco routers default to L1-L2 type routers.
  - We will see how to change this in a moment.

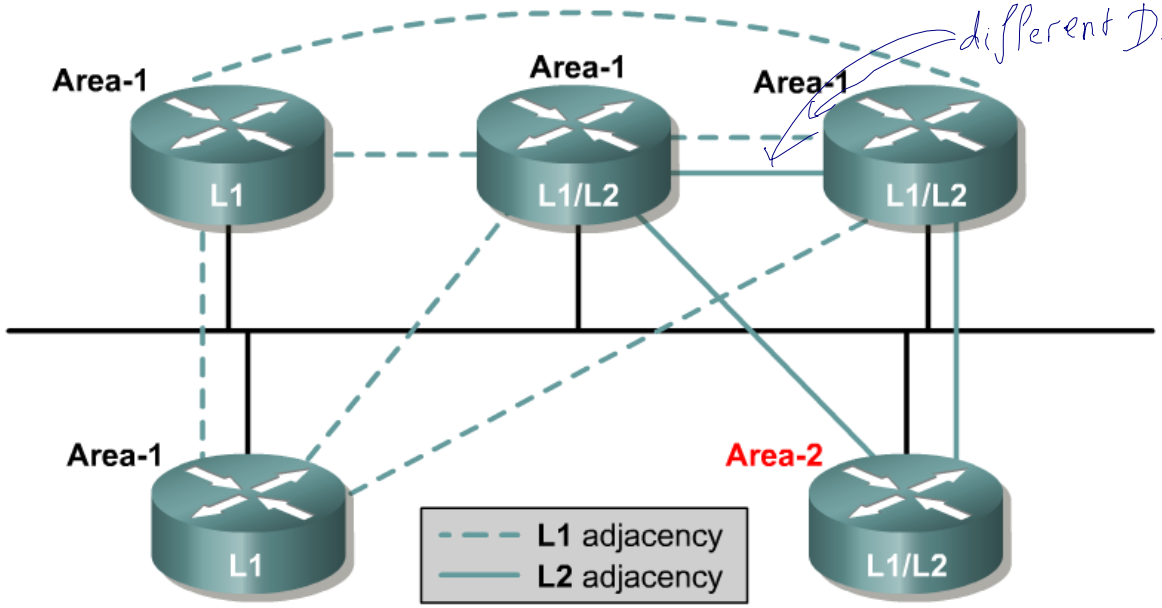
- send hello on each link.
- check Area ID &. only communicate with other routers on the same level.

Hello Messages

- IS-IS uses **Hello PDUs** to establish adjacencies with other routers
- L1-only routers and L1/L2 routers → L1 adjacency
- L2-only routers and L1/L2 routers → L2 adjacency
- L1-only and L2-only routers → No adjacency
- Rules:
  - Two L1-only routers form an L1 adjacency only if their AIDs match
  - Two L2-only routers from an L2 adjacency, even if their AIDs are different
  - An L1-only router forms an L1 adjacency with an L1/L2 router only if their AIDs match
  - An L2-only router forms an L2 adjacency with an L1/L2 router even if their AIDs are different
  - Two L1/L2 routers form both L1 and L2 adjacencies if their AIDs match
  - Two L1/L2 routers form only and L2 adjacency if their AIDs do not match

Adjacencies

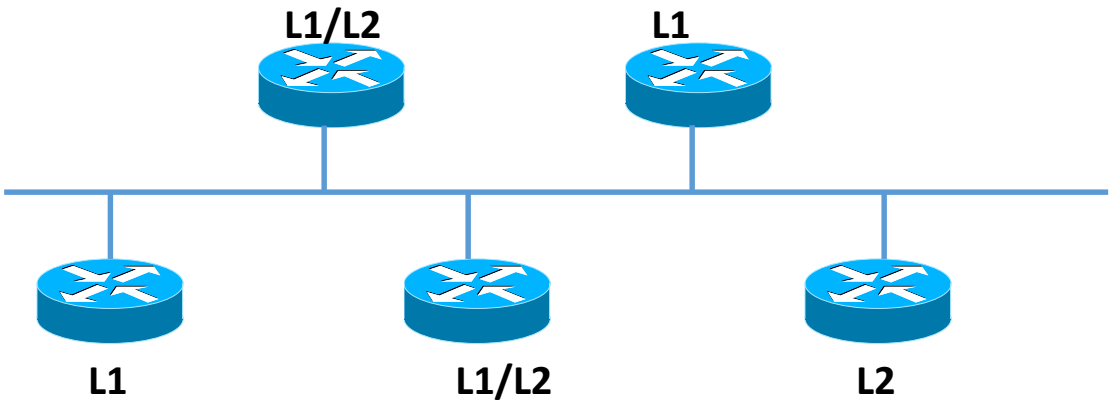
LAN Adjacencies



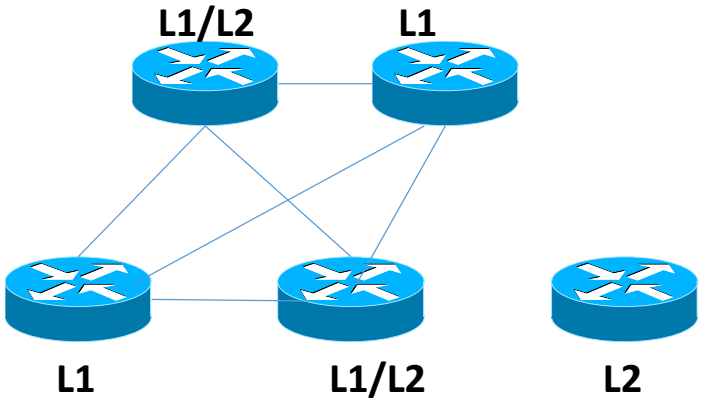
Adjacencies are established based on the area address announced in the incoming IIHs and the type of the router.

- L1 routers form L1 adjacencies with L1 and L1-L2 routers in their area.
- L2 routers form L2 adjacencies with L2 and L1-L2 routers in their area **or** another area.
- L1 router does not form an adjacency with an L2 router

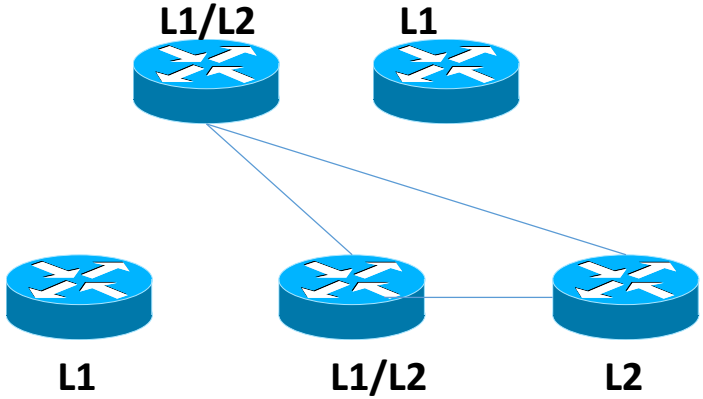
Level 1 and Level 2 Adjacencies



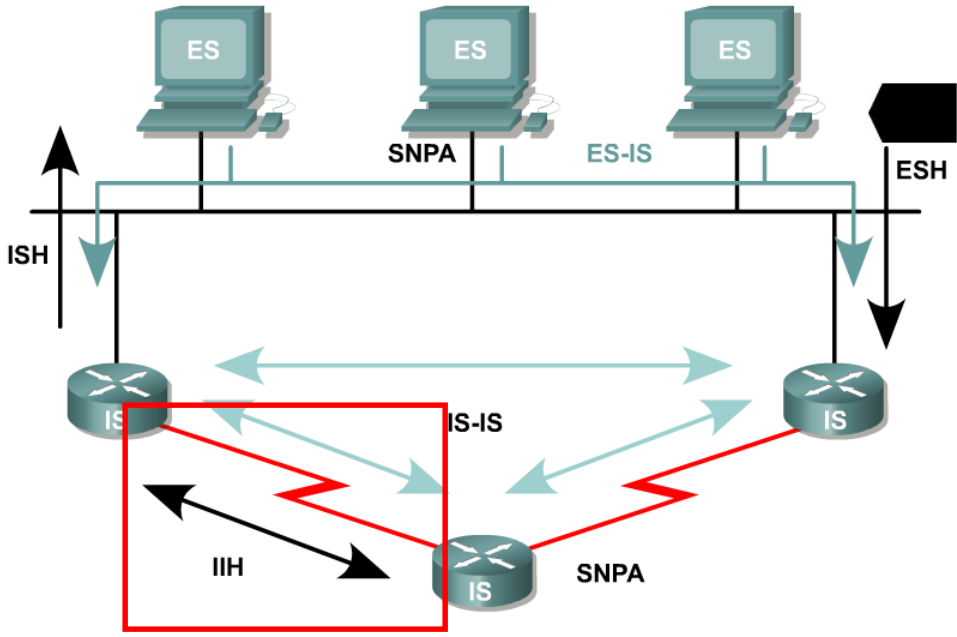
Level 1 Adjacencies



Level 2 Adjacencies

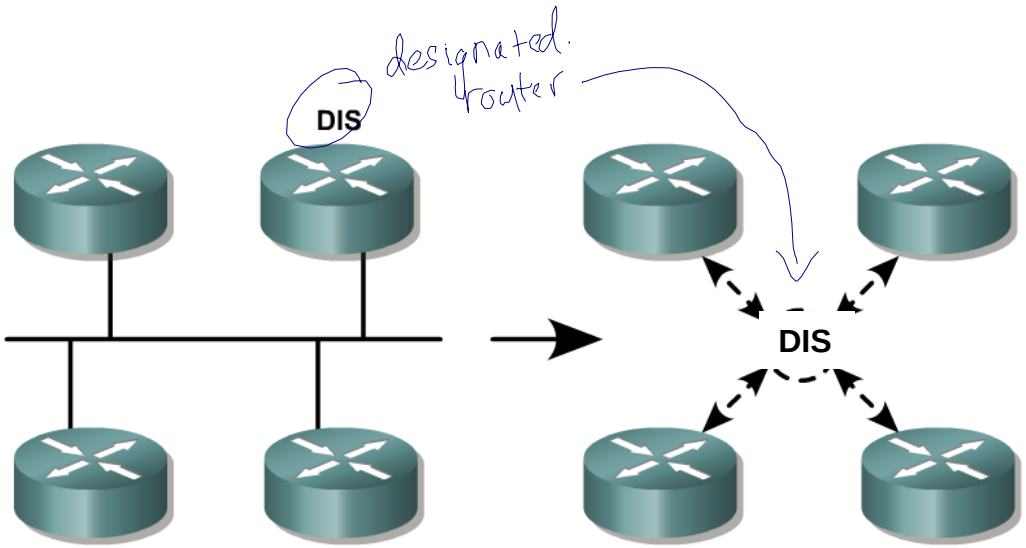


Neighbors and Adjacencies



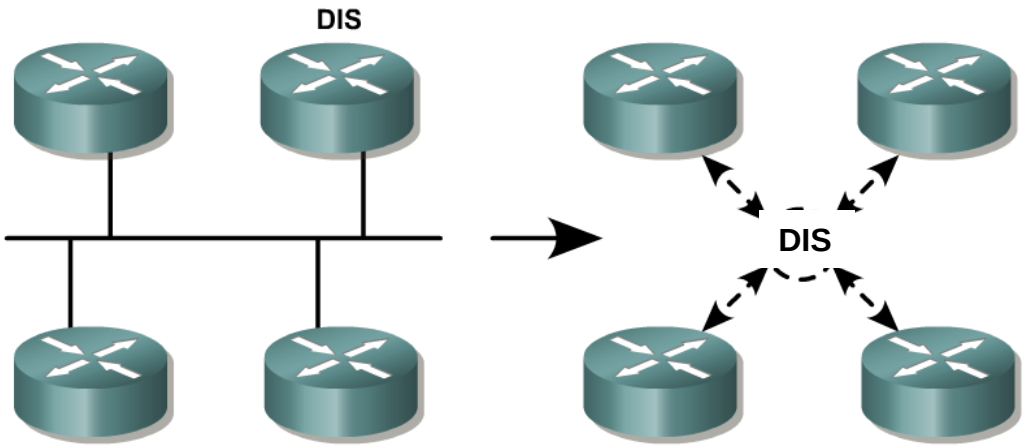
- IS-IS discover neighbors and forms adjacencies using **IS-IS Hello PDUs.**
  - Transmitted every **10 seconds**
  - Can be changed using the interface command, **`is hello-interval`**
- **Hold time** defaults to **3 times** the Hello time (**30 seconds**), before declaring a neighbor dead.
  - Changed using the interface command **`is hello-multiplier`**
  - Default is 3

LAN Representation and Adjacencies



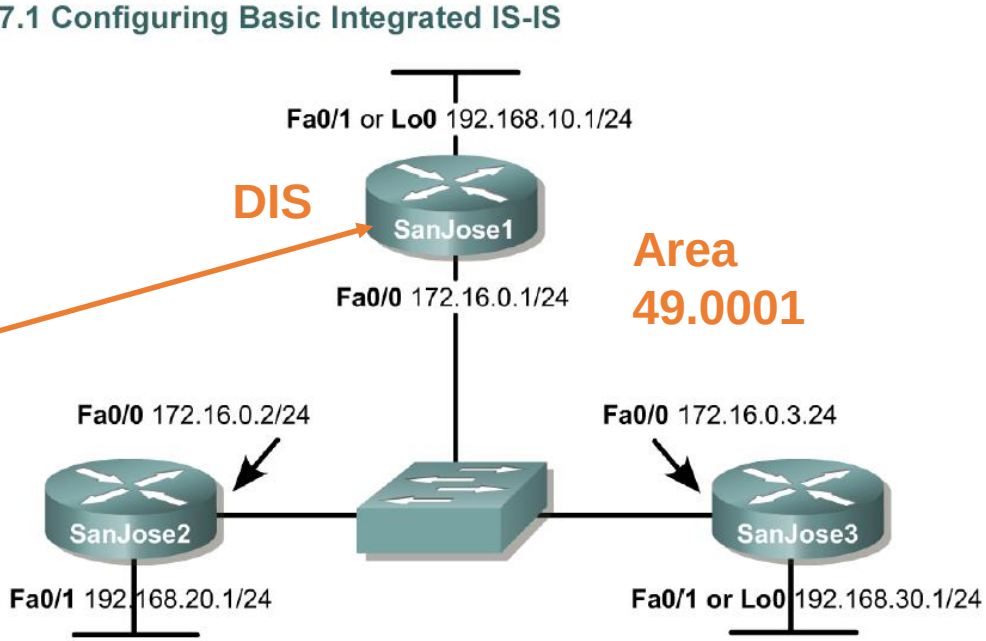
- Similar to the DR in OSPF…
- **DIS (Designated IS)** is elected to generate the LSP (Link State Packet, ie. LSA) representing the virtual router connecting all attached routers to a star-shaped topology
- LAN uses a virtual node called **pseudo node**.
  - Represents the LAN
  - Sent by the DIS

LAN Representation and Adjacencies



- **Election of DIS**:
  - Router with highest **priority** (in the range of 0-127, Cisco default is 64)
  - Router with highest **MAC address**
- No Backup DIS
- No way to make a router ineligible from being DIS (no OSPF priority 0)
- New router (IS) can cause a new election, unlike OSPF
- Periodically broadcasts CSNPs (OSPF DBD) every 10 seconds
- Elect both L1 and L2 DISs ← elect separately on different levels.

Configuring IS-IS (so far)



SanJose1

```
interface FastEthernet0/0
 ip address 172.16.0.1 255.255.255.0
 ip router isis
 isis priority 100
router isis
 net 49.0001.1111.1111.1111.00
```

SanJose2

```
interface FastEthernet0/0
 ip address 172.16.0.2 255.255.255.0
 ip router isis
router isis
 net 49.0001.2222.2222.2222.00
        Area . System ID . NSEL
```

SanJose3

```
interface FastEthernet0/0
 ip address 172.16.0.3 255.255.255.0
 ip router isis
router isis
 net 49.0001.3333.3333.3333.00
```

- **`isis priority`**: Sets DIS priority on a LAN interface, default 64

IS-IS Routing Process

- IS-IS Routing Process is divided into four stages:
  - Update
  - Decision
  - Forwarding
  - Receive

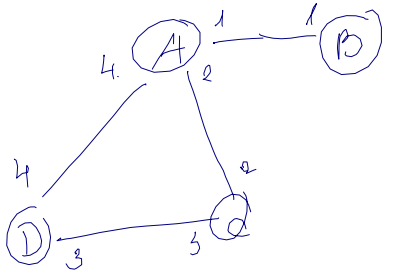
IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

The Update Process

- Routers can only forward data packets if they have an understanding of the network topology.

- **LSPs are generated and flooded** throughout the network whenever:
  - An adjacency comes up or down (example: a new router comes online).
  - An interface on a router changes state or is assigned a new metric.
  - An IP route changes (example: because of redistribution)



Topology

SystemID link sequence no.

A-1. – 10 → A-1-11. (receiver)

A-2. – 10

A-3. – 10

(11: newer)

if 2 neighbors has same A-1, the sequence no is the "version" of the link state.

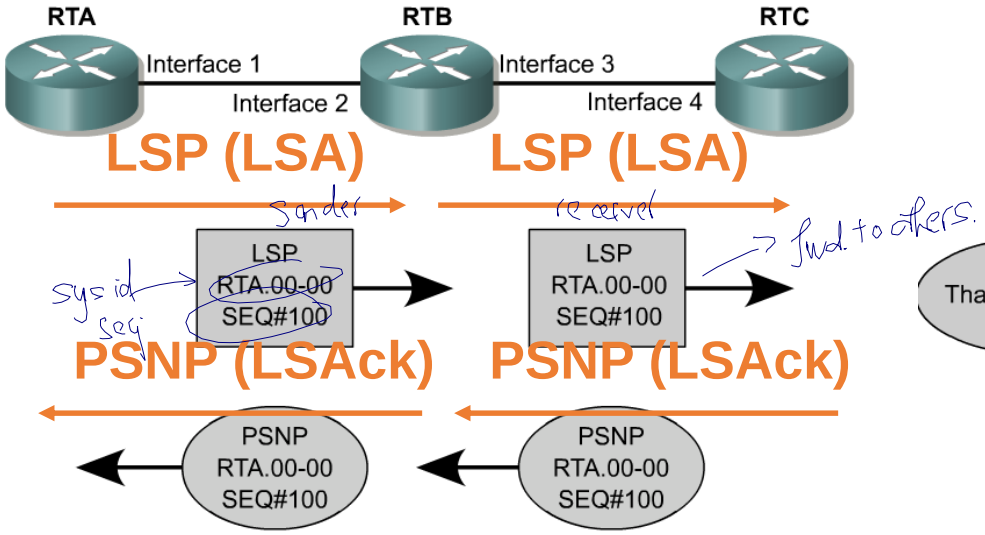
IS-IS Routing Process: Update

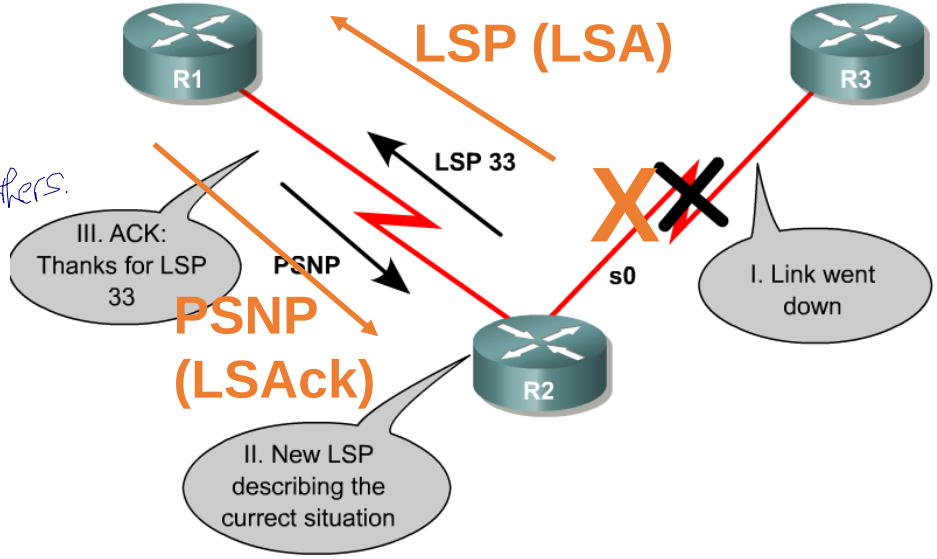
IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

Sending and Receiving an LSP

- **Receiving an LSP**
  - If the LSP is already present in the database (LSDB), the router (IS) acknowledges (PSNP) and ignores it.
    - The router sends the duplicated LSP it its neighbors.
    - Level 1 LSPs are flooded throughout the area
    - Level 2 LSPs are sent across all L2 adjacencies.

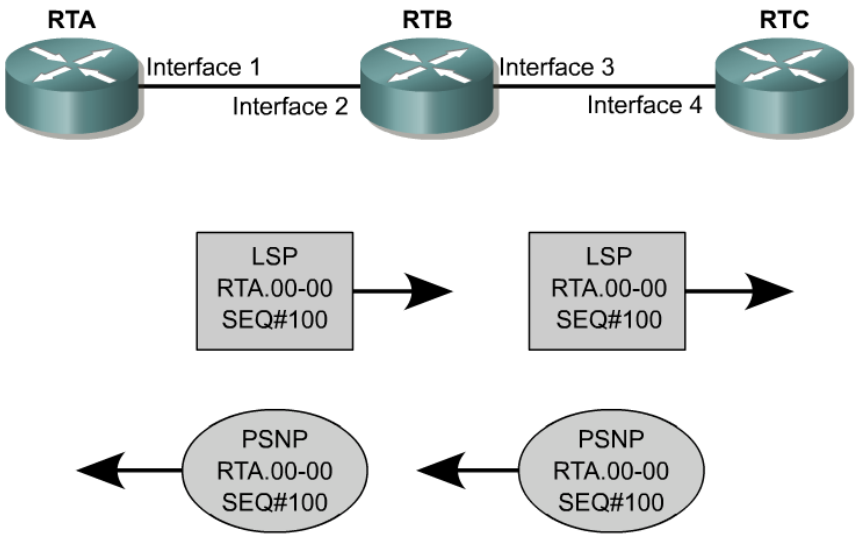
LSDB Synchronization and Update Process

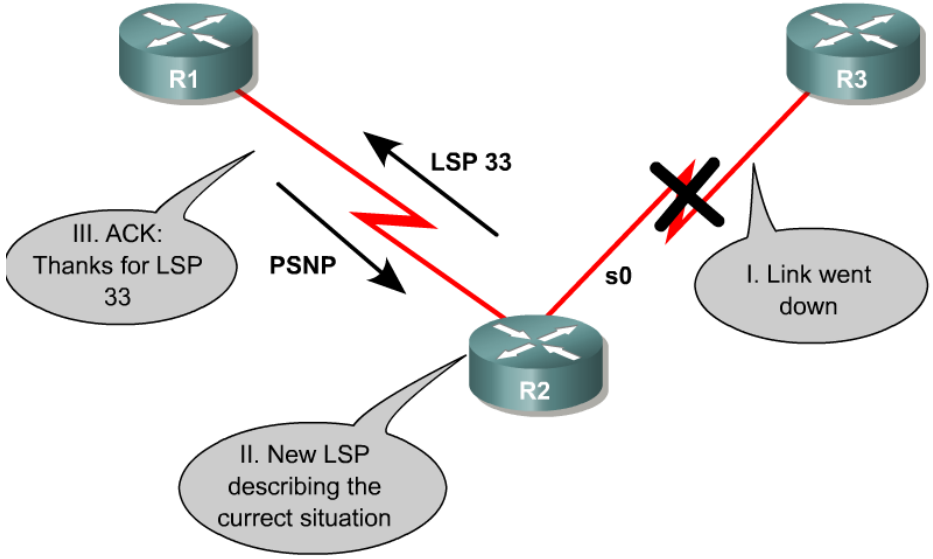




- IS-IS LSDB is accomplished by using special PDUs, known as SNPs (Sequence Number PDUs):
  - **CSNP** (Complete Sequence Number PDU) – (OSPF: **DBD**)
    - List of LSPs held by the router
  - **PSNP** (Partial Sequence Number PDU) – (OSPF: **LSAck/LSR**)
    - Acknowledge the receipt of a LSP
    - Request a complete LSP for a missing entry

Update Process





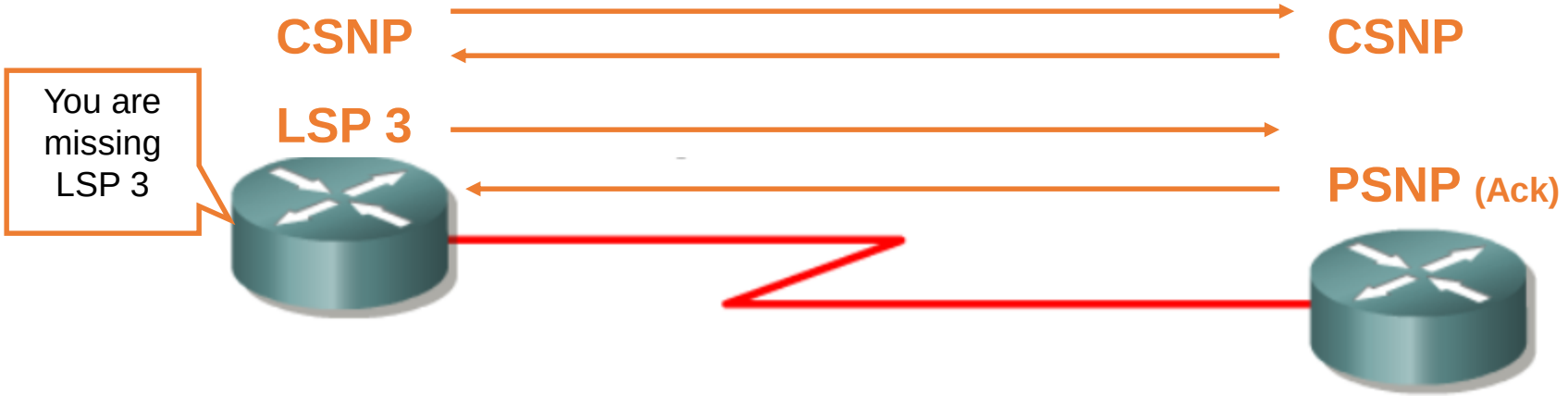
- Point-to-Point networks:
  - Once an LSP is sent, router sets a timer (minimumLSPTransmissionInterval) of 5 seconds
  - If PSNP (ACK) not received, resends LSP.

IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

Sending and Receiving an LSP:

- **Propagating (sending) LSPs on a Point-to-Point Interface**
  - When an adjacency is established both routers send a CSNP (*OSPF DBD*) summary of their LSDB.
  - If the receiving router has any LSPs that were not present in the CSNP it received, it sends a copy of the missing LSP to the other router.

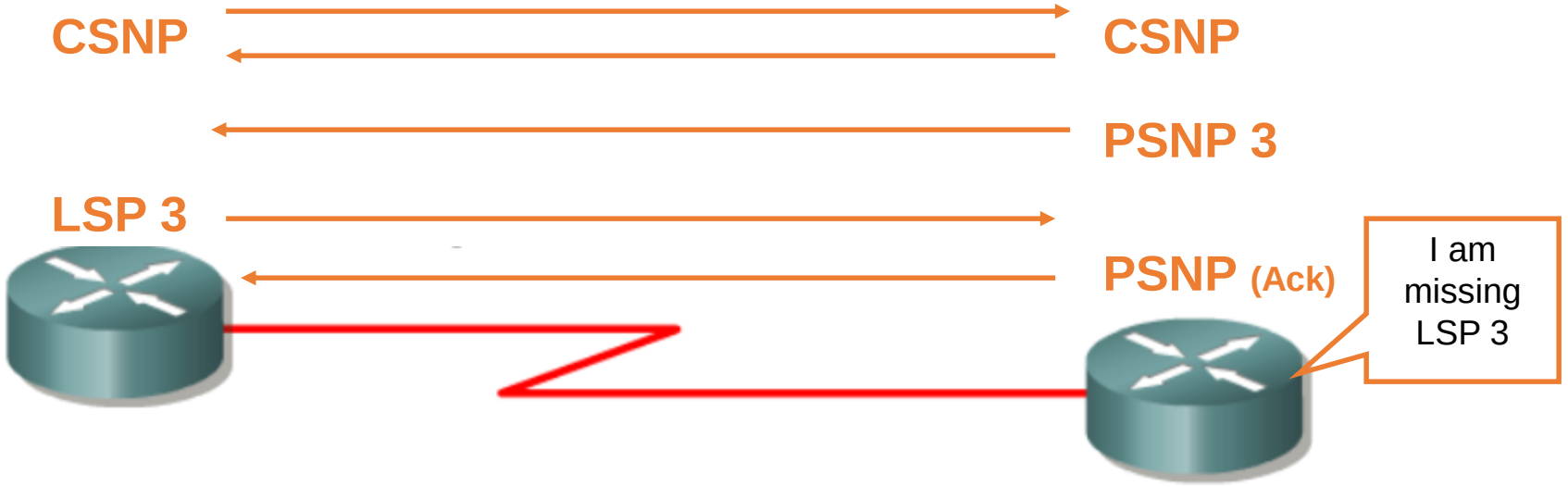


IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

Sending and Receiving an LSP:

- **Propagating (sending) LSPs on a Point-to-Point Interface**
  - Likewise, if the receiving router is missing any LSPs received in the CSNP, the receiving router sends a PSNP (*OSPF LSR*) requesting the full LSP to be sent.
  - LSPs are acknowledges with a PSNP (*OSPF LSAck*)
  - When the LSP is sent, the router sets a timer.
    - If the acknolwedgement (PSNP) is not received within 5 seconds (Cisco default), the LSP is resent.



IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

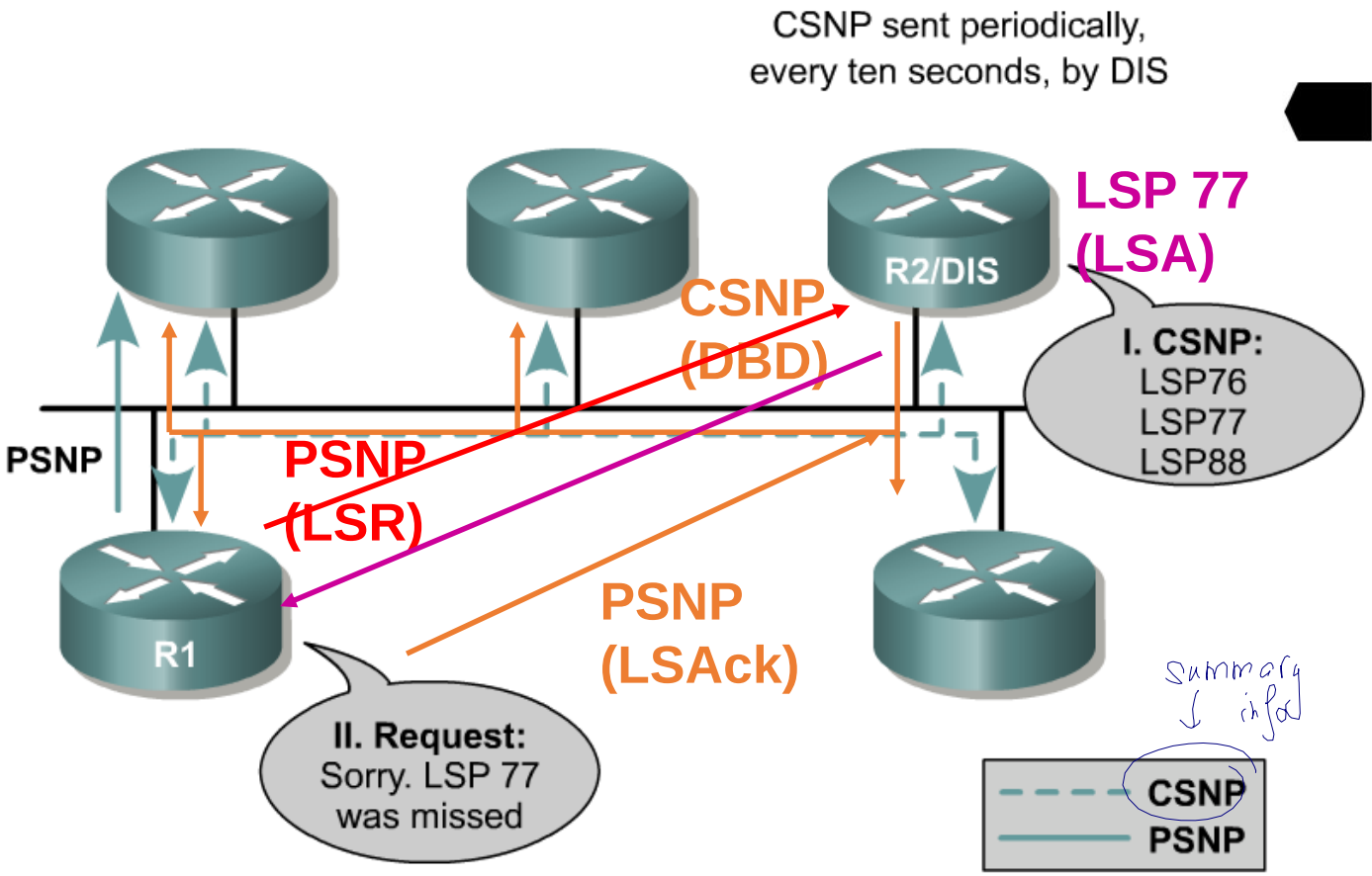
Sending and Receiving an LSP:

- **Propagating (sending) LSPs on a Broadcast Interface**
  - The DIS (*OSPF DR*) takes on much of the responsibility for synchronizing the databases on behalf of the pseudo node.
  - LSPs are not acknowledged by each receving router
  - DIS periodically multicast a CSNP that describes every LSP in the LSDB
  - DIS has three tasks:
    - Creating and maintaining adjacencies
    - Creating and updating the pseudonode LSP
    - Flooding the LSPs over the LAN.

Update Proc

PSNP (OSPF LSR) goes to DIS.

III. LSP 77 is sent by DIS to R1



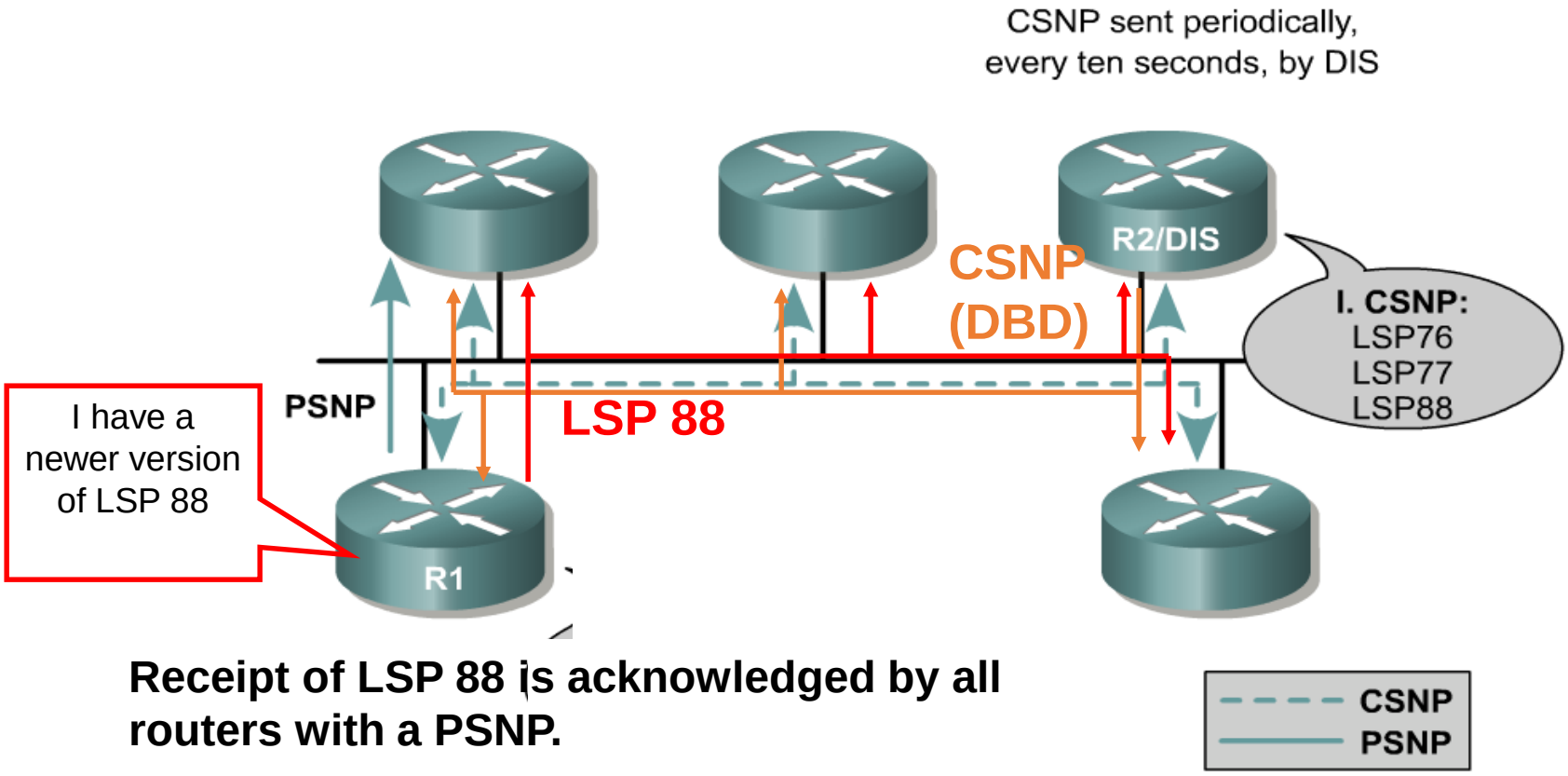
- On Broadcast networks:
  - LSPs are not acknowledged by each receiving router.
  - **DIS** periodically multicasts a **CSNP** (OSPF DBD) that describes every LSP in LSDB.
    - Default is every10 seconds
  - L1 CSNPs are multicast to AllL1ISs
  - L2 CSNPs are multicast to AllL2ISs

IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

Sending and Receiving an LSP:

- **Propagating (sending) LSPs on a Broadcast Interface**
  - On receiving a CSNP the router compares it with its LSDB…
  - If the receiving router has a newer version of the LSP then what was sent in the CSNP, or if the CSNP did not contain one of its LSPs, the router multicasts the LSP to all routers on the LAN.



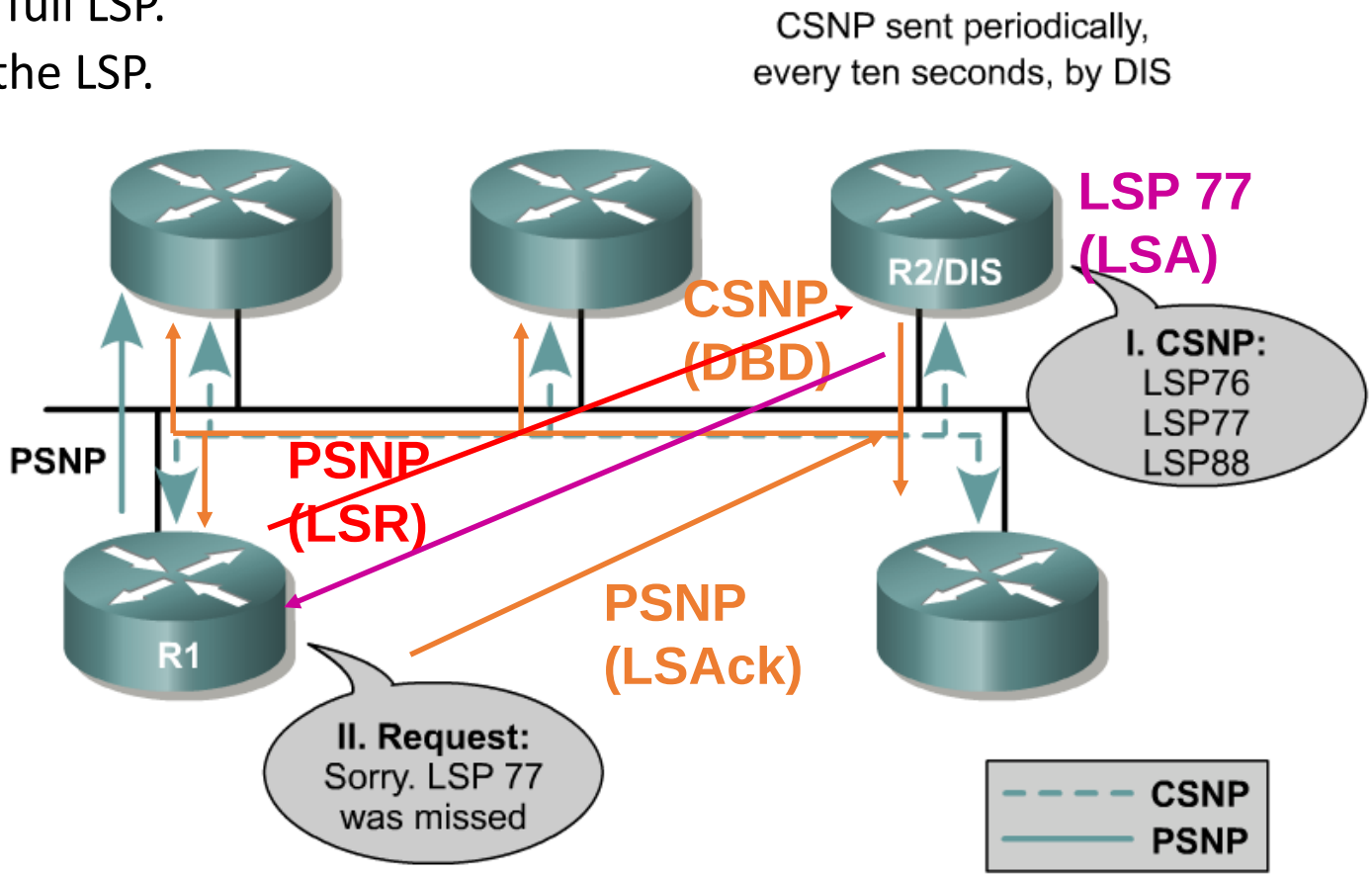
Receipt of LSP 88 is acknowledged by all routers with a PSNP.

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

IS-IS Routing Process: Update

Sending and Receiving an LSP:

- **Propagating (sending) LSPs on a Broadcast Interface**
  - On receiving a CSNP the router compares it with its LSDB…
  - If the database is missing an LSP that was in the CSNP, it sends a PSNP requesting the full LSP.
  - The DIS sends the LSP.



IS-IS Routing Process: Update

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

- Determining if an LSP is valid:
  - Receiving router uses three fields to help determine if the received LSP is more than the one in its LSDB.
  - **Remaining Lifetime**
    - Used to age-out or delete LSPs
    - Lifetime is set to 0 and flooded ← tell neighbor that it will be aged out.
    - Receiving routers recognize this means the route is bad and deletes the LSP from their LSDB, rerunning SPF algorithm, new SPT, new routing table.
    - **Note**: **LSPs have a maximum age of 20 minutes** in an IS-IS LSDB (can be increased to 65535 seconds, ~18.2 hours), and are **re-flooded (refreshed) every 15 minutes**.
    - Expired LSP will be kept in the LSDB for 60 seconds (**ZeroAgeLifetime**)
  - **Sequence Number**
    - First LSP starts with a sequence number of 1, with following LSPs incremented by 1.
    - When sequence number reaches maximum (0xffffffff), the IS-IS process shuts down for 21 minutes (MaxAge + ZeroAgeLifetime) to allow old LSPs to age out
  - **Checksum**
    - If received LSP's checksum does not computer correctly, the LSP is flushed and the lifetime set to 0.
    - The receiving router floods the LSP with the lifetime set to 0.
    - When the originating router gets this LSP (lifetime = 0) it retransmits a new LSP.

IS-IS Routing Process: Decision

- IS-IS Routing Process is divided into four stages:
  - Update
  - **Decision**
  - Forwarding
  - Receive

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

IS-IS Routing Process: Decision

- The Decision Process
  - Uses **Dijkstra's algorithm** to build a SPT (Shortest Path Tree)
  - The SPT is used to create the forwarding table, also known as the routing table.
  - Several tables are used during this process:
    - **PATH table**
      - PATH table is the SPT during the construction of the LSDB
      - Each candidate route is placed in the PATH table while the metric is examined to determine if it is the shortest path to the destination.
    - **TENT** is the tentative database (a scratchpad) during this process

IS-IS Metrics ← default to 10, no idea of BW

- Specified in ISO 10589
  - **Default** – Must be supported
  - **Delay** – Optional. Reflect the transit delay of a subnetwork
  - **Expense** – Optional. Reflect the monetary cost of using the subnetwork
  - **Error** – Optional. Reflect the residual error probability of the subnetwork.
  - Cisco only supports the default metric

IS-IS Routing Process: Decision

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

Determining the best route

- Criteria by which the lowest cost paths are selected and placed in the forwarding database are:
  - Internal paths are chosen before external paths outside the routing domain, to prevent sub-optimal routes and routing loops.
  - Level 1 paths within the area are "more attractive" than Level 2 paths outside the area, to prevent sub-optimal routes and routing loops.
  - If there is no path, the forwarding database sends the packet to the nearest Level 2 router, which is the default router.

interior first then exterior

L2 router knows more, it might know

IS-IS Routing Process: Forwarding

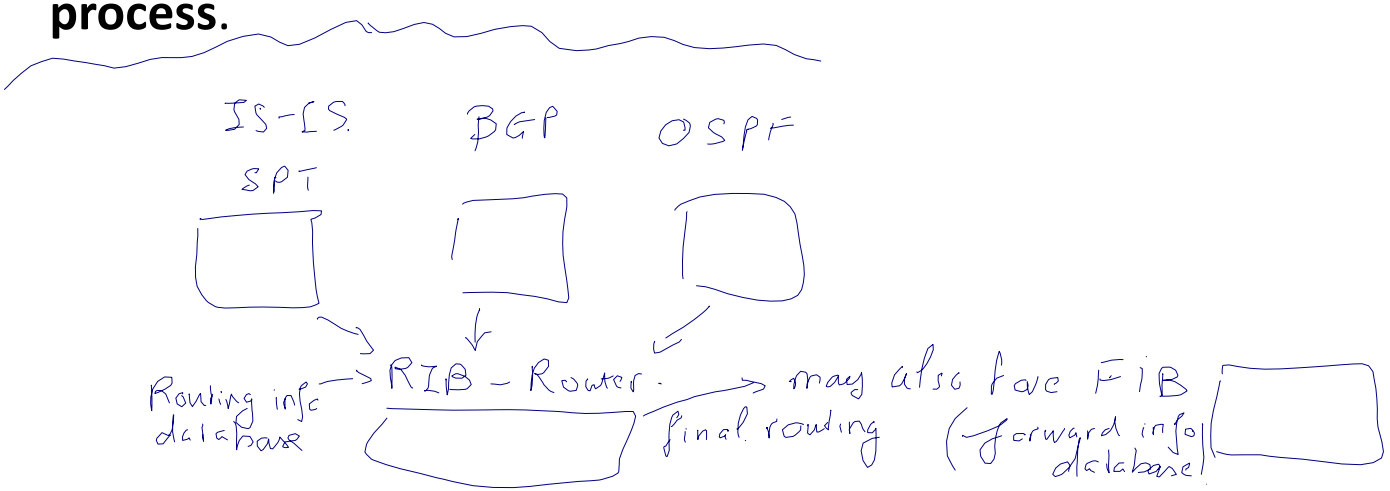
- IS-IS Routing Process is divided into four stages:
  - Update
  - Decision
  - **Forwarding**
  - **Receive**

IS-IS Routing Process: Forwarding and Receiving

IS-IS Routing Process
- Update
- Decision
- Forwarding
- Receive

- **Forwarding process**
  - ***After the SPT has been built the forwarding database can be created***.
  - The **forwarding table** is the lookup table for the longest match.

- **Receive process**
  - If the frame is valid, the receive process passes user data and error reports to the **forwarding process**.
  - Whereas routing information: Hellos, LSPs, and SNPs are sent to the **update process**.



Odds and Ends

- L1L2 routers run two IS-IS processes, one for its L1 LSDB and another for its L2 LSDB.

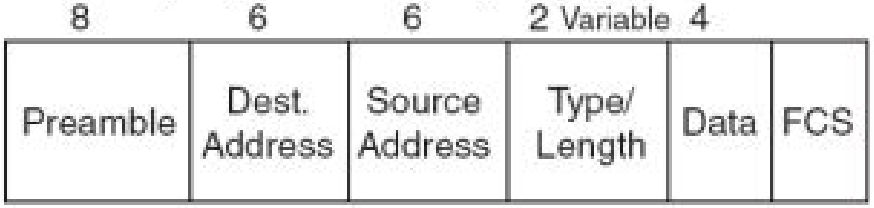
IS-IS Packet Format

on top of MAC, does not need IP address for routing in ISIS

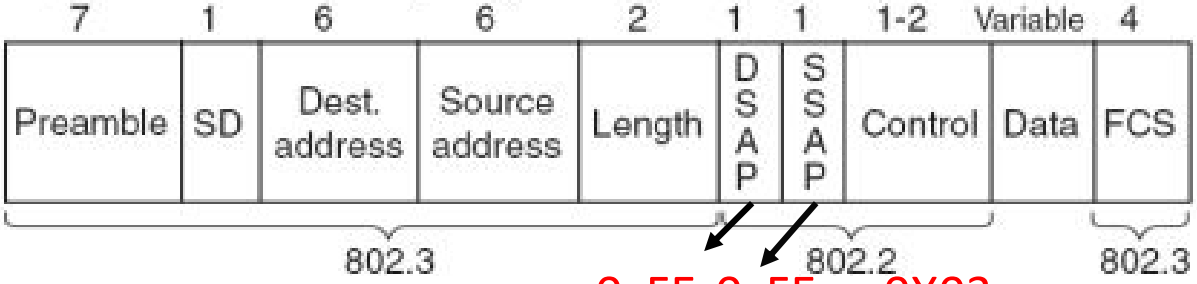
MAC Hdr	IS-IS Hdr	IS-IS type-specific Data

- MAC Header
  - Src – MAC addr of sending interface
  - Dst – 01-80-C2-00-00-14 for Level-1 ISs
    01-80-C2-00-00-15 for Level-2 ISs
  - IEEE 802.2 LLC Frame format
- IS-IS Header
  - Intra-domain Routing Protocol Discriminator: 0x83
  - Length – length of the header in bytes
  - Version/Protocol ID: 1
  - ID Length: length of the system ID
  - PDU Type
  - Version: always set to 1
  - Max Area Addresses: # of area addresses permitted for this IS Area

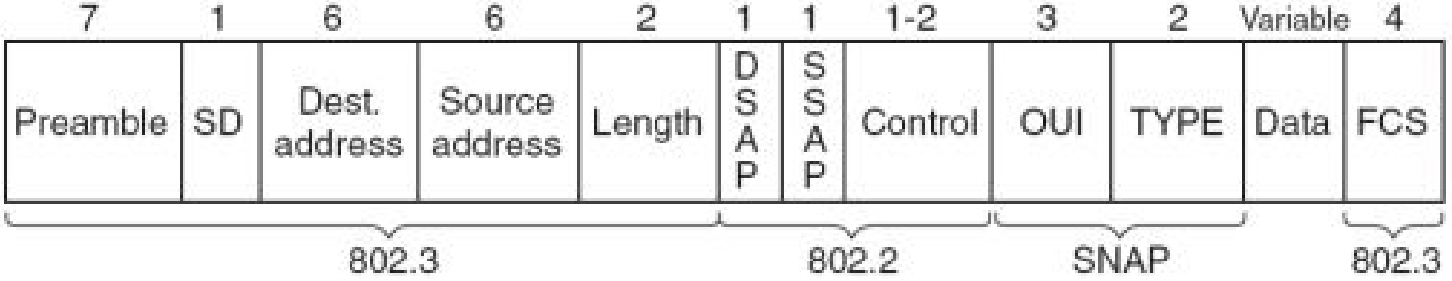
Ethernet (DIX) and Revised (1997) IEEE 802.3



Original IEEE Ethernet (802.3)

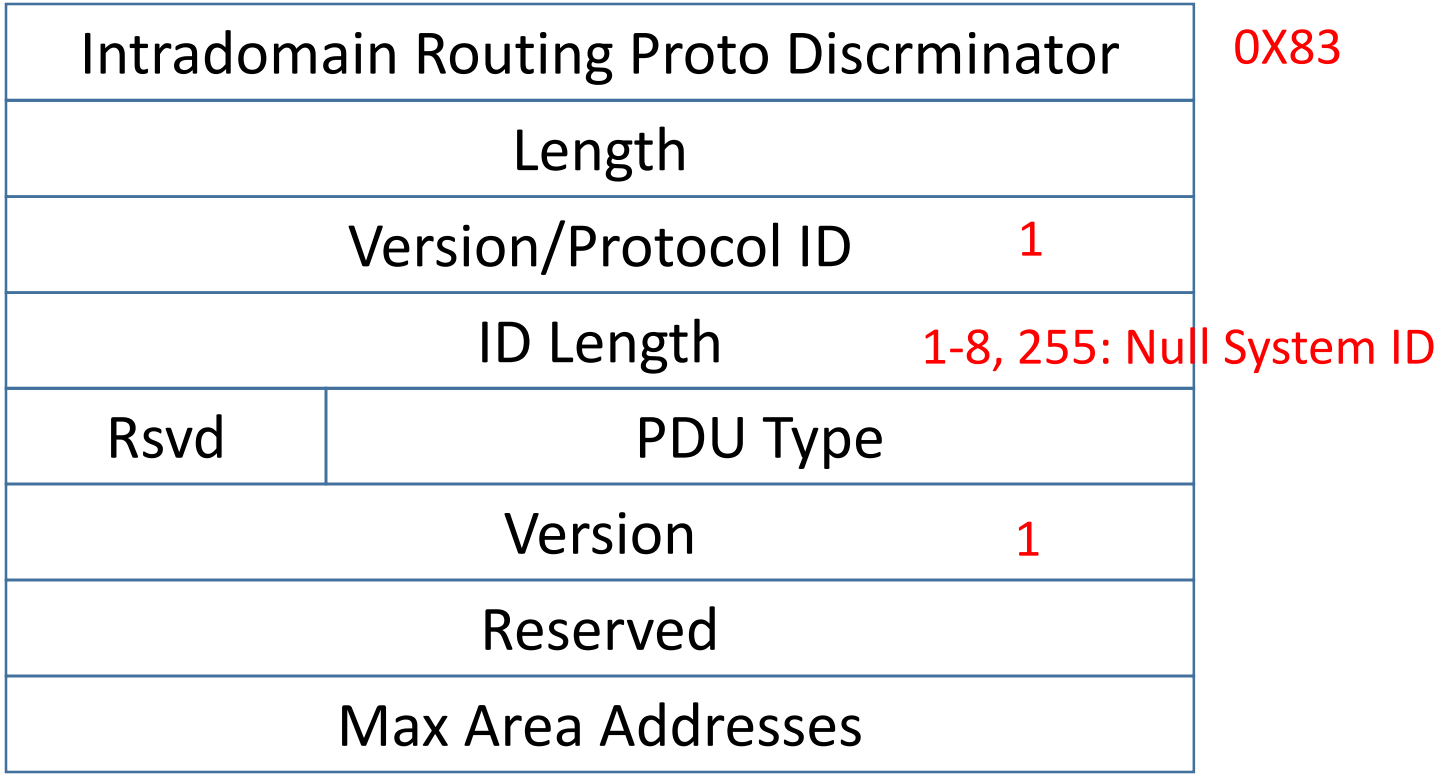


IEEE 802.3 with SNAP Header



0xFE -- ISO Network Layer Protocol

IS-IS Header Format



- Length – the length of the fixed header in octets
- ID Length – the length of the System ID field. 0: 6 octets, 255: zero octet
- Max Area addresses – the number of area address permitted for this IS area. In the range of 1-254, 0: 3 addresses

IS-IS PDU Types

IS-IS PDU Type	Value
Hello PDUs	
Level 1 LAN Hellos	15
Level 2 LAN Hello	16
Point-to-point Hello	17
Link State PDUs	
Level 1 LSP	18
Level 2 LSP	20
Sequence Number PDUs	
Level 1 CSNP	24
Level 2 CSNP	25
Level 1 PSNP	26
Level 2 PSNP	27

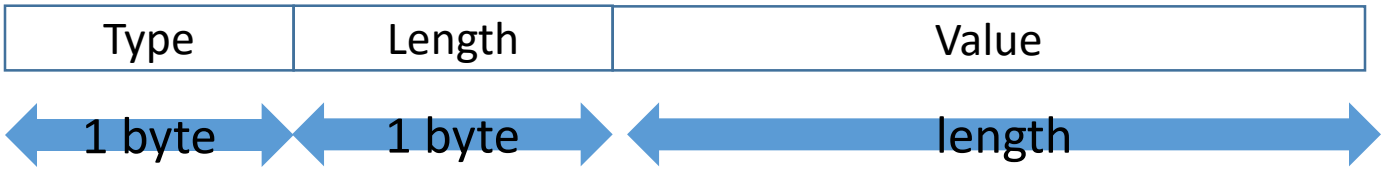
Terminology

- CLV (Code/Length/Value) and TLV (Type/Length/Value)
  - Same thing, CLV is more of the OSI term.
  - There are variable length fields in a PDU.
    - Code or Type specifies the type of information.
    - Length specifies the size of the Value field.
    - Value is the information itself.
      - Example CLV or **TLV 128** defines the capability to carry IP routes in IS-IS packets, in essence TLV 128 is Integrated IS-IS.

type - length - value.
2 4 SVU.

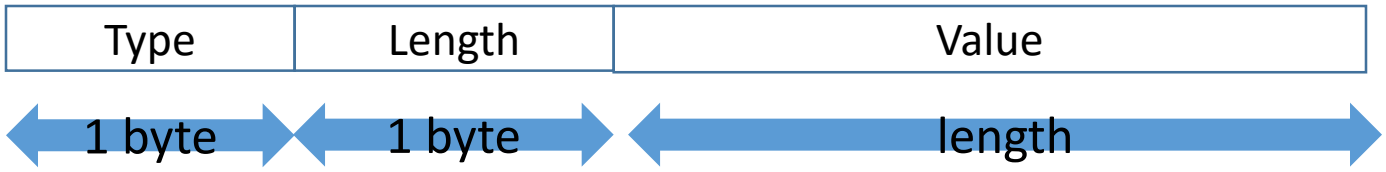
IS-IS TLV Codes – Specified in ISO 10589

Type	TLV	Description
1	Area Addresses	Area address of the originating IS
2	IS Neighbors	List the originator's IS-IS neighbors and the metrics
3	ES Neighbors	Not relevant to IP routing
4	Partition Designated Level 2 IS	Not supported
5	Prefix Neighbors	**Reachable address prefix neighbors**
6	IS Neighbors (Hellos)	**System IDs of all neighbors whose Hellos have been heard within the last Hold time.**
8	Padding	Pad a Hello PDU to minimum 1492 bytes or the MTU
9	LSP Entries	Summarize LSPs
10	Authentication Information	**Authentication type and information**
14	LSP Buffer size	The LSP buffer size of the originator



IS-IS TLV Codes – Specified in RFC 1195

Type	TLV	Description
128	IP Internal Reachability Information	List IP addr/mask within the routing domain
129	Protocols Supported	Protocols supported by the originator (v4, v6…)
130	IP External Reachability Information	List IP addr/mask external to the routing domain
131	Inter-Domain Routing Protocol Information	Carry information from external routing protocols transparently through the IS-IS domain
132	IP Interface Address	IP address of the interface out which the PDU was sent
133	Authentication Information	Authentication type and information



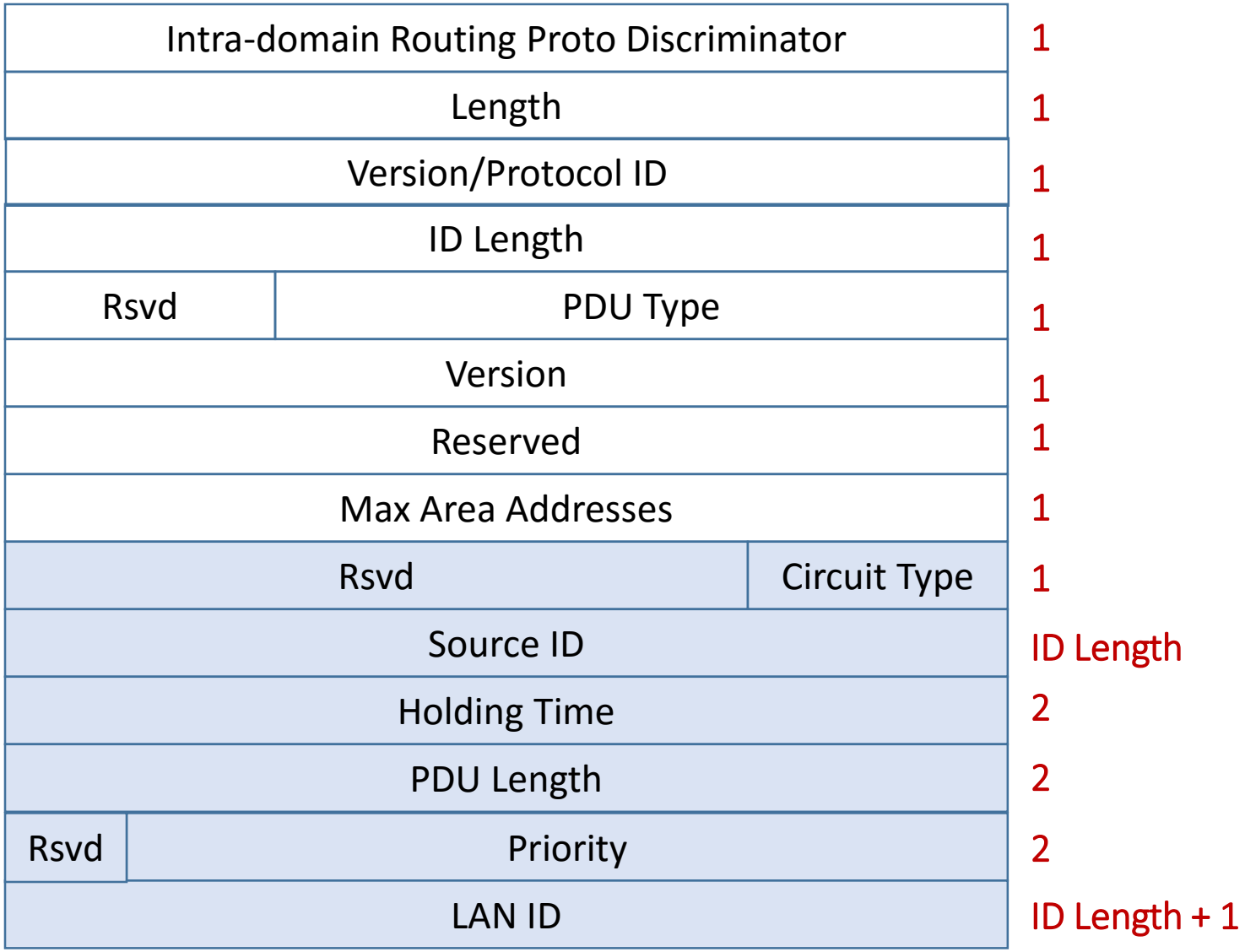
IS-IS TLV used in each PDU

Type	TLV	15	16	17	18	20	24	25	26	27
		Hello			LSP		Sequence #			
1	Area Addresses	X	X	X	X	X				
2	IS Neighbors				X	X				
3	ES Neighbors				X					
4	Partition Designated Level 2 IS					X				
5	Prefix Neighbors					X				
6	IS Neighbors (Hellos)	X	X							
8	Padding	X	X	X						
9	LSP Entries						X	X	X	X
10	Authentication Information	X	X	X	X	X	X	X	X	X
128	IP Internal Reachability Information				X	X				
129	Protocols Supported	X	X	X	X	X				
130	IP External Reachability Information				X	X				
131	Inter-Domain Routing Protocol Information					X				
132	IP Interface Address	X	X	X	X	X				

IS-IS TLV Codes – Extending Capabilities

Type	TLV	RFC	Description
12	Optional Checksum	3358	Add checksum capability to SNPs
22	Extended IS Reachability	3784	Add traffic engineering capabilities, replace type 2 TLV
134	Traffic Engineering Router ID	3784	traffic engineering capabilities
135	Extended IP Reachability	3784	traffic engineering capabilities, replace type 128 and 130 TLVs
137	Dynamic Hostname	2763	Identified by hostname instead system ID
211	Restart	3847	Graceful Restart
222	MT Intermediate Systems	Draft	Multi-topology support
229	Multi-Topology	Draft	Multi-topology support
232	IPv6 Internet Address	Draft	Type 132 TLV equivalent
235	MT Reachable IPv4 Prefixes	Draft	Multi-topology support
236	IPv6 Reachability	Draft	Type 128, 130 TLV equivalent
237	MT Reachable IPv6 Prefixes	Draft	Multi-topology support
240	Point-to-point Three-way Adjacency	3373	
250	Experimental	Draft	

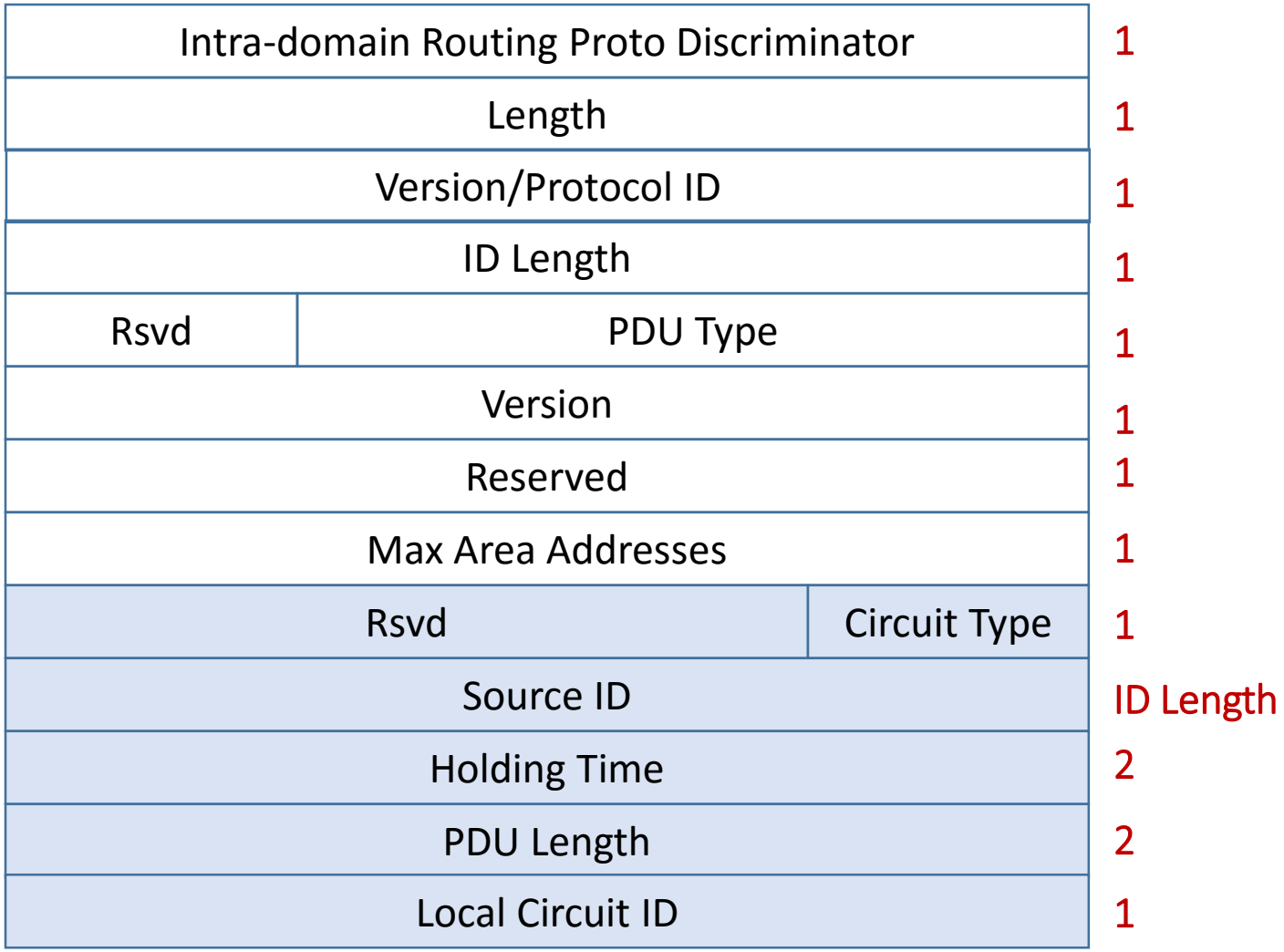
IS-IS Hello PDU Format



Hello PDU Fields

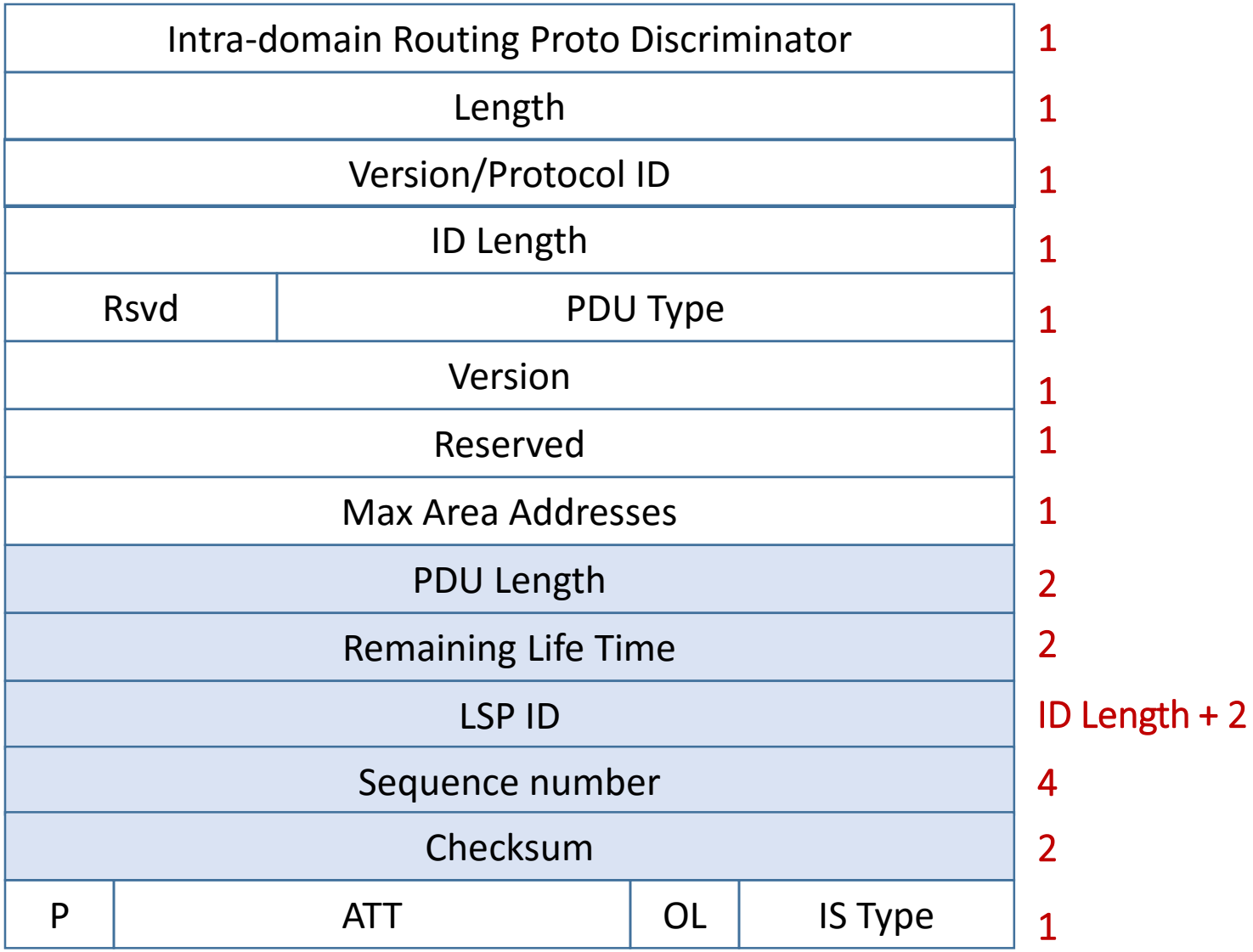
- Source ID – System ID of the router that originated the Hello
- Holding Time – time should wait before declaring the originating router dead
- PDU length – Length of the entire PDU
- Priority – Used for electing DR. Range 0 – 127 with higher number means higher priority
- LAN ID – System ID of the DR plus one more octet (the pseudo node ID)

IS-IS Hello PDU Format – Point-to-point

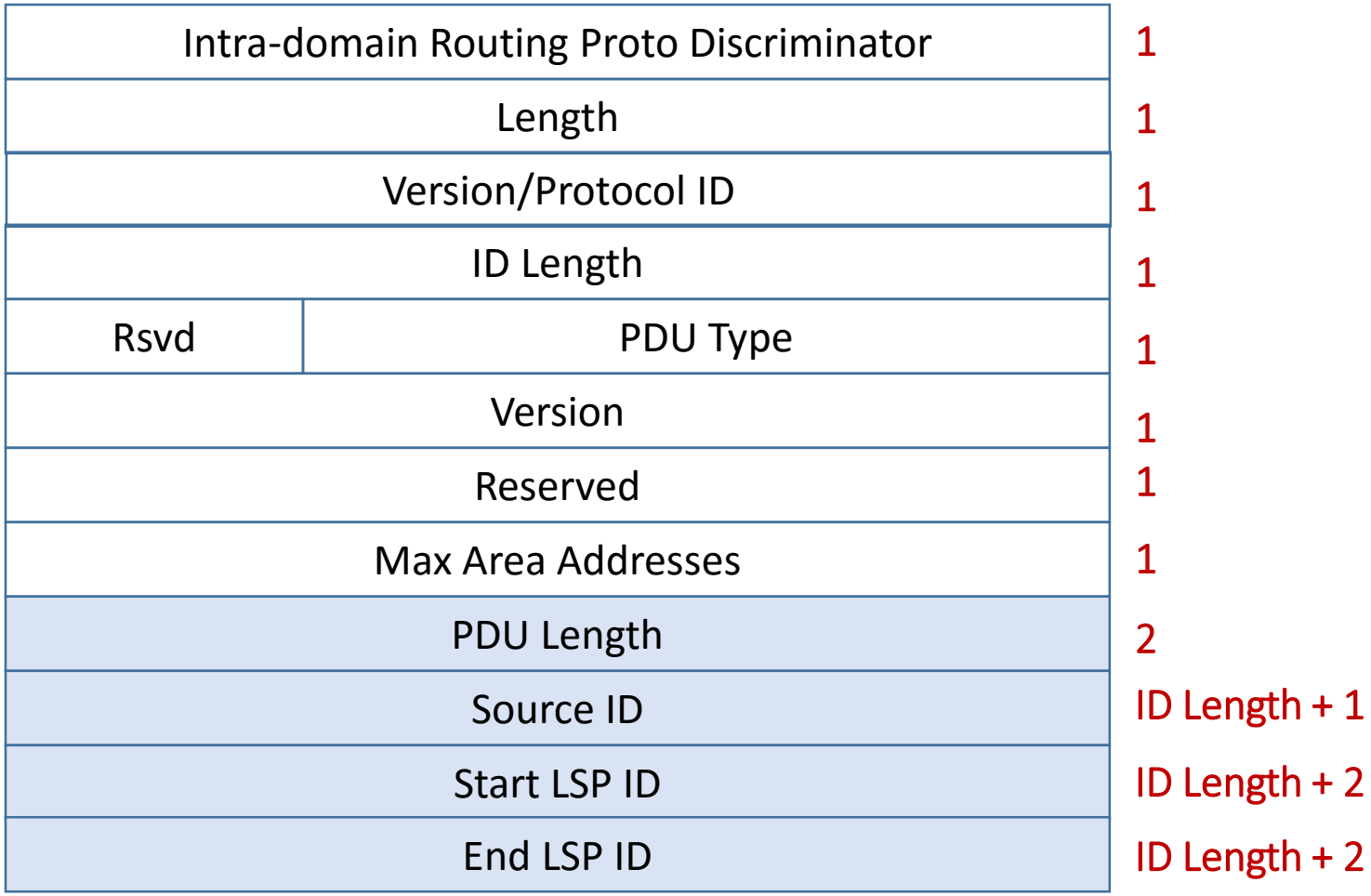


Local Circuit ID – Assigned by the originating router and is unique among the router's interfaces

IS-IS LSP PDU Format



IS-IS CSNP Format



IS-IS PSNP Format