IS-IS Introduction

Intermediate System to Intermediate System

IS-IS, which stands for **Intermediate System to Intermediate System**, is a dynamic routing protocol originally developed by the International Organization for Standardization (ISO). Its primary purpose was to route packets for the OSI (Open Systems Interconnection) protocol suite, specifically utilizing **CLNS (Connectionless Network Service)**.

Historical Context: OSI vs. TCP/IP

To appreciate IS-IS, it's helpful to understand its origins. IS-IS was developed around the same time the IP protocol was gaining traction, during a period when the OSI model was a strong contender to become the dominant networking standard.

- In the familiar **TCP/IP model**, Layer 3 is synonymous with **IP** (Internet Protocol), which can be either IPv4 or IPv6 nowadays. IP is responsible for encapsulating data for network-layer.

- In the **OSI model**, the general Layer 3 service for connectionless data transmission was termed **CLNS**. The actual protocol that would encapsulate data at Layer 3, analogous to IP in the TCP/IP world, is **CLNP (Connectionless Network Protocol)**.

The initial design of IS-IS was therefore to route CLNP packets, not IPv4. However, as TCP/IP's adoption outpaced OSI, IS-IS adapted to carry IPv4 information as well. This enhanced version is known as **Integrated IS-IS** (or Dual IS-IS), as specified in **RFC 1195**.

How IS-IS's OSI Origins Affect Its Operation with IP

The fact that IS-IS wasn't initially designed for IP leads to some unique characteristics when compared to IP-native routing protocols like OSPF and EIGRP:

1. **Router Identification (Network Entity Title - NET):**

    - OSPF and EIGRP utilize a 32-bit **Router ID**, typically expressed in dotted-decimal notation (similar to an IP address). If not manually configured, these protocols can often derive the Router ID from an interface's IP address.

- IS-IS, employs a **Network Entity Title (NET)** for router identification. The NET is a variable-length OSI address, typically ranging from 8 to 20 bytes, and is not based on IP addressing. It has a specific structure (we will discuss NET Later)

- an IS-IS router **cannot automatically derive its NET** from an IP address due to this different addressing architecture. The NET **must be manually configured** on each IS-IS router; otherwise, the IS-IS process will not start.

2. **Packet Encapsulation:**

   - When you inspect network traffic (e.g., with wireshark) for protocols like OSPF or EIGRP, their protocol headers are found *after* a Layer 3 header (IP)

   - IS-IS packets, even when carrying IP routing information in an Integrated IS-IS environment, are generally encapsulated **directly within Layer 2 frames** (e.g., Ethernet frames using a specific LLC/SNAP header for IS-IS). You'll observe the IS-IS header immediately following the Layer 2 header, without an intermediary IP header for the IS-IS PDU itself.

IS-IS vs. ES-IS

- **IS-IS (Intermediate System to Intermediate System):** This is the routing protocol focusing on communication *between routers* (Intermediate Systems). It's responsible for building the routing table and forwarding packets between different network segments.

- **ES-IS (End System to Intermediate System):** This protocol was designed for communication *between an end host/server (End System) and a router (Intermediate System)*. Its function was somewhat analogous to ARP (Address Resolution Protocol) in the IP world, helping end systems discover their local routers and routers discover local end systems within the OSI framework. ES-IS is largely considered obsolete and is not commonly encountered in modern IP-centric networks.

The Architect: Radia Perlman

It is noteworthy that the principal designer of IS-IS is **Radia Perlman**, a prominent figure in networking who also invented the Spanning Tree Protocol (STP), a foundational technology for preventing loops in switched Ethernet networks. During her time at Digital Equipment Corporation (DEC), IS-IS was developed as a core component of **DECnet Phase V Routing**. The international standard for IS-IS is **ISO/IEC 10589**, with its capabilities for routing IP packets (Integrated IS-IS) detailed in **RFC 1195**.

IS-IS vs. OSPF

IS-IS vs. OSPF: A High-Level Comparison

Both IS-IS (Intermediate System to Intermediate System) and OSPF (Open Shortest Path First) are **Link-State Routing Protocols**. They share many operational similarities due to this common classification but also shows distinct differences in their design and behavior.

Key Similarities

1. **IGP Role:** Both are primarily designed to function as **Interior Gateway Protocols (IGPs)**, distributing routing information within a single autonomous system.

2. **Link-State Information:**

    - OSPF uses various types of **Link State Advertisements (LSAs)** to describe the network topology (Normally 7 LSAs for OSPFv2 , 9 LSAs for OSPFv3)

    - IS-IS uses **Link State Packets/PDUs (LSPs)**. While there are fundamentally two types of LSPs (Level 1 and Level 2), they utilize a flexible system of **Type-Length-Value (TLV)** fields to carry diverse topological information.

3. **Algorithm:** Both protocols employ the **Dijkstra Shortest Path First (SPF) algorithm** to calculate the best loop-free paths through the network.

4. **Area Concept:** Both support a hierarchical network design using **areas** to divide a large topology into smaller, more manageable segments, improving scalability and efficiency.

5. **Link-State Database (LSDB):** Each protocol maintains an **LSDB** where it stores the received LSAs (for OSPF) or LSPs (for IS-IS). The SPF algorithm processes this database to compute the routing table.

6. **Neighbor Discovery & Maintenance:** Both rely on **Hello packets** to dynamically discover potential neighbors and maintain existing adjacencies.

7. **Two-Level Hierarchy:** Both offer a two-level hierarchical structure:

   - **OSPF:** Routers within a non-backbone area have full routing information for that area. To learn about routes in other areas, they rely on **Area Border Routers (ABRs)**, which connect their respective areas to a central **backbone area (Area 0)**. All inter-area traffic transits Area 0.

   - **IS-IS:** Routers within an area (Level 1 routers) know all intra-area routes. To route to other areas, they forward traffic to a **Level 1-Level 2 (L1/L2) router**. The **Level 2 routers** form a contiguous backbone, effectively a "super-area," which handles inter-area routing. Unlike OSPF's Area 0, the IS-IS backbone is a collection of L2-capable routers rather than a specifically numbered area.

8. **Summarization & Filtering:** Both protocols provide mechanisms for **address summarization** (route aggregation) at area/Level boundaries and **route filtering**.

9. **Classless Operation:** Both are **classless routing protocols**, meaning they send subnet mask information with routing updates, enabling support for Variable Length Subnet Masking (VLSM) and Classless Inter-Domain Routing (CIDR).

10. **Designated Routers:** On broadcast multi-access network segments, both elect a representative router to optimize LSDB synchronization:

- OSPF elects a **Designated Router (DR)** and a Backup DR (BDR).
- IS-IS elects a **Designated Intermediate System (DIS)**.

11. **Authentication:** Both support **authentication mechanisms** to ensure that routing updates are accepted only from trusted peers.

Key Differences

1. **Administrative Distance (AD):**
    - OSPF: Typically has a default AD of **110**.
    - IS-IS: Typically has a default AD of **115**.

2. **Area Membership & Router Role:**
    - **OSPF:** An *interface* on a router is assigned to a specific area. Therefore, a single router (an ABR) can have interfaces in multiple different areas simultaneously (e.g., Area 0 and Area 1).
    - **IS-IS:** The *entire router* is configured to belong to a single area (its Area ID is part of its Network Entity Title - NET).
        - A router can be a **Level 1 router** (intra-area only), a **Level 2 router** (backbone routing only), or a **Level 1-Level 2 router** (participating in its configured L1 area and the L2 backbone).
        - While the router itself is in one L1 area, an L1/L2 router serves as a gateway for that L1 area to the L2 backbone, and can form L2 adjacencies with other L2 or L1/L2 routers regardless of their L1 area affiliation.

3. **Forming Adjacencies and Area Boundaries:**

- **OSPF:** To form an adjacency, interfaces on neighboring routers must belong to the **same area** (and typically the same subnet). Adjacencies do not form if area IDs mismatch on a link.

- **IS-IS:**

  - **Level 1 Adjacency:** Requires that both routers share the **same Area ID**. These are for intra-area communication.

  - **Level 2 Adjacency:** Can be formed between L2-capable routers (L2-only or L1/L2 routers) **regardless of their configured L1 Area IDs**. This allows L2 routers to form the backbone across different L1 areas. An L1/L2 router in Area X can form an L2 adjacency with an L1/L2 router in Area Y.

  - This means an IS-IS L1/L2 router acts as a boundary not by having interfaces in different areas, but by its capability to form L1 adjacencies within its area and L2 adjacencies for inter-area communication.

IS-IS Hierarchical Design

IS-IS Router Levels and Operational Rules

In IS-IS, routers (or Intermediate Systems - IS) operate at different levels, which dictates their role in the network hierarchy, the type of adjacencies they form, the Link State PDUs (LSPs) they exchange, and the scope of their routing knowledge. There are three primary roles an IS-IS router can be configured in:

1. **Level 1 (L1) System/Router:** Primarily concerned with routing *within* its designated area.

2. **Level 2 Only (L2) System/Router:** Forms the routing backbone, responsible for routing *between* different areas.

3. **Level 1-Level 2 (L1/L2) System/Router:** A router that participates in both Level 1 (within its area) and Level 2 (backbone) routing. This is the default operational mode on Cisco platforms.

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1. Level 1 (L1) Routers

An L1 router has a localized view of the network, primarily focused on its own area.

- **Analogy:** Think of an L1 router as being similar to an OSPF internal router within a NSSA area. It knows the details of its own area but relies on a connection to the backbone (via an L1/L2 router) for all inter-area destinations.

- **Rules & Characteristics:**

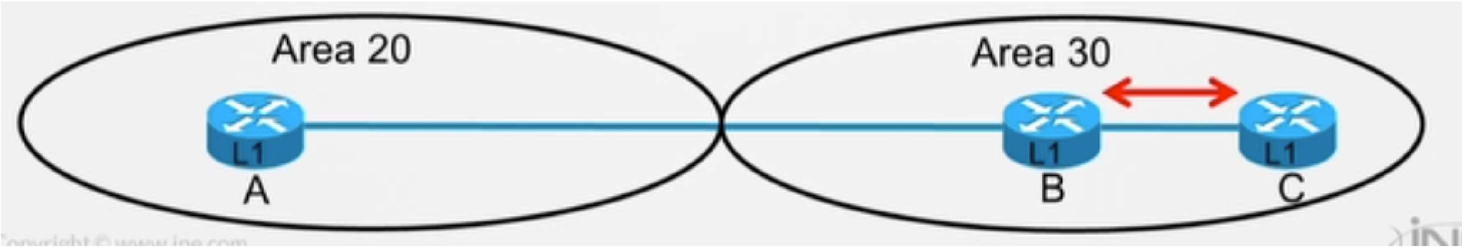
  - **Adjacencies:** Forms L1 adjacencies **only** with other L1 or L1/L2 routers that are in the **exact same area**. An L1 router cannot form an adjacency with another L1 router in a different area.

  - **Routing Scope:** Routes packets destined for prefixes **within its own area**. To reach destinations outside its area, L1 router forwards traffic to the nearest L1/L2 router within its area. This L1/L2 router signals its availability as a gateway by setting the **Attached Bit (ATT-bit)** in its L1 LSP (more about this later), effectively advertising a default route to the L1 routers.

  - **Database:** Maintains only a **Level 1 Link-State Database (LSDB)**, containing detailed topology information of its own area.

  - **PDUs Exchanged:** Sends and receives **Level 1 Hello PDUs** to discover and maintain L1 adjacencies, and exchanges **Level 1 LSPs** containing its intra-area link-state information.

- **Routes Known:**
  - Detailed routes for all prefixes *within its own area*.
  - Any routes *redistributed* directly into its L1 area.
  - A default route (`0.0.0.0/0`) advertised by an L1/L2 router, pointing towards the L2 backbone for inter-area traffic.



Router A in Area 20 and Routers B & C in Area 30, if they were purely L1 and isolated to their areas without an L2 connection, would only know about their local area.)

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2. Level 2 Only (L2 Only) Routers

An L2 router is part of the IS-IS backbone and is responsible for inter-area routing.

- **Analogy:** L2 router's role is comparable to an OSPF backbone router within Area 0, as it connects different areas and facilitates routing between them.

- **Rules & Characteristics:**

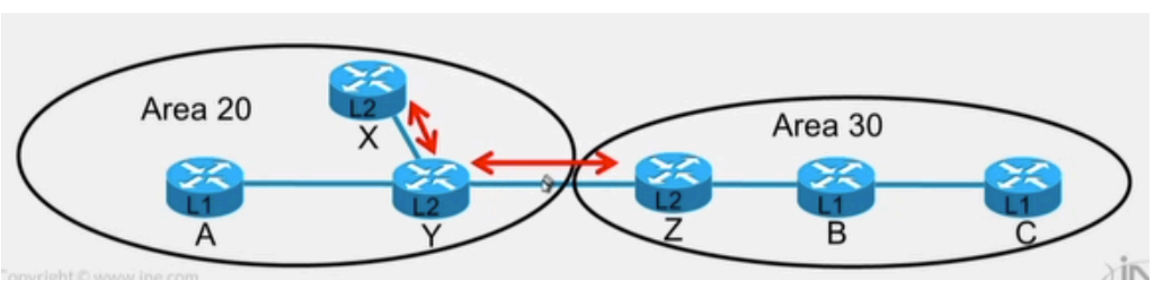
  - **Adjacencies:** Forms L2 adjacencies **only** with other L2 or L1/L2 routers. The area ID of the L2 neighbors is **not a constraint** for forming L2 adjacencies; they can be in the same or different configured L1 areas, as L2 routing forms an independent backbone topology.

  - **Routing Scope:** Routes packets **between different IS-IS areas**. It learns about prefixes in various L1 areas from connected L1/L2 routers and advertises these across the L2 backbone.

  - **Database:** Maintains only a **Level 2 LSDB**, containing the topology of the L2 backbone and summary information about prefixes reachable in various L1 areas.

  - **PDUs Exchanged:** Sends and receives **Level 2 Hello PDUs** for L2 adjacencies and exchanges **Level 2 LSPs** containing backbone link-state information and inter-area reachability.

- **Routes Known:**
  - Detailed routes for the L2 backbone topology.
  - Prefixes from all L1 areas that are advertised into the L2 backbone by L1/L2 routers.
  - Any routes *redistributed* directly into the L2 domain.



X and Y are L2 capable in Area 20, and Z is L2 capable in Area 30, forming an L2 link between Y and Z for inter-area traffic.

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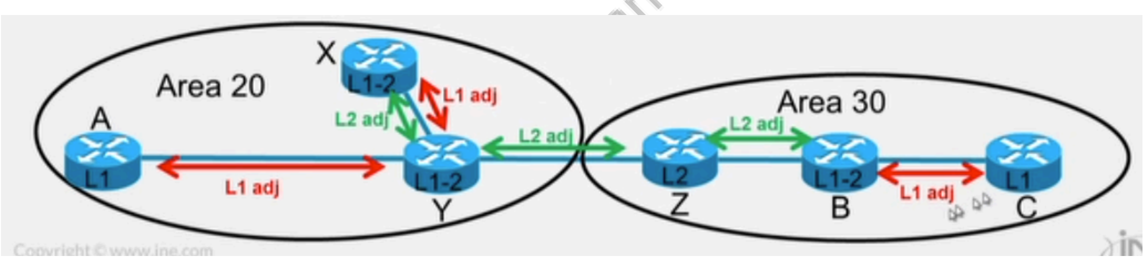
3. Level 1-Level 2 (L1/L2) Routers (Cisco Default)

L1/L2 router's role is comparable to an OSPF Area Border Router (ABR), it acts as a bridge between its local L1 area and the L2 backbone, performing both roles simultaneously. This is the default configuration for IS-IS on Cisco routers.

- **Rules & Characteristics:**
    - **Adjacencies:** Can form **L1 adjacencies** with L1 and other L1/L2 routers *within its own configured area*. It can also form **L2 adjacencies** with L2 and other L1/L2 routers, which can be in the *same or different areas* (for L2 backbone purposes).
    - **Routing Scope:** Routes packets *within its local L1 area* and also routes packets *between its L1 area and other areas* via the L2 backbone. L1/L2 routers are critical for propagating L1 routes into the L2 backbone and advertising the L2 backbone (often as a default route via the ATT-bit) into their local L1 area.
    - **Databases:** Maintains **two separate LSDBs**: one for Level 1 and one for Level 2. It runs the SPF algorithm independently on each database, resulting in separate L1 and L2 SPF trees.
    - **PDUs Exchanged:** Sends and receives both **Level 1 and Level 2 Hello PDUs** (on appropriate interfaces) and exchanges both **Level 1 LSPs** (for its area) and **Level 2 LSPs** (for the backbone).
- **Routes Known (Comprehensive View):**
    - Detailed routes for all prefixes from L1 neighbors *within its own area*.
    - Any routes *redistributed* into its local L1 area.
    - Routes from different areas learned via its L2 adjacencies and the L2 LSDB.
    - It also advertises routes from its L1 area into the L2 backbone so other areas can learn them.



illustrates L1/L2 routers (X, Y, B) forming L1 adjacencies within their respective areas and L2 adjacencies to create the backbone (Y-Z, Z-B, X-Y), enabling full connectivity.)

This hierarchical structure allows IS-IS to scale efficiently in large networks by segmenting the topology and controlling the scope of LSP flooding.

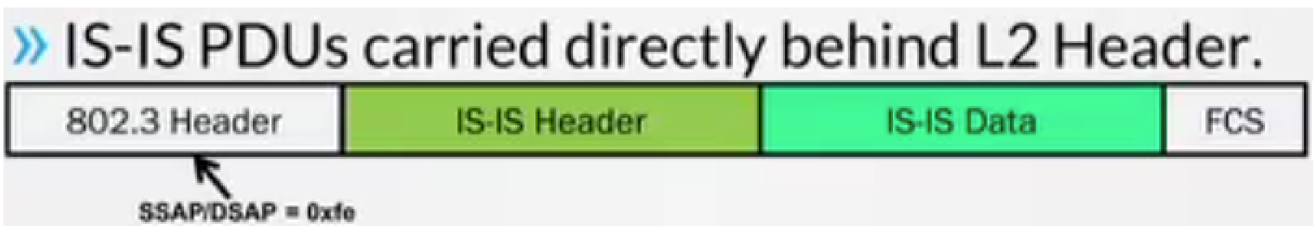
IS-IS PDUs

PDU Structure, Encapsulation, and Types

To truly grasp how IS-IS (Intermediate System to Intermediate System) functions, it's essential to understand its Protocol Data Units (PDUs) – the messages routers exchange. This note explores how IS-IS PDUs are structured, how they're carried across the network, and the roles of the different PDU types.

IS-IS PDU Encapsulation & On-the-Wire Format

A defining characteristic of IS-IS is its direct operation over Layer 2, a contrast to many IP-native routing protocols.



- **Direct Layer 2 Encapsulation:** IS-IS PDUs are typically encapsulated directly after Layer 2 frames. On Ethernet networks, this commonly involves an **IEEE 802.3 frame format**

- **LLC Service Access Points (SAPs):** Within the LLC header, both the Destination SAP (DSAP) and Source SAP (SSAP) fields are often set to the value `0xFE`. This hexadecimal value signals that the payload belongs to the ISO Connectionless Network Service (CLNS) protocol family, of which IS-IS is a part of.

- **Common PDU Header:** All IS-IS PDUs begin with a **common 8-octet header**. This standardized header provides essential information consistent across all PDU types.

- **Value (TLV) System:** Following the common header, IS-IS PDUs carry specific information using a flexible **Type-Length-Value (TLV)** system. Each TLV encodes a particular piece of information (e.g., an area address, an IP prefix, a neighbor ID). Routers are designed to ignore and pass through any TLVs they don't understand, which allows for graceful protocol extensions and new features.

Destination MAC Addresses on Broadcast Networks

On broadcast media like Ethernet, IS-IS uses specific Layer 2 multicast MAC addresses for its PDUs, allowing efficient communication with relevant groups of routers:

- `01-80-C2-00-00-14` **(AllL1ISs):** This multicast MAC address is used as the destination for **Level 1 LAN Hellos** and for **Level 1 LSPs, CSNPs, and PSNPs** when sent on broadcast segments by IS-IS routers operating at Level 1.

- `01-80-C2-00-00-15` **(AllL2ISs):** Similarly, this is the multicast destination MAC address for **Level 2 LAN Hellos** and for **Level 2 LSPs, CSNPs, and PSNPs** on broadcast segments for routers participating in the Level 2 backbone.

- `09-00-2B-00-00-05` **(AllISs):** This Multicast MAC address is used as destination when an Ethernet link is converted to P2P.

(It's worth noting that other MAC addresses like `09-00-2B-00-00-05` (AllISs) and `09-00-2B-00-00-04` (AllESs) are primarily associated with the ES-IS protocol, which handles End System (host) to Intermediate System (router) communication, rather than IS-IS router-to-router PDUs.)

Overview of IS-IS PDU Categories

IS-IS employs three primary categories of PDUs to manage its operations:

1. **Hello PDUs (IIHs - IS-to-IS Hello PDUs):** For neighbor discovery and adjacency maintenance.

2. **Link State PDUs (LSPs):** To advertise network topology and reachability information.

3. **Sequence Number PDUs (SNPs):** For Link-State Database (LSDB) synchronization.

Let's delve into each category.

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1. Hello PDUs (IIHs)

Hello PDUs are the "handshake" messages of IS-IS, enabling routers to discover each other and maintain their adjacencies. There are three distinct types:

- **Level 1 IIH (PDU Type 15):** Exchanged on broadcast networks (like Ethernet) by routers to establish and maintain Level 1 (intra-area) adjacencies.

- **Level 2 IIH (PDU Type 16):** Used on broadcast networks by routers to establish and maintain Level 2 (inter-area/backbone) adjacencies.

- **Point-to-Point IIH (PDU Type 17):** Utilized on point-to-point links. These Hellos can establish either L1 or L2 adjacencies, with the specific level indicated within the PDU.

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2. Link State PDUs (LSPs)

LSPs carrying the detailed topological information (router adjacencies, reachable prefixes, metrics, etc.) that each router uses to build its map of the network (LSDB).

- **Level 1 LSP (PDU Type 18):** Originated by L1 routers and L1/L2 routers. These LSPs are confined to their specific IS-IS area and describe the topology and prefixes *within that area*.

- **Level 2 LSP (PDU Type 20):** Originated by L2 routers and L1/L2 routers. These LSPs are flooded across the Level 2 backbone and contain information about the backbone's topology and inter-area prefixes learned from various L1 areas.

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3. Sequence Number PDUs (SNPs)

SNPs are vital for ensuring that all routers within a given level (L1 or L2) have a synchronized and consistent LSDB.

- **Complete Sequence Number PDU (CSNP)**:
  - **Level 1 CSNP (PDU Type 24)**
  - **Level 2 CSNP (PDU Type 25)**

  - **Purpose:** CSNPs provide a summary list of all LSPs (their IDs, sequence numbers, and checksums) currently in the sender's LSDB for a specific level.

  - **LSDB Synchronization & the DIS Role (Comparison to OSPF DR):**

    - On broadcast networks (like Ethernet), IS-IS elects a **Designated Intermediate System (DIS)** for each level active on the segment. A key role of the DIS is to periodically multicast CSNPs. Other routers on the segment listen to these CSNPs and compare the LSP Header information against their own LSDB. If a router finds discrepancies (e.g., it's missing an LSP mentioned in the CSNP or has an older version), it can then request the missing piece using a PSNP or flood its own newer LSP.

    - This mechanism is conceptually similar to the role of the **Designated Router (DR)** in OSPF on broadcast segments. In OSPF, the DR (and BDR) are central points for LSA exchange. Routers send their LSAs to the DR/BDR (multicast to `224.0.0.6`), and the DR is responsible for flooding those LSAs to all other routers on the segment (multicast to `224.0.0.5`).

- Both the IS-IS DIS (with CSNPs/PSNPs) and the OSPF DR serve to optimize LSDB synchronization on broadcast media by reducing redundant PDU transmissions and providing a reference point for database consistency.

  The DIS acts more like a "database synchronizer" by announcing what *should be* in the database, while the OSPF DR acts more like a "centralized distribution point" for new updates.

- **Partial Sequence Number PDU (PSNP)**:
  - **Level 1 PSNP (PDU Type 26)**
  - **Level 2 PSNP (PDU Type 27)**
  - **Purpose:** PSNPs have two primary uses:

    1. **Requesting LSPs:** If a router identifies from a CSNP (or other means) that it's missing specific LSPs or has outdated versions, it can send a PSNP to the DIS (or a neighbor on a point-to-point link) to explicitly request those LSPs.

    2. **Acknowledging LSPs:** On point-to-point links, PSNPs are often used as an explicit acknowledgment mechanism for received LSPs, ensuring reliable transmission.

IS-IS PDUs Table

Category	Packet Type	Type Number
Hello	LAN Level-1 Hello	15
	LAN Level-2 Hello	16
	Point-to-point Hello	17
LSP	Level-1 LSP	18
	Level-2 LSP	20
SNP	Level-1 Complete SNP	24
	Level-2 Complete SNP	25
	Level-1 Partial SNP	26
	Level-2 Partial SNP	27

IS-IS Backbone

IS-IS Backbone and Route Exchange

The concept of a "backbone" in IS-IS is fundamental to its hierarchical design, but it operates differently from OSPF's well-known Area 0.

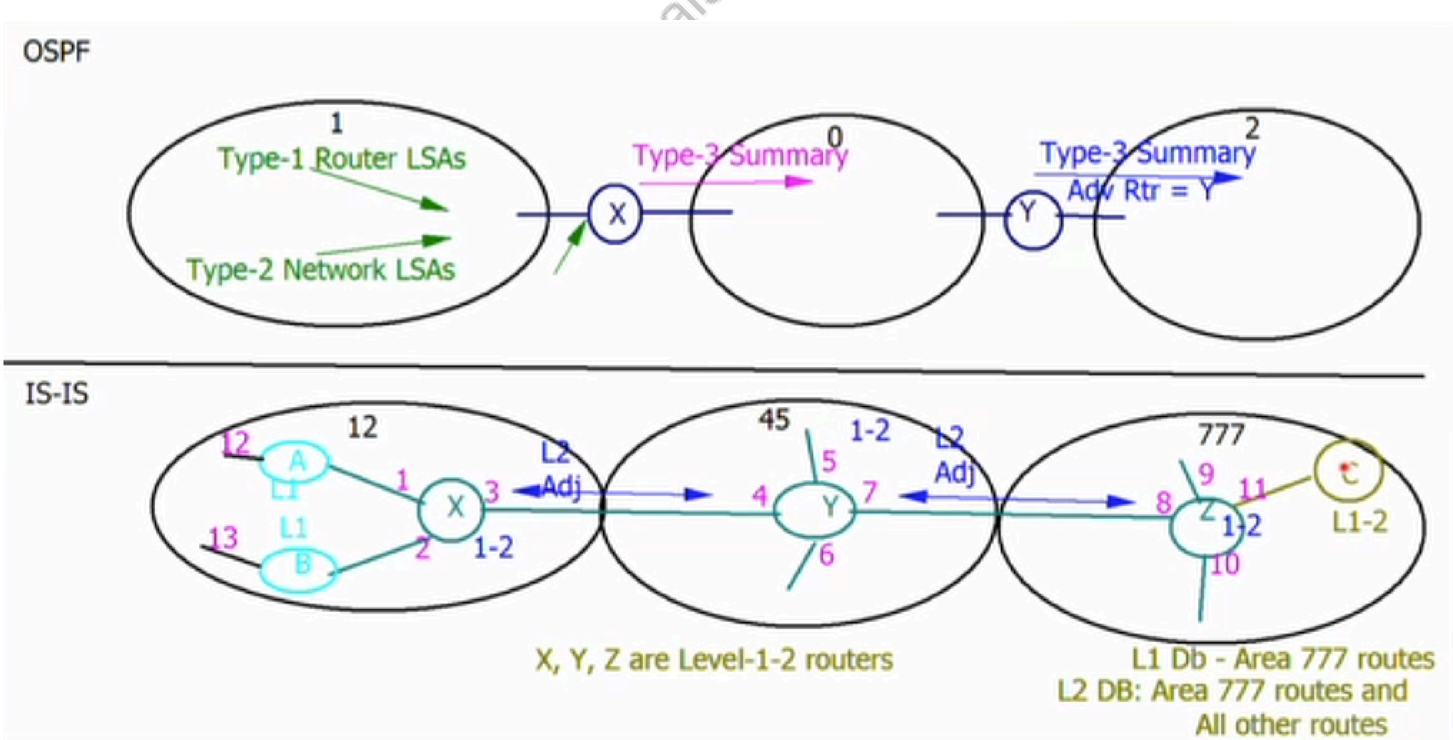
What is the IS-IS Backbone?

In OSPF, **Area 0** is explicitly designated as the backbone area, and all other areas must connect to it, typically via an Area Border Router (ABR) that has interfaces in Area 0 and another area.

With IS-IS, the backbone isn't tied to a specific area number. Instead, the **router's level capability defines the backbone**. All routers that are **Level 2 capable** (i.e., Level 2-only routers or Level 1-Level 2 routers) are considered part of the IS-IS backbone.

This is because Level 2 routers are responsible for inter-area routing, exchanging information about prefixes outside of their local L1 area using **Level 2 LSPs.**

Imagine the IS-IS backbone as a **contiguous "line" of Level 2 capable routers**, with various Level 1 areas attaching to this L2 infrastructure via L1/L2 routers.



Each L2-capable router generates its own L2 LSP detailing all the L2-known routes. Once created, this L2 LSP is flooded throughout the entire Level 2 domain, reaching all other L2-capable routers, regardless of their specific L1 area affiliation.

How LSPs are Created and Routes Exchanged

Let's use a scenario like the above shared diagram to illustrate the LSP exchange:

Scenario: Router is Level 1 Only
Router A, a purely L1 router in Area 12, with L1 neighbors B (L1) and X (L1/L2) in the same Area 12

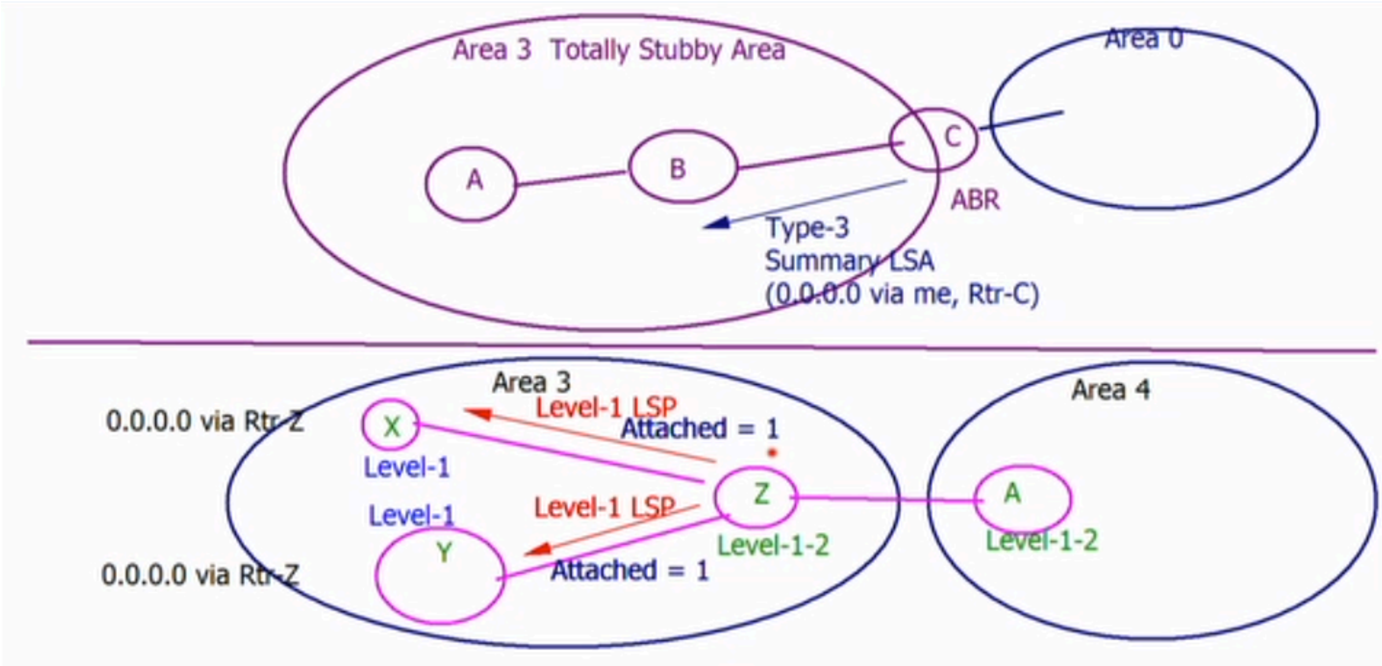
1. **LSP Creation:** Router A creates a single **L1 LSP**. This LSP describes all its directly connected L1 interfaces that is enabled for IS-IS Routing, their metrics, and any routes redistributed into its L1 process.

2. **LSP Flooding (Intra-Area):** Router A floods this L1 LSP to its L1 neighbors within Area 12 (Router B and Router X).

3. **LSP Reception:** Router A receives L1 LSPs from Router B and Router X.

4. **Intra-Area Knowledge:** After this exchange, Router A has a complete L1 LSDB for Area 12 and can calculate paths to all prefixes originated or redistributed within Area 12.

5. **Reaching Outside the Area (Default Route):** If Router A's L1/L2 neighbor (Router X) has connectivity to other areas (via the L2 backbone), Router X will set the **Attached Bit (ATT-bit)** in its L1 LSP that it sends to Router A. (



The ATT-bit is visible like below packet capture. Upon seeing this ATT-bit set, Router A will install a default route (0.0.0.0/0) pointing towards Router X. This allows Router A to send traffic destined for other areas to its L1/L2 gateway.

```
▼ ISO 10589 ISIS Link State Protocol Data Unit
    PDU length: 98
    Remaining lifetime: 1199
    LSP-ID: 2222.2222.2222.00-00
    Sequence number: 0x0000000f
    Checksum: 0x01ac [correct]
    [Checksum Status: Good]
  ▶ Type block(0x0b): Partition Repair:0, Attached bits:1, Overload bit:0, IS type:3
  ▶ Area address(es) (t=1, l=4)
  ▶ Protocols supported (t=129, l=1)
  ▶ Hostname (t=137, l=2)
  ▶ IS Reachability (t=2, l=12)
  ▶ IP Interface address(es) (t=132, l=4)
  ▶ IP Internal reachability (t=128, l=36)
```

6. **L1 LSP Scope:** The flooding of L1 LSPs is strictly confined to their own area. An L1 LSP from Area 12 will not enter Area 45.

7. **L1 LSDB Size:** The L1 LSDB on Router A will contain one L1 LSP from every L1 and L1/L2 router within Area 12 (so, LSPs from A, B, and X in this example).

Scenario: Router is Level 1-Level 2

Router X, an L1/L2 router in Area 12, with L1 neighbors A & B, and an L2 neighbor Y L1/L2 in Area 45

1. **L1 Operations:**
    - Router X creates its own **L1 LSP** for Area 12, describing its L1 links and prefixes.
    - It exchanges these L1 LSPs with its L1 neighbors (A and B) within Area 12.
    - Router X now has a complete L1 LSDB for Area 12 (containing LSPs from A, B, and itself).
2. **L2 Operations & Route Leaking:**
    - Router X also creates one **L2 LSP**.
    - Into this L2 LSP, Router X places:
        - Information about its directly connected IS-IS links.
        - Prefixes learned from its L1 LSDB (i.e., from Area 12, including routes from A, B). This is how routes from an L1 area are "leaked" or advertised into the L2 backbone.
3. **L2 LSP Flooding:**
    - Router X floods its L2 LSP to its L2 neighbors (Router Y). Router Y will then flood it to its L2 neighbors (Router Z), and so on (Router C). This ensures all L2 routers (X, Y, Z, C) learn X's L2 information.
    - Transit L2 LSPs are typically not filtered or summarized by intermediate L2 routers; only the originating L2 router controls the content of its L2 LSP.
4. **L2 LSDB Size:** Router X's L2 LSDB will eventually contain L2 LSPs from all other L2-capable routers in the backbone (e.g., from Y, Z, and C, plus its own).

This dual-level process allows L1/L2 routers to connect L1 areas to the L2 backbone, enabling full network reachability.

How Level 1 Routers Send Packets Outside Their Area

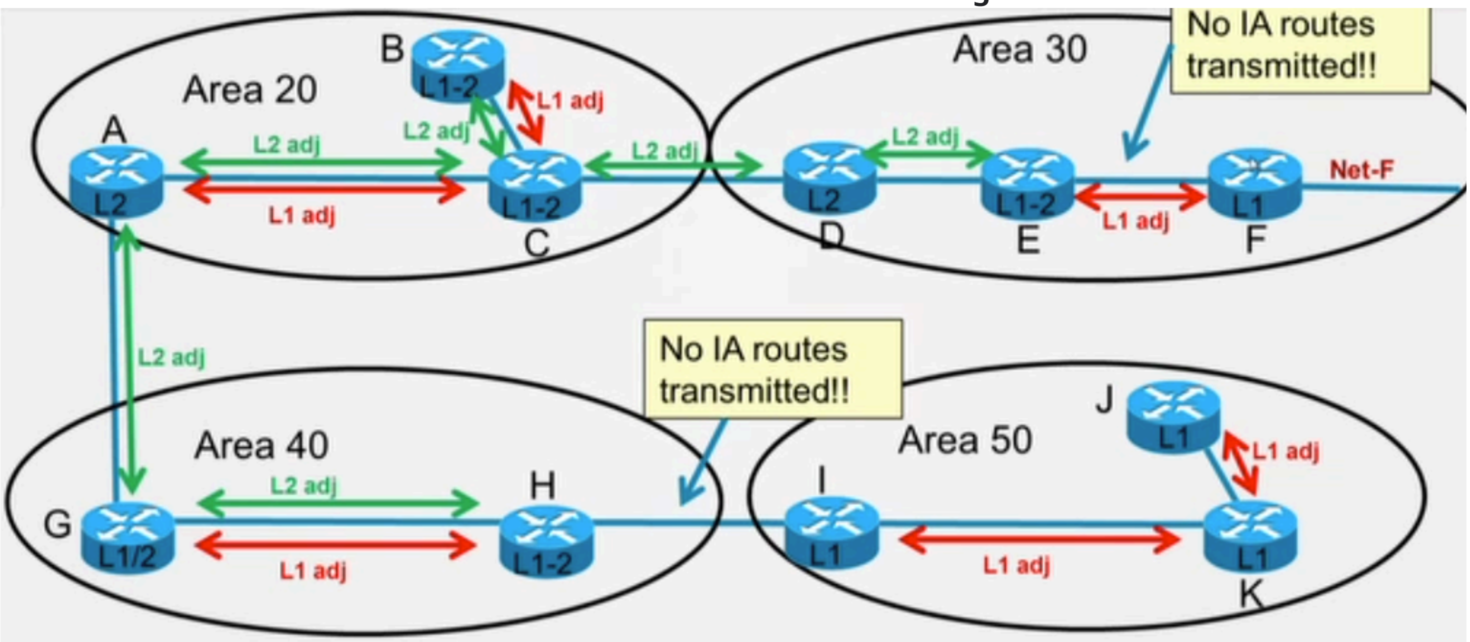
1. As established, L1 routers maintain an L1 LSDB which only contains detailed topological information for routes *local to their own area*.

2. L1 routers *do not receive or process L2 LSPs*, so they have no direct visibility into prefixes in other areas.

3. When an L1 router (like Router A) detects an L1/L2 router (like Router X) in its area, and that L1/L2 router advertises itself as a gateway to other areas by setting the **ATT-bit** in its L1 LSP, the L1 router installs a default route pointing to that L1/L2 router.

4. If there are multiple L1/L2 routers in the area setting the ATT-bit, the L1 router will choose the L1/L2 router that is closest in terms of IS-IS metric as its default gateway.

Critical note: Does Router F create a default route in the below diagram?



Router F is an L1 router in Area 30. Router E is an L1/L2 router in Area 30. Router D is an L2-only router.

The answer is: Router F will only create a default route towards Router E if Router E sets the ATT-bit in its L1 LSP that it floods within Area 30

- Router E would set the ATT-bit if its L2 connection (to Router D, for instance) provides valid paths to other IS-IS areas beyond what's locally known or reachable via L1 in Area 30.

- If Router E's L2 connection does *not* lead to any other areas, it should *not* set the ATT-bit. hence likely not setting the ATT-bit, so F would not install a default route to E.

- Router D, being L2-only, does not generate L1 LSPs and thus doesn't directly influence F's default route decision through an ATT-bit mechanism for Area 30.

Database Consistency in IS-IS

Database consistency is vital for loop-free routing.

- All routers **within the same L1 area** must have an identical copy of the L1 LSDB for that area.

- All L2 and L1/L2 routers forming the **L2 backbone** must have an identical copy of the L2 LSDB.

This consistency ensures that all routers in a given level/area make their SPF calculations based on the same topological information. To maintain this, only the originator of an LSP can modify or withdraw its own LSP. Summarization and filtering primarily occur when information is passed between levels (L1 to L2, or L2 to L1 by an L1/L2 router) or during route redistribution from other protocols.

Route Preference Hierarchy in IS-IS

On an L1/L2 router, when deciding how to reach a prefix:

- Routes learned via its **L1 LSDB (intra-area routes for its directly connected area)** are generally preferred over routes for the *same prefix* if learned via its **L2 LSDB (inter-area routes)**. This ensures that an L1/L2 router uses the intra-area path to reach destinations within its own L1 area, rather than going out to the L2 backbone and potentially looping back in.

ISIS NET

Network Entity Title (NET)

Unlike IGPs such as OSPF or EIGRP which were designed primarily for IP, IS-IS has its roots in the OSI CLNS world. This dictates its unique approach to router identification.

While IP-native IGPs often use a 32-bit Router ID (typically resembling an IPv4 address and often derivable from an interface IP), IS-IS uses a **Network Entity Title (NET)** for ISIS router identification.

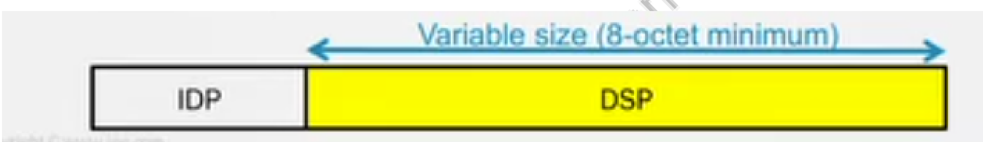
- **OSI Origins:** Because IS-IS was initially designed to route OSI's Connectionless Network Protocol (CLNP) packets, not IPv4, its identifier (the NET) doesn't follow IPv4 addressing conventions.

- **Manual Configuration Required:** An IS-IS router cannot dynamically derive its NET from an IP address. The NET **must be manually configured** for the IS-IS process to start.

NET Structure and Size

The NET is a type of NSAP (Network Service Access Point) address that specifically identifies the routing process on an Intermediate System (router).

- **Variable Size:** A NET's length can range from **8 to 20 octets (bytes)**.



- **Key Components:** Generally, a NET is composed of:

1. **Authority and Format Identifier (AFI):** 1 byte.

2. **Initial Domain Identifier (IDI):** Variable length (or absent in some private NET schemes).

3. **Domain Specific Part (DSP):** This part contains:
    - **High Order DSP (HO-DSP):** Often used to specify the IS-IS area. Variable length.

    - **System Identifier (System ID):** Typically 6 bytes for routers. This uniquely identifies the router within its area (and often, within the entire domain).

    - **NSEL (NSAP Selector):** 1 byte. For a router's NET, this is **always** `00`.

NET Configuration Options

While OSI defines various NSAP structures, for IS-IS NETs in IP networks, we have two primary scenarios:

1. Public/Inter-Domain IS-IS (Less Common for Enterprise IGP use)

If an organization needed to connect its IS-IS domain to another distinct IS-IS domain using globally unique OSI addressing (e.g., an ISP connecting to another ISP via CLNS a long time ago), it would use NETs with an IDP (Initial Domain Part) assigned by a registration authority like ISO.

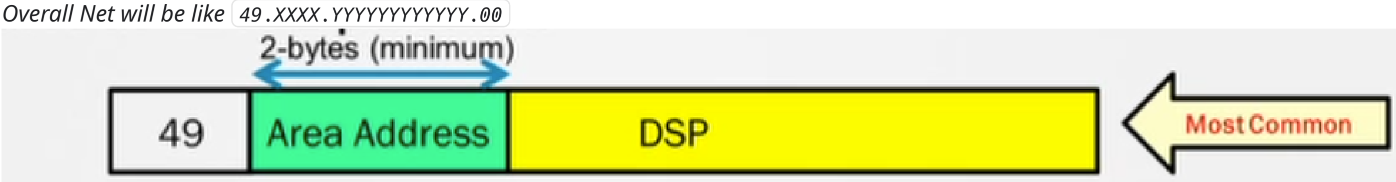
- **IDP = AFI + IDI:**
  - **AFI (Authority and Format Identifier):** 1 byte, indicating the format and allocation authority for the IDI.
  - **IDI (Initial Domain Identifier):** Variable length, assigned by the authority to ensure global uniqueness.
- **DSP = HO-DSP (Area) + System ID + NSEL:** The rest of the NET follows the DSP structure.

2. Private IS-IS (Most Common Scenario)

When IS-IS is used as an IGP within a single organization's network (the typical use case for Integrated IS-IS routing IP), a private addressing scheme is used. The most common and recommended format uses an AFI of **`49`**.

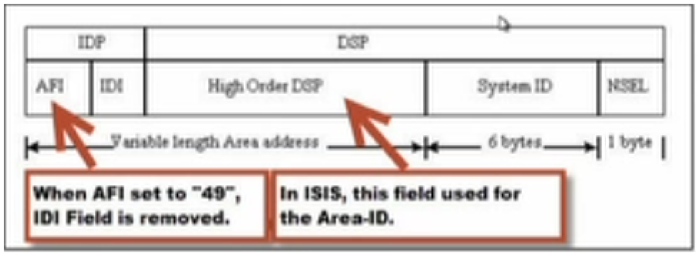
- **AFI `49`:** This AFI value specifically designates a privately administered NSAP address.
- **No IDI:** When AFI `49` is used, a distinct IDI field is generally not present or is considered part of the HO-DSP.
- **Structure:** The NET typically takes the form: `49.<Area_ID>.<System_ID>.00`
  - `49`: The 1-byte AFI for private NETs.
  - `<Area_ID>`: This is the High Order DSP (HO-DSP), representing the IS-IS area. Its length is variable, but commonly 1 to 3 bytes (e.g., `0001` for area 1).
  - `<System_ID>`: The 6-byte System ID, unique to the router.
  - `00`: The 1-byte NSEL.

Overall Net will be like `49.XXXX.YYYYYYYYYYYY.00`



Dissecting the Domain Specific Part (DSP)

The DSP is crucial for identifying the area and the specific router.



- **High Order DSP (HO-DSP) / Area ID:**
  - This portion is used to define the IS-IS area to which the router belongs.
  - While variable in length, it's common to use 1 to 3 bytes for the area ID in AFI `49` NETs.

- **System Identifier (System ID):**
  - This **must be unique** for each router within the IS-IS domain.
  - Cisco routers require a **6-byte** System ID. Although RFCs allow for 1-8 bytes, all IS-IS routers in a domain must use the same System ID length. Using 6 bytes is standard.
  - **Derivation:**
    - It can be an arbitrary hexadecimal number.
    - Often derived from a router's **MAC address**.
    - A common practice in Service Provider networks is to derive it from the router's **management loopback IP address**. For example, an IP like `192.168.1.1` might be converted to `1921.6800.1001` (padding each octet of the IP to three digits and then grouping them).

1. 1.22.123.44= IP Address
2. 001.022.123.044 (add leading zeros to make each octet a 3-digit number).
3. 0010.2212.3044 (move decimal points and viola!! You have a System-ID!)

- **NSEL (NSAP Selector):**
  - This is a **1-byte** field.
  - For a router's **NET address**, the NSEL is **always** `00`. This signifies that the NSAP address identifies the system (router) itself for routing purposes.
  - Non-zero NSEL values are used in NSAP addresses assigned to specific services or interfaces on an End System or Intermediate System in a pure OSI environment, but not for the router's own IS-IS identity.

Common Private NET Structure Summarized

The most prevalent NET format you'll configure and encounter is:
`AFI (49) | Area ID (HO-DSP) | System ID | NSEL (00)`
Example: `49.0001.1234.5678.9ABC.00`

- `49`: AFI (1 byte)
- `0001`: Area ID (e.g., 2 bytes for area 1)

- `1234.5678.9ABC`: System ID (6 bytes)
- `00`: NSEL (1 byte)

Configuration Example (Cisco IOS)

```
R1(config)# router isis MY_PROCESS_NAME  // Process name is locally significant
R1(config-router)# net 49.0001.0100.4200.2006.00
```

IS-IS Adjacencies

Forming IS-IS Adjacencies

IS-IS is often considered to have a simpler adjacency formation process compared to OSPF. Here are some key characteristics:

1. **Rapid Adjacency:** Adjacency is typically established after a quick exchange of Hello packets.

2. **Area Rules for Adjacency:**

   - **Level 1 (L1) Adjacencies:** Routers **must be in the same IS-IS area** to form an L1 adjacency.

   - **Level 2 (L2) Adjacencies:** Routers **do not need to be in the same area** to form an L2 adjacency. This allows L2 routers to form the backbone across different underlying area configurations.

3. **Flexible Timers:** IS-IS Hello and Hold-down timers **do not need to match** between neighbors for an adjacency to form.

4. **Fewer Strict Parameter Matches:** Compared to OSPF, IS-IS is generally less stringent about matching various parameters for adjacency formation (though significant mismatches like MTU can still impact LSP exchange).

The Role of the System ID

The **System ID** is a crucial 6-byte component of the Network Entity Title (NET).

- It uniquely identifies an IS-IS router within the routing domain.
- The System ID is included in IS-IS Hello packets and is used to identify and differentiate neighbors.

Types of IS-IS Adjacencies by Level

IS-IS adjacencies are fundamentally categorized by the router level involved:

1. **Level 1 Adjacency:**

  - Established between two routers operating at Level 1 (either L1-only routers or L1/L2 routers acting in their L1 capacity).
  - Uses **Level 1 IS-IS Hellos**
  - **Condition:** Both routers must share the same Area ID.

2. **Level 2 Adjacency:**
  - Established between two routers operating at Level 2 (either L2-only routers or L1/L2 routers acting in their L2 capacity).
  - **Level 2 IS-IS Hellos**
  - **Condition:** Area IDs do not need to match.

Adjacency Categorization by Link Medium Type

The underlying Layer 2 medium influences how adjacencies are formed:

1. **Broadcast Links:** Typically Ethernet, where multiple routers can share the medium.

2. **Point-to-Point (P2P) Links:** Links like serial connections with HDLC or PPP encapsulation, or Ethernet links configured to operate in P2P mode for IS-IS.

Adjacency Formation: Broadcast vs. Point-to-Point

1. Broadcast Links (e.g., Ethernet)

- **Hello Transmission:**
  - An L1-only router sends **L1 IIHs** to the multicast MAC address `0180.C200.0014` (AllL1ISs).
  - An L2-only router sends **L2 IIHs** to the multicast MAC address `0180.C200.0015` (AllL2ISs).
  - An L1/L2 router (the default) sends both L1 IIHs (to `0180.C200.0014`) and L2 IIHs (to `0180.C200.0015`).

- **Listening:** Routers listen on these multicast addresses for Hellos from potential neighbors.

```
▶ Frame 16: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
▶ IEEE 802.3 Ethernet
▶ Logical-Link Control
▶ ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
▼ ISIS HELLO
    .... ..01 = Circuit type: Level 1 only (0x1)
    0000 00.. = Reserved: 0x00
    SystemID {Sender of PDU}: 1111.1111.1111
    Holding timer: 30
    PDU length: 1497
    .100 0000 = Priority: 64
    0... .... = Reserved: 0
    SystemID {Designated IS}: 1111.1111.1111.01
  ▶ Protocols Supported (t=129, l=1)
  ▶ Area address(es) (t=1, l=4)
  ▶ IP Interface address(es) (t=132, l=4)
  ▶ Restart Signaling (t=211, l=3)
  ▶ Padding (t=8, l=255)
  ▶ Padding (t=8, l=255)
  ▶ Padding (t=8, l=255)
  ▶ Padding (t=8, l=255)
  ▶ Padding (t=8, l=255)
  ▶ Padding (t=8, l=163)
```

- **IS-IS States:**
  - **Down:** The initial state. The router is sending Hellos but has not yet heard from any other IS-IS router on this segment, or a previous adjacency has been torn down.
  - **Initializing:** The router has received a Hello from a neighbor, but it doesn't see its own System ID listed in the "Neighbor" field (or IS Neighbors TLV) of the received Hello. This means the neighbor hasn't fully recognized the local router yet.
  - **Up:** The router has received a Hello from a neighbor, and that Hello *does* list the local router's System ID as a recognized neighbor. This confirms a bi-directional detection and completes the three-way handshake. At this point, the adjacency is considered UP, even before the full LSDB exchange begins.

```
▶ Frame 17: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
▶ IEEE 802.3 Ethernet
▶ Logical-Link Control
▶ ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
▼ ISIS HELLO
     .... ..01 = Circuit type: Level 1 only (0x1)
     0000 00.. = Reserved: 0x00
     SystemID {Sender of PDU}: 2222.2222.2222
     Holding timer: 30
     PDU length: 1497
     .100 0000 = Priority: 64
     0... .... = Reserved: 0
     SystemID {Designated IS}: 2222.2222.2222.01
   ▶ Protocols Supported (t=129, l=1)
   ▶ Area address(es) (t=1, l=4)
   ▶ IP Interface address(es) (t=132, l=4)
   ▶ Restart Signaling (t=211, l=3)
   ▼ IS Neighbor(s) (t=6, l=6)
        Type: 6
        Length: 6
        IS Neighbor: aa:bb:cc:00:01:10 (aa:bb:cc:00:01:10)
   ▶ Padding (t=8, l=255)
   ▶ Padding (t=8, l=255)
   ▶ Padding (t=8, l=255)
   ▶ Padding (t=8, l=255)
   ▶ Padding (t=8, l=255)
   ▶ Padding (t=8, l=155)
```

2. Point-to-Point Links (e.g., HDLC, PPP, or P2P-configured Ethernet)

- **Hello Transmission:** A single **Point-to-Point IIH (P2P IIH)** is used. If the router is L1/L2 capable, this single P2P Hello can indicate both L1 and L2 adjacency capabilities through specific TLVs (like the "IS-IS neighbor TLV for P2P adjacencies").

```
▼ ISIS HELLO
     .... ..11 = Circuit type: Level 1 and 2 (0x3)
     0000 00.. = Reserved: 0x00
     SystemID {Sender of PDU}: 2222.2222.2222
     Holding timer: 30
     PDU length: 1499
     Local circuit ID: 0
   ▶ Restart Signaling (t=211, l=3)
   ▼ Point-to-point Adjacency State (t=240, l=1)
        Type: 240
        Length: 1
        Adjacency State: Down (2)
```

- **No Multicast MACs (on traditional P2P):** On serial links using HDLC/PPP. Frames are simply sent out the interface.

- **Two-Way Handshake (using Adjacency State TLV):** Point-to-Point IIHs contain an "Adjacency Three-Way State" TLV (for P2P links) which facilitates a simpler handshake.

- **Down:** Initial state.

```
▼ ISIS HELLO
      .... ..11 = Circuit type: Level 1 and 2 (0x3)
      0000 00.. = Reserved: 0x00
      SystemID {Sender of PDU}: 2222.2222.2222
      Holding timer: 30
      PDU length: 1499
      Local circuit ID: 0
    ▶ Restart Signaling (t=211, l=3)
    ▼ Point-to-point Adjacency State (t=240, l=1)
         Type: 240
         Length: 1
         Adjacency State: Down (2)
```

- **Initializing:** A router sends a P2P IIH. When it receives a P2P IIH back from its peer, and sees its own System ID acknowledged by the peer (often initially in an "Initializing" state from the peer's perspective), it moves to this state. The local router will indicate the peer's state as "Initializing" in its next Hello.


```
▼ ISIS HELLO
      .... ..10 = Circuit type: Level 2 only (0x2)
      0000 00.. = Reserved: 0x00
      SystemID {Sender of PDU}: 3333.3333.3333
      Holding timer: 30
      PDU length: 1499
      Local circuit ID: 1
    ▶ Restart Signaling (t=211, l=3)
    ▼ Point-to-point Adjacency State (t=240, l=1)
         Type: 240
         Length: 1
         Adjacency State: Initializing (1)
```

- **Up:** When a router receives a P2P IIH from its peer, and the "Adjacency Three-Way State" TLV in that received Hello indicates the local router with a state of "Up," the adjacency transitions to UP. This confirms mutual recognition.

```
▶ Frame 13: 1504 bytes on wire (12032 bits), 1504 bytes captured (12032 bits) on interface 0
▶ Cisco HDLC
▶ ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
▼ ISIS HELLO
    .... ..10 = Circuit type: Level 2 only (0x2)
    0000 00.. = Reserved: 0x00
    SystemID {Sender of PDU}: 3333.3333.3333
    Holding timer: 30
    PDU length: 1499
    Local circuit ID: 1
  ▶ Restart Signaling (t=211, l=3)
  ▼ Point-to-point Adjacency State (t=240, l=1)
      Type: 240
      Length: 1
      Adjacency State: Up (0)
```

- **Point-to-Point over Ethernet:** If an Ethernet interface is configured for IS-IS point-to-point operation, P2P IIHs are used. These are typically sent using `0900.2B00.0005` **MAC address**.

Conditions for Adjacency Failure

An IS-IS adjacency may fail to come up or might flap due to several reasons:

- **Level Mismatch:** L1-only router cannot form an adjacency with L2-only router.
  - L1 routers form adjacencies with other L1 or L1/L2 routers (if in the same area).
  - L2 routers form adjacencies with other L2 or L1/L2 routers (area matching not required).

- **Area Mismatch (for L1):** L1 adjacencies require routers to be in the same IS-IS area.

- **Network Type Mismatch:** If one router is configured for broadcast and the other for point-to-point on the same segment, they will likely fail to form an adjacency as their Hello mechanisms and expectations differ.

- **Authentication Failure:** If IS-IS authentication is configured, mismatched keys or authentication types will prevent adjacency.

- **Duplicate System ID:** System IDs must be unique. If two routers on the same segment have the same System ID, an adjacency will not form correctly.

Hello and Hold-down Timers

- **Hello Interval:** The period at which Hello packets are sent. A common default is **10 seconds**.

- **Hold-down Timer (Hold Time):** The duration a router will wait for a Hello from a neighbor before declaring the adjacency down. This is typically a multiple of the Hello interval, commonly **3 times the**

Hello interval (e.g., 30 seconds).

- **No Match Required:** Unlike OSPF, these timers do not need to match between IS-IS neighbors for an adjacency to establish. Each router uses its own configured hold time based on the Hellos it *receives*.

IS-IS Configurations

Basic IS-IS Configuration: IOS XE & IOS XR

Configuring IS-IS involves a few key steps at both the router process level and the interface level.

1. Global IS-IS Process Configuration

This involves enabling the IS-IS routing process, defining the router's Network Entity Title (NET), and setting its operational level.

IOS XE:

```
R1(config)# router isis MY_ISIS_PROCESS  // The process name is optional and locally significant
R1(config-router)# net 49.0001.1111.1111.1111.00 // 49.<AreaID>.<SystemID>.00
R1(config-router)# is-type level-1 // Options: level-1, level-2-only, level-1-2 (default)
```

- **`router isis <PROCESS_NAME>`**: Enables the IS-IS process.
- **`net <NET_ADDRESS>`**: Assigns the crucial Network Entity Title.
    - `49` is the common AFI for private networks.
    - The next segment (e.g., `0001`) is the Area ID.
    - The following 6 bytes (e.g., `1111.1111.1111`) are the unique System ID.
    - `.00` is the NSEL, always `00` for a router's NET.
- **`is-type <level>`**: Defines the router's capability, it defaults to `level-1-2`.

IOS XR:

```
RP/0/0/CPU0:CORE-P1(config)# router isis MY_ISIS_PROCESS
RP/0/0/CPU0:CORE-P1(config-isis)# net 49.0001.2222.2222.2222.00 // Note the .00 for NSEL
RP/0/0/CPU0:CORE-P1(config-isis)# is-type level-2-only
RP/0/0/CPU0:CORE-P1(config-isis)# address-family ipv4 unicast // Enable IPv4 routing capability
RP/0/0/CPU0:CORE-P1(config-isis-af)# exit // Exit address-family config
```

- The commands are similar, but note the explicit enabling of an address family (like `ipv4 unicast`) under the IS-IS process in IOS XR for it to route those types of packets.

Why Router Level (is-type) is Important?
The chosen level dictates:

- **LSDBs Created**: `level-1-2` routers maintain separate L1 and L2 databases. L1-only or L2-only routers maintain a single database for their respective level.

- **Hellos Sent**: An L1/L2 router sends both L1 and L2 Hellos by default. L1-only sends L1 Hellos; L2-only sends L2 Hellos.

- **LSPs Generated:** An L1/L2 router generates both L1 and L2 LSPs. L1-only generates L1 LSPs; L2-only generates L2 LSPs.

---

2. Interface-Level IS-IS Configuration

Next, enable IS-IS on the desired interfaces and optionally tune interface-specific parameters.

IOS XE:

```
R1(config)# interface GigabitEthernet0/0/0
R1(config-if)# ip router isis MY_ISIS_PROCESS // Enable IS-IS using the global process name
R1(config-if)# isis hello-interval 5       // Optional: Default is 10 seconds
R1(config-if)# isis hello-multiplier 3     // Optional: Hold time = 3 * hello-interval (e.g., 15s here)
R1(config-if)# isis circuit-type level-1   // Optional: Restrict interface to L1 adjacencies
```

- **`ip router isis <PROCESS_NAME>`:** Activates IS-IS on the interface.
- **`isis hello-interval <seconds>`:** Modifies the Hello packet frequency.
- **`isis hello-multiplier <count>`:** Sets the number of Hellos that can be missed before the adjacency drops. Hold time = hello-interval * hello-multiplier.
- **`isis circuit-type <level>`:** If the router is L1/L2 capable, this command can restrict the type of adjacencies formed *on this specific interface* (e.g., only L1, only L2, or both L1 and L2 which is default for L1/L2 capable router). This does **not** change the router's global `is-type`. It's an optimization to control which Hellos (and thus adjacency types) are attempted on a link.

IOS XR:

```
RP/0/0/CPU0:CORE-P1(config-isis)# interface GigabitEthernet0/0/0/0
RP/0/0/CPU0:CORE-P1(config-isis-if)# address-family ipv4 unicast // Enable IS-IS for IPv4 on this interface
RP/0/0/CPU0:CORE-P1(config-isis-if)# circuit-type level-1
RP/0/0/CPU0:CORE-P1(config-isis-if)# hello-interval 5
RP/0/0/CPU0:CORE-P1(config-isis-if)# hello-multiplier 3
RP/0/0/CPU0:CORE-P1(config-isis-if-af)# exit // Exit address-family config
RP/0/0/CPU0:CORE-P1(config-isis-if)# exit    // Exit interface config
```

- In IOS XR, IS-IS is enabled on an interface within the context of an address family (typically `ipv4 unicast` or `ipv6 unicast`) under the `router isis <PROCESS_NAME>` and then `interface <type/number>` hierarchy.
- The `circuit-type`, `hello-interval`, and `hello-multiplier` commands are similar in function to IOS XE but applied under the interface configuration mode within the IS-IS process.

Verification Commands

- `show isis neighbors`
- `show clns neighbors`

```
System Id      Type Interface   IP Address      State Holdtime Circuit Id
Router-3       L1   Fa0/0       1.3.1.3         UP    22       Router-1.01
Router-1#
```

```
Router-1#sho clns neighb
System Id      Interface   SNPA                State  Holdtime  Type Protocol
Router-3       Fa0/0       001b.d4dc.5ac8      Up     25        L1   IS-IS
Router-1#
```

- Displays established IS-IS adjacencies.

- **System ID/Hostname:** Shows the neighbor's System ID. If TLV 137 (Dynamic Hostname TLV) is exchanged, the neighbor's hostname is displayed for readability.

- **Interface:** The local interface on which the adjacency is formed.

- **SNPA (Subnetwork Point of Attachment):** For broadcast links like Ethernet, this shows the neighbor's MAC address.

- `show ip protocols`
- `show protocols`
- `show running-config router isis`
- `show isis protocol`
- `show isis instance <PROCESS_NAME> protocol`

System ID Display (TLV 137 - Dynamic Hostname)

By default, IS-IS routers exchange their hostnames using **TLV 137** in their LSPs (and Hellos). This allows `show isis neighbors` to display a human-readable hostname instead of just the 6-byte System ID.

To revert to displaying the System ID instead of the dynamic hostname:

- **IOS XE:**

```
R1(config)# router isis MY_ISIS_PROCESS
R1(config-router)# no dynamic hostname
```

- **IOS XR:**

```
RP/0/0/CPU0:CORE-P1(config)# router isis MY_ISIS_PROCESS
RP/0/0/CPU0:CORE-P1(config-isis)# hostname dynamic disable
```

Useful Logging & Debugging

- **Log Adjacency Changes:** To get syslog messages when adjacencies change state (useful for troubleshooting flapping).

- **IOS XE:**

  ```
  R1(config-router)# log-adjacency-changes
  ```

- **IOS XR:**

  ```
  RP/0/0/CPU0:CORE-P1(config-isis)# log adjacency changes
  ```

- **Debug Adjacency Packets (IOS XE):** To see IS-IS Hello packet exchanges and adjacency formation attempts. Use with caution in production.

  ```
  R1# debug isis adjacency-packets
  ```

  For IOS XR, debugging is typically done using `debug isis <feature>` commands or more detailed trace options, e.g., `debug isis adj`.

IS-IS Metric

IS-IS Default Metric

Like OSPF, IS-IS is a link-state routing protocol. This means:

- Level 1 LSPs (Link State PDUs) are flooded **within their area of origin**.
- Level 2 LSPs are flooded to **all Level 2 capable routers**, forming the backbone, regardless of area.
- Routers operating as Level 1-Level 2 maintain **separate LSDBs (Link State Databases)** for each level and compute **separate SPF (Shortest Path First) trees** for each.

While OSPF uses a single metric called **cost** (typically derived from `Reference Bandwidth / Interface Bandwidth`), the original IS-IS specification (ISO 10589) defines **four types of metrics** for a link:

1. **Default Metric:** Also known as the "routing metric." This is the primary metric used for path calculation.
2. **Delay Metric:** Intended to represent the transit delay on a link.
3. **Expense Metric:** Intended to represent the monetary cost of using a link.
4. **Error Metric:** Intended to represent the residual error probability of a link.

However, in **Cisco IOS XE, IOS XR and most vendors implementations, IS-IS primarily supports and uses only the "Default Metric."** The other three (Delay, Expense, Error) are generally not used for path calculation. When LSPs are exchanged, bits within the relevant TLVs usually indicate that these other metrics are not supported or should be ignored for path selection.

he rationale is that calculating SPF trees for four different metrics and then trying to combine them for a single best path would be computationally intensive and complex.

Understanding IS-IS Metric

Cisco routers implement two main "styles" for the default metric:

1. **Narrow Metrics (Default/Legacy):**

    - **Interface Metric:** Each link is assigned a metric value between **1 and 63** (a 6-bit value).

    - **Default Value:** By default, all interfaces have an IS-IS metric of **10**, regardless of their bandwidth. This can, and usually should, be changed.

    - **Path Metric:** The total cost to a destination is the sum of the interface metrics along the path. With narrow metrics, the maximum path metric is **1023** (a 10-bit value). This can be a limitation in large or complex networks.

2. **Wide Metrics:**
    - **Interface Metric:** Allows for a much larger range, typically up to (a 24-bit value).
    - **Path Metric:** The total path metric can be up to (a 32-bit value).
    - **Purpose:** Introduced to overcome the limitations of narrow metrics, especially for large service provider networks, high-bandwidth links, and to support features like MPLS Traffic Engineering (TE).
    - To use wide metrics, it must be explicitly configured on the routers.

Key Metric Configuration and Behavior

- **Changing the Default Metric of 10:**
    - You can change the default metric globally for all interfaces under the IS-IS process or on a per-interface basis.
    - You can also specify if the change applies to Level 1, Level 2, or both.

- `isis metric maximum`:
    - This command sets the metric for an interface to a very high, effectively "unusable" value. This is useful to prevent a link from being used for transit traffic, even if it's the only path.
    - **Interaction with Metric Styles:**
        - If `metric-style narrow` (default) is active, `isis metric maximum` will set the interface metric to **63**.

```
uter-3(config-if)#isis metric maximum
rning: for metrics greater than 63, 'metric-style wide'  should be configured on level-1-2,
' it will be capped at 63.
uter-3(config-if)#
```

        - If `metric-style wide` is active, `isis metric maximum` sets the metric to a much larger value (e.g., `16777214`).

- Therefore, for `isis metric maximum` to make a link truly "infinitely" costly in a network potentially using wide metrics, `metric-style wide` should be enabled first.

Configuration Commands

1. Changing the Default Metric

- **IOS XE:**
  - Globally (under IS-IS process):

```
R1(config)# router isis MY_PROCESS
R1(config-router)# metric <1-16777214> [level-1 | level-2]
```

(If level is omitted, applies to both. The max value here assumes wide metrics might be enabled; with narrow, it's effectively 1-63).

  - Per Interface:

```
R1(config)# interface GigabitEthernet0/0/0
R1(config-if)# isis metric <1-16777214> [level-1 | level-2]
```

- **IOS XR:**
  - Globally (under IS-IS process & address family):

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/0/CPU0:R1(config-isis-af)# metric <1-16777215> [level-1 | level-2 | level-1-2]
```

  - Per Interface (under IS-IS process, interface, & address family):

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# interface GigabitEthernet0/0/0/0
RP/0/0/CPU0:R1(config-isis-if)# address-family ipv4 unicast
RP/0/0/CPU0:R1(config-isis-if-af)# metric <1-16777215> [level-1 | level-2 | level-1-2]
```

2. Enabling Wide Metrics

- **IOS XE:**

```
R1(config)# router isis MY_PROCESS
R1(config-router)# metric-style wide [level-1 | level-2]
```

(It's generally recommended to enable wide metrics for both levels if making the transition.)

- **IOS XR:**

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/0/CPU0:R1(config-isis-af)# metric-style wide [level-1 | level-2 | level-1-2] [transition]
```

3. Setting Maximum Metric on an Interface

- **IOS XE:**

```
R1(config)# interface GigabitEthernet0/0/0
R1(config-if)# isis metric maximum [level-1 | level-2]
```

- **IOS XR:**

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# interface GigabitEthernet0/0/0/0
RP/0/0/CPU0:R1(config-isis-if)# address-family ipv4 unicast
RP/0/0/CPU0:R1(config-isis-if-af)# metric maximum [level-1 | level-2 | level-1-2]
```

IS-IS DIS

IS-IS Designated Intermediate System (DIS)

Understanding how IS-IS operates on broadcast multi-access networks (like Ethernet) requires a look at the role of the Designated Intermediate System (DIS). This concept has similarities to OSPF's Designated Router (DR) but also some crucial differences.

IS-IS vs. OSPF Adjacencies on Broadcast Links

- **OSPF:** On a broadcast segment, OSPF routers form full adjacencies (exchange all LSAs) only with the DR and Backup DR (BDR). With other routers (DROTHERs), they only reach a 2-WAY state (Hellos exchanged, but no full LSDB synchronization directly between DROTHERs).

- **IS-IS:** On a broadcast segment, IS-IS routers form **full adjacencies with all other IS-IS routers** on that same segment and for the same IS-IS level. This means all routers on the segment directly exchange LSPs (Link State PDUs) with each other.

What is the DIS (Designated Intermediate System)?

Despite all routers forming full adjacencies, IS-IS still elects a DIS on broadcast network segments. The DIS takes on specific responsibilities to optimize operation on the shared medium.

- **Analogy to OSPF DR:** The idea is similar to OSPF's DR, which acts as a central point for certain functions on a broadcast segment.

- **No Backup DIS:** Unlike OSPF, IS-IS **does not elect a Backup DIS (BDR)**. If the current DIS fails, a new DIS election occurs among the remaining routers.

DIS Election Process

When IS-IS is enabled on a broadcast interface, an election process determines the DIS for each IS-IS level active on that segment (L1 and/or L2).

1. **Priority:** Each router advertises its DIS priority in its Hello packets. The priority is an 8-bit value (0-127), with a default of **64**. The router with the **highest priority** wins the election for that level.

2. **MAC Address Tie-Breaker:** If priorities are tied (common with default settings), the router with the **highest MAC address** on that segment becomes the DIS.

3. **System ID Tie-Breaker (Rare):** In scenarios where MAC addresses might be identical (e.g., certain non-Ethernet multi-access networks like Frame Relay using the same DLCI mapping, or misconfiguration), the router with the **highest System ID** wins.

4. **Preemptive:** The DIS election process is **preemptive**. If a new router joins the segment with a higher priority than the current DIS, the new router will take over the DIS role.

Responsibilities of the DIS

The DIS has two primary responsibilities:

1. LSDB Synchronization via CSNPs (Complete Sequence Number Packets)

This is how the DIS facilitates a consistent view of the LSDB on the broadcast segment and provides an implicit acknowledgment mechanism.

- **How other protocols handle ACKs:**
    - EIGRP uses explicit per-neighbor acknowledgments for its updates.
    - OSPF routers send LSAs to the DR/BDR, and the DR implicitly acknowledges by flooding the LSA back out or explicitly with LSAcks.
    - BGP relies on TCP's inherent reliability and acknowledgment mechanisms.

- **IS-IS CSNP Mechanism:**
    - When an IS-IS router floods an LSP on a broadcast segment, it multicasts it to all its neighbors on that segment for the appropriate level.
    - The **DIS periodically multicasts CSNPs** (default every 10 seconds) for its level (L1 CSNPs or L2 CSNPs). A CSNP contains a list of LSP entries (LSP ID, sequence number, checksum, remaining lifetime) from the DIS's own LSDB for that level.
    - When other routers on the segment receive this CSNP, they compare it against their own LSDB:
        - If a router sees its own recently originated LSP listed in the DIS's CSNP, it knows that the DIS (and likely other routers, as the DIS is the central reference) has successfully received it.
        - If a router *doesn't* see its most recent LSP in the CSNP, or if the CSNP lists an older version, the router will re-flood its LSP.

        - If a router sees LSPs in the CSNP that it's missing or has an older version of, it can request the newer LSP (typically via a PSNP - Partial Sequence Number Packet).

    - The assumption is that if the DIS has a complete and up-to-date view of the LSPs for the segment, all other routers on that segment can synchronize with the DIS.

```
▶ Frame 73: 100 bytes on wire (800 bits), 100 bytes captured (800 bits) on interface 0
▶ IEEE 802.3 Ethernet
▶ Logical-Link Control
▼ ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
    Intradomain Routeing Protocol Discriminator: ISIS (0x83)
    Length Indicator: 33
    Version/Protocol ID Extension: 1
    ID Length: 0
    000. .... = Reserved: 0x0
    ...1 1000 = PDU Type: L1 CSNP (24)
    Version: 1
    Reserved: 0
    Maximum Area Addresses: 0
▼ ISO 10589 ISIS Complete Sequence Numbers Protocol Data Unit
    PDU length: 83
    Source-ID: 2222.2222.2222.00
    Start LSP-ID: 0000.0000.0000.00-00
    End LSP-ID: ffff.ffff.ffff.ff-ff
  ▼ LSP entries (t=9, l=48)
      Type: 9
      Length: 48
    ▼ LSP Entry
        LSP Sequence Number: 0x00000058
        Remaining Lifetime: 1193
        LSP checksum: 0x559f
      LSP-ID: 1111.1111.1111.00-00
    ▶ LSP Entry
      LSP-ID: 2222.2222.2222.00-00
    ▶ LSP Entry
      LSP-ID: 2222.2222.2222.01-00
```

A sniffer trace of a CSNP would show it primarily contains LSP headers, not the full LSP content.

2. Creation and Advertisement of the Pseudonode LSP

To represent the broadcast network itself in the link-state topology, the DIS creates and advertises a special LSP called the **pseudonode LSP**.

- **Virtual Node:** The pseudonode represents the shared LAN segment as a virtual router in the SPF calculation. This simplifies the topology from a full mesh of connections between all routers on the LAN to a star topology with each router connecting to the pseudonode.

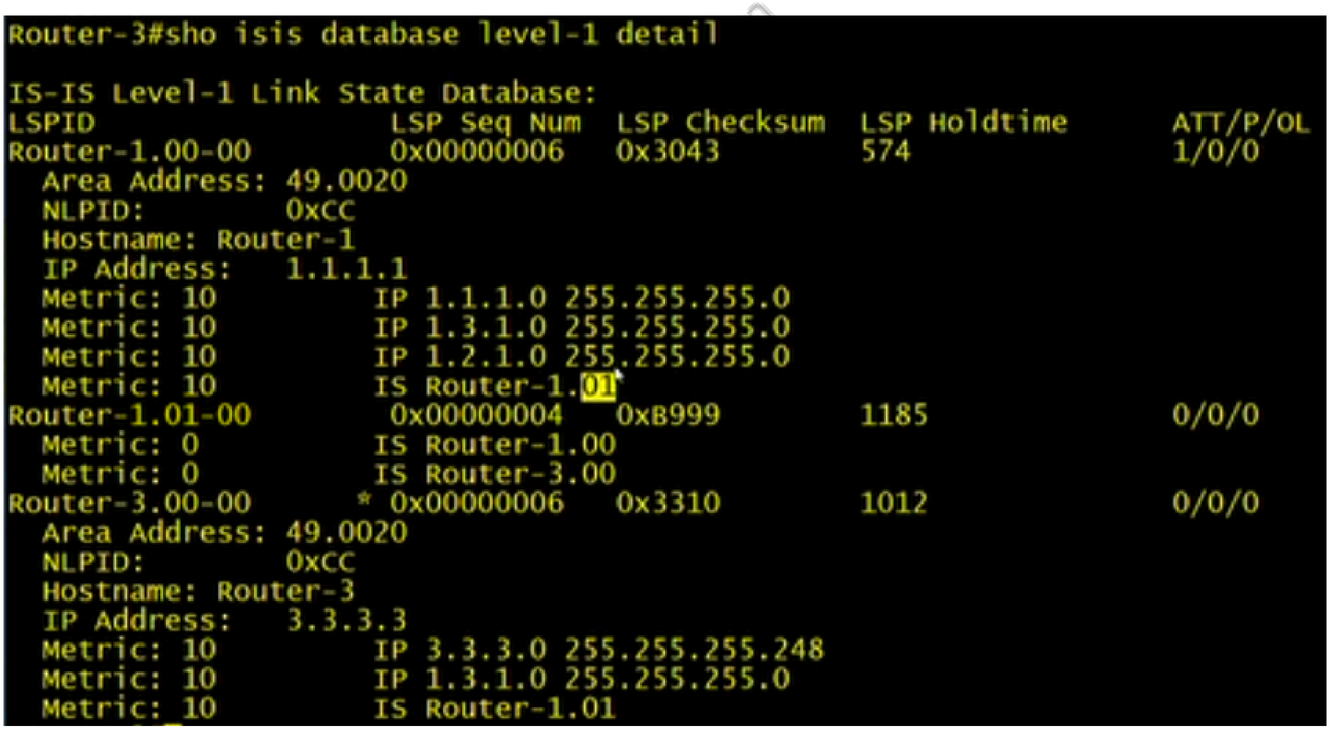
- **Pseudonode LSP Content:** This LSP does *not* advertise any IP prefixes. Instead, it lists all the IS-IS routers (neighbors) currently up on that broadcast segment and connected to the pseudonode.

- **Metrics:** The links from the real routers *to* the pseudonode typically have a metric of 0. The links *from* the pseudonode *back to* the real routers also have a metric, usually 0. This ensures the cost of transiting the LAN itself is correctly represented (often as negligible or based on the entry/exit point).

Identifying the DIS and Pseudonode LSP

- **Pseudonode LSP ID:** A regular router LSP has an LSP ID of the form `<SystemID>.00-00`. A pseudonode LSP, originated by the DIS, has an LSP ID of the form `<DIS_SystemID>.<NonZeroCircuitID>-00`. The non-zero Circuit ID (typically starting from `01`) distinguishes it as a pseudonode LSP.
  - Example: `RouterA.00-00` (Router A's own LSP)
  - `RouterA.01-00` (Pseudonode LSP for a segment where Router A is the DIS)

- **Verification Commands:**
  - `show isis database`: Examine the LSDB. Look for LSPs where the last two digits of the first part of the LSP ID (the Circuit ID) are non-zero. The System ID part of that LSP ID is the System ID of the DIS.



```
Router-3#sho isis database level-1 detail

IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
Router-1.00-00        0x00000006   0x3043        574               1/0/0
  Area Address: 49.0020
  NLPID:        0xCC
  Hostname: Router-1
  IP Address:   1.1.1.1
  Metric: 10         IP 1.1.1.0 255.255.255.0
  Metric: 10         IP 1.3.1.0 255.255.255.0
  Metric: 10         IP 1.2.1.0 255.255.255.0
  Metric: 10         IS Router-1.01
Router-1.01-00        0x00000004   0xB999        1185              0/0/0
  Metric: 0          IS Router-1.00
  Metric: 0          IS Router-3.00
Router-3.00-00      * 0x00000006   0x3310        1012              0/0/0
  Area Address: 49.0020
  NLPID:        0xCC
  Hostname: Router-3
  IP Address:   3.3.3.3
  Metric: 10         IP 3.3.3.0 255.255.255.248
  Metric: 10         IP 1.3.1.0 255.255.255.0
  Metric: 10         IS Router-1.01
```

  - `show clns interface <interface_name>` (IOS XE): Shows interface-specific IS-IS details, including the Circuit ID, current DIS for each level, and local interface priority.
  - `show isis neighbors detail` (or similar): Can sometimes give clues about the DIS based on the Circuit ID information associated with neighbors on broadcast links.

```
R1#show isis neighbors

System Id       Type Interface    IP Address       State Holdtime Circuit Id
R2              L1   Et0/1        192.168.12.2     UP    9        R2.01
R1#
```

Important Considerations for DIS and Pseudonodes

1. **Broadcast Only:** The DIS election and pseudonode concept apply **only to broadcast network types**. On point-to-point links (either native P2P encapsulations or Ethernet interfaces configured as `isis network point-to-point`), there is no DIS election, and no pseudonode LSP is generated. This is often a recommended optimization for P2P Ethernet links to reduce IS-IS overhead.

2. **Separate DIS per Level:** If an interface is participating in both L1 and L2 adjacencies (e.g., on an L1/L2 router), a **separate DIS election occurs for each level**. It's possible for the same router to be DIS for both L1 and L2 if it has the highest priority/MAC/SystemID for both, or different routers could be DIS for L1 and L2 on the same segment.

3. **Influencing DIS Election:** To control which router becomes the DIS, you can adjust the IS-IS priority on the interface. A higher priority is preferred. Setting a priority of 0 means the router will never become DIS for that level on that interface.

   - **IOS XE:**

     ```
     R1(config-if)# isis priority <0-127> [level-1 | level-2]
     ```

   - **IOS XR:**

     ```
     RP/0/0/CPU0:R1(config-isis-if)# priority <0-127> [level-1 | level-2]
     ```

   - *(Specify `level-1` or `level-2` if you want to set priority for a specific level; otherwise, it may apply to all levels the interface participates in, depending on the platform.)*

IS-IS LSPs

IS-IS Link State PDUs (LSPs)

Link State PDUs (LSPs) are the fundamental data packets IS-IS uses to distribute routing and topology information. Each router originates LSPs to describe its local state (interfaces, neighbors, reachable prefixes), and these LSPs are flooded throughout the appropriate IS-IS level.

How Many LSPs Does a Router Originate?

The number of LSPs a single router originates depends on two main factors:

1. **Router's Operational Level:**
    - An **L1-only** router originates one L1 LSP.
    - An **L2-only** router originates one L2 LSP.
    - An **L1/L2** router (the default) originates **two LSPs**: one L1 LSP for its area and one L2 LSP for the backbone.

2. **Role as DIS (Designated Intermediate System) on a Broadcast Link:**
    - If a router is elected DIS on a broadcast segment for Level 1, it originates an additional **L1 Pseudonode LSP** for that segment.
    - If a router is elected DIS on a broadcast segment for Level 2, it originates an additional **L2 Pseudonode LSP** for that segment.

Therefore, a single router can originate a **maximum of four LSPs**:

- Its own L1 Router LSP (if L1 or L1/L2 capable).
- Its own L2 Router LSP (if L2 or L1/L2 capable).
- An L1 Pseudonode LSP (if it's the L1 DIS on a broadcast segment).
- An L2 Pseudonode LSP (if it's the L2 DIS on a broadcast segment).

LSPs in a Router's Database

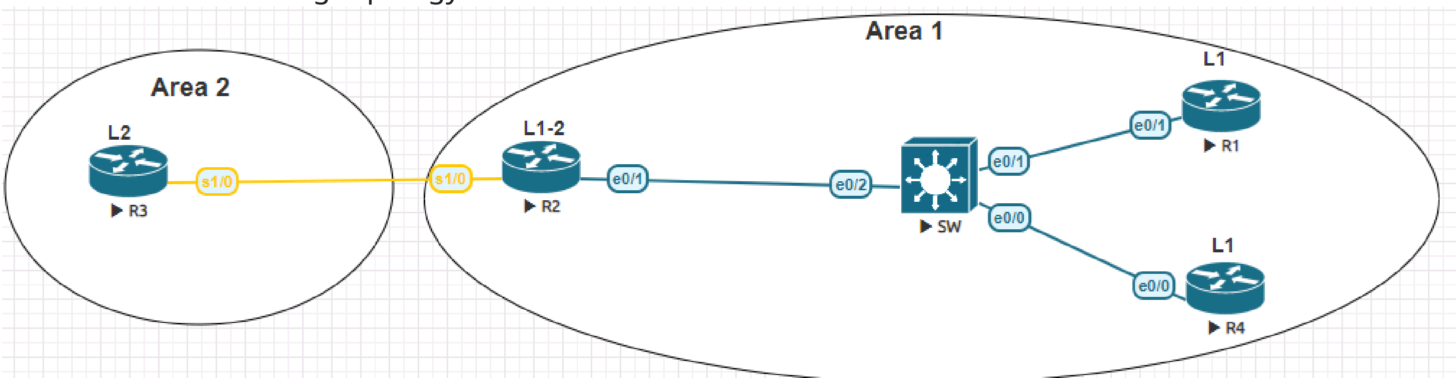
Each IS-IS router maintains an LSDB (Link State Database) for each level it participates in (L1, L2, or both).

- An L1/L2 router will have two separate LSDBs.

- Each LSDB will contain:
  - The LSP(s) originated by the router itself for that level.
  - LSPs received from other IS-IS routers operating at that level.
  - Pseudonode LSPs originated by the DIS on any broadcast segments within that level's topology.

Database Consistency: Routers within the same L1 area **must** have identical L1 LSDBs. Similarly, all routers participating in the L2 backbone must have identical L2 LSDBs. This ensures consistent SPF calculations.

let's check the following topology:



Now let's check R4 Link state database:

```
R4#show isis database level-1

IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
R1.00-00              0x00000257   0xEA3C        1145              0/0/0
R2.00-00              0x00000267   0x1D69        1116              1/0/0
R4.00-00            * 0x0000000D   0x190F        353               0/0/0
R4.01-00            * 0x0000000B   0x5407        391               0/0/0
R4#
```

an asterisk `*` next to an LSP ID typically indicates that the LSP was originated by the local router which is R4 in our example.

we can confirm that R4 has total of 4 LSPs as follow:

1. R4 is L1 router, so it generates L1 LSP only
2. R4 is the DIS on the shared segment, so it generates Pseudonode LSP
3. R1 is L1 router within the same area (1) with R4, so it generate L1 LSP as well
4. R2 is L1/L2 routers so it generates L1 LSP and share it with area 1, while L2 LSP only being flooded to R3 forming the backbone.

Structure of an LSP

L1 and L2 Router LSPs share a common basic structure, primarily consisting of a fixed PDU header followed by a series of variable Type-Length-Value (TLV) triplets.

1. PDU Common Header (IS-IS Header):

- **Intra-domain Routing Protocol Discriminator:** (1 byte, `0x83` for IS-IS)
- **PDU Length:** (2 bytes, total length of PDU including header)
- **Version/Protocol ID Extension:** (1 byte, usually `0x01`)
- **System ID Length:** (1 byte, `0x00` indicates default 6-byte System ID, or actual length)
- **PDU Type:** (1 byte, e.g., `0x12` for L1 LSP / `0x14` for L2 LSP - decimal 18/20)
- **Version:** (1 byte, usually `0x01`)
- **Reserved:** (1 byte, `0x00`)
- **Maximum Area Addresses:** (1 byte)

2. LSP Specific Fixed Header (after IS-IS Header):

- **PDU Length (again, but different context within LSP sequence):** This field is often part of the fixed header for LSPs.
- **Remaining Lifetime:** (2 bytes) How long the LSP is valid (default 1200 seconds / 20 minutes). The originator refreshes the LSP before this expires.
- **LSP ID:** (8 bytes) Composed of `<Originating_SystemID>.<PseudonodeID>-<LSP_Number>`.
  - For Router LSPs: `<SystemID>.00-00` (LSP number is 00).
  - For Pseudonode LSPs: `<DIS_SystemID>.<CircuitID>-00` (CircuitID is non-zero, LSP number is 00).

- **Sequence Number (SN):** (4 bytes) Starts with a value and increments with each new version of the LSP. Used to determine the newest version.
- **Checksum:** (2 bytes) checksum covering the LSP contents for integrity.
- **Flags:** (1 byte)
  - **P-bit (Partition Repair support):** Indicates if the router supports partition repair (rarely used).
  - **ATT-bit (Attached Bit):** Set by L1/L2 routers in their L1 LSP to indicate connectivity to the L2 backbone, acting as a gateway for L1 routers.
  - **OL-bit (Overload Bit):** Set by a router to indicate it's overloaded and should not be used for transit traffic (though it's still reachable).
  - **IS Type bits:** Indicate if the LSP originator is L1-only (01) or L2-capable (11 for L1/L2 or L2-only).

3. Variable TLVs (Type-Length-Value triplets):
This is where the actual routing information is carried. Common TLVs include:

- **Area Address(es) TLV (Type 1):** Lists the area address(es) of the originating router.
- **IS Reachability TLV (Type 2) / Extended IS Reachability TLV (Type 22):** Describes adjacencies to other ISs (routers or pseudonodes), including the metric.
  - On broadcast links, a router's LSP will list an adjacency to the pseudonode with the configured metric.
  - On point-to-point links, it lists the real IS neighbor.
- **Protocols Supported TLV (Type 129):** Indicates network layer protocols supported (e.g., IPv4 - `0xCC`, IPv6 - `0x8E`).
- **IP Internal Reachability TLV (Type 128) / Extended IP Reachability TLV (Type 135):** Advertises IP prefixes directly connected to the router or learned within the IS-IS domain, along with their metrics.

- **Hostname TLV (Type 137):** Carries the hostname of the LSP originator (optional but enabled by default on Cisco).

Finally this is a screenshot of how LSP looks like in IS-IS router LSDB:

```
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
R1.00-00              0x0000025C   0xE041        754               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  Hostname: R1
  Metric: 10         IS R4.01
  IP Address:   1.1.1.1
  Metric: 10         IP 1.1.1.0 255.255.255.0
  Metric: 10         IP 192.168.12.0 255.255.255.0
```

Structure of a Pseudonode LSP

A Pseudonode LSP is simpler and has a specific purpose:

- **Originated by the DIS** for a broadcast segment.
- **LSP ID:** `<DIS_SystemID>.<NonZeroCircuitID>-00`.
- **Content:** Primarily contains **IS Reachability TLVs** listing all IS-IS routers (neighbors) currently up and adjacent on that broadcast segment. The metric from the pseudonode to these neighbors is typically **0**.
- **No IP Prefixes:** Pseudonode LSPs do **not** advertise IP prefixes. Their role is to model the broadcast LAN in the SPF calculation.

  This is screenshot for Pseudonode LSP:

```
R4.01-00              0x00000011   0x480D        1060              0/0/0
  Metric: 0          IS R4.00
  Metric: 0          IS R1.00
  Metric: 0          IS R2.00
```

LSP Timers and Refresh Mechanism

- **Maximum LSP Lifetime (`max-lsp-lifetime`):**
  - The maximum duration an LSP can remain in an LSDB without being refreshed.

    - Default: **1200 seconds (20 minutes)** in IS-IS (compared to 3600 seconds / 60 minutes in OSPF).
    - If an LSP is not refreshed by its originator within this time, it's purged from the LSDB.

- **LSP Refresh Interval (`lsp-refresh-interval`):**
    - How often the originating router re-floods its self-originated LSPs, even if no changes have occurred. This ensures LSPs don't age out.
    - Default: **900 seconds (15 minutes)** in IS-IS (compared to 1800 seconds / 30 minutes in OSPF).
    - LSPs are typically refreshed well before their lifetime expires.

Configuration (IOS XE):

```
R1(config)# router isis MY_PROCESS
R1(config-router)# max-lsp-lifetime <1-65535>  // In seconds
R1(config-router)# lsp-refresh-interval <1-65535> // In seconds
```

Configuration (IOS XR):

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# max-lsp-lifetime <1-65535> // In seconds
RP/0/0/CPU0:R1(config-isis)# lsp-refresh-interval <1-65535> // In seconds
```

Useful `show` Commands for LSPs

- `show isis database`
- `show isis database level-1`
- `show isis database level-2`
- `show isis database detail`
- `show isis database <LSP_ID>` (e.g., `show isis database R1.00-00`)
- `show isis database <LSP_ID> verbose`

IS-IS LSP Details

Content of Level 1 vs. Level 2 LSPs

- **Level 1 LSP (L1 LSP):**
  - Describes the L1 adjacencies of the originating router within its area.
  - Advertises IP prefixes for interfaces on the local router that are participating in IS-IS Level 1 within that area.
  - Includes any external prefixes redistributed into IS-IS at Level 1 by that router.

- **Level 2 LSP (L2 LSP):**
  - Describes the L2 adjacencies of the originating router, forming the IS-IS backbone.
  - Advertises IP prefixes for interfaces on the local router that are participating in IS-IS Level 2.
  - If the originator is an L1/L2 router, its L2 LSP will also typically contain IP prefixes **learned from its Level 1 area's LSPs**. This allows the L2 backbone to know about prefixes within attached L1 areas.
  - Includes any external prefixes redistributed directly into IS-IS at Level 2 by that router.

Flooding Scope of LSPs

The level of an LSP dictates how far it travels in the network:

- **Level 1 LSPs:**
  - Flooded by L1 or L1/L2 routers.
  - Their flooding scope is **strictly limited to the IS-IS area** in which they originated. They do not cross into other areas. (This is similar to OSPF's intra-area LSAs like Type 1 Router LSAs and Type 2 Network LSAs).

- **Level 2 LSPs:**
  - Flooded by L2 or L1/L2 routers.
  - Their flooding scope is the **entire IS-IS Level 2 domain (the backbone)**, reaching all L2-capable routers, regardless of their configured area ID. (This wide flooding is somewhat similar to OSPF Type 3 Summary LSAs propagating throughout non-stub areas or Type 5 External LSAs across the OSPF domain, though the content and exact purpose differ).

Why to Change Router Level (Beyond Default L1/L2)?

While `level-1-2` is the default on many platforms, explicitly setting the router level based on its role in the network design is important for optimization:

- **Resource Consumption:** An L1/L2 router maintains two separate LSDBs (one for L1, one for L2), generates and processes LSPs for both levels, and runs SPF calculations for both. This consumes more memory, CPU, and potentially link bandwidth for LSP flooding and refreshes.

- **Design Intent:** In large networks, clearly defining L1-only areas and an L2 backbone enhances scalability and stability. Using L1-only routers in areas that don't need L2 participation (especially on lower-end hardware) reduces their resource burden.

When Does an LSP Sequence Number (SN) Change?

The 4-byte sequence number in an LSP header is critical for identifying the newest version of an LSP.

- **LSP Content Change:** The sequence number is **incremented by one** by the originating router ONLY when the **content of the LSP changes**. This includes adding/removing a prefix, an adjacency state changing, or a metric modification.

- **LSP Refresh:** When an LSP is periodically refreshed by its originator (default every 15 minutes in IS-IS), the sequence number **does NOT change**. The LSP is re-flooded with the same sequence number but with its "Remaining Lifetime" reset to the maximum (default 20 minutes).

CSNPs and PSNPs: IS-IS LSDB Synchronization

IS-IS uses Complete Sequence Number Packets (CSNPs) and Partial Sequence Number Packets (PSNPs) to ensure LSDB synchronization.

- **CSNP (Complete Sequence Number Packet):**
  - Lists the headers (LSP ID, sequence number, checksum, lifetime) of all LSPs in the sender's LSDB for a particular level.
  - On LAN segments, the DIS periodically multicasts CSNPs.
  - On point-to-point links, CSNPs are typically exchanged only during initial adjacency bring-up.
  - Routers use CSNPs to identify missing LSPs or LSPs for which they have an older version.

- **PSNP (Partial Sequence Number Packet):**

- Used to explicitly **request** one or more specific LSPs (by listing their LSP ID and sequence number) from a neighbor.
- Also used on point-to-point links to **acknowledge** the receipt of LSPs.

Together, CSNPs and PSNPs form the core mechanism for ensuring consistent LSDBs across the IS-IS domain.

Key Flags in LSPs

The LSP header contains a flags byte with several important bits:

```
ISO 10589 ISIS Link State Protocol Data Unit
  PDU length: 98
  Remaining lifetime: 439
  LSP-ID: 1111.1111.1111.00-00
  Sequence number: 0x00000016
  Checksum: 0xf5db [correct]
  Type block(0x03): Partition Repair:0, Attached bits:0, Overload bit:0, IS type:3
    0... .... = Partition Repair: Not supported
    .000 0... = Attachment: 0
      .... 0... = Error metric: Not set
      .... .0.. = Expense metric: Not set
      .... ..1. = Delay metric: Set
      .... ...1 = Default metric: Set
    .... .0.. = Overload bit: Not set
    .... ..11 = Type of Intermediate System: Level 2 (3)
  Area address(es) (4)
```


- **(P) Partition Repair Bit:**
  - Originally intended for a mechanism to heal area partitions.
  - This feature is **not supported by Cisco routers**, and the P-bit is always set to zero in LSPs generated by Cisco devices.

- **(A) Attached Bit (ATT-bit):**
  - A single bit set **only in Level 1 LSPs** by an L1/L2 router.
  - **Purpose:** It signals to other L1 routers within the same area that the L1/L2 router has connectivity to the Level 2 backbone
  - **Action:** Pure L1 routers, upon receiving an L1 LSP from an L1/L2 router with the ATT-bit set, will install a default route (`0.0.0.0/0`) pointing towards that L1/L2 router as their gateway to other areas.
  - If an L1/L2 router learns about L2 connectivity from another L1/L2 router (which itself has its ATT-bit set or has L2 reachability), it will also set the ATT-bit in its own L1 LSPs to propagate this gateway capability to L1 routers in its area. If multiple L1/L2 routers advertise the ATT-bit, an L1 router will choose the closest one based on metric.

- **(O) Overload Bit (OL-bit):**
    - A critical feature often used in ISPs Network, and this is one of the reasons why IS-IS is preferred over OSPF in Service Provider networks.
    - **Automatic Setting:** An IS-IS router can automatically set the OL-bit in its LSPs if it's experiencing a resource shortage (e.g., low memory).
    - **Effect:** When the OL-bit is set, other routers will still see this router in their SPF calculations and can route traffic *destined to the overloaded router's directly connected prefixes*. However, they will **avoid using the overloaded router for transit traffic** to other destinations. This prevents the router from blackholing or dropping traffic.
    - **Manual Setting:** The OL-bit can also be set manually for administrative purposes, such as during maintenance or to gracefully remove a router from a transit path.

    IOS XE/XR Command:

    ```
    // IOS XE
    R1(config-router)# set-overload-bit [on-startup <seconds> | wait-for-bgp]
    // IOS XR
    RP/0/0/CPU0:R1(config-isis)# set-overload-bit [on-startup <seconds> | wait-for-bgp]
    ```

        - `on-startup <seconds>`: Keeps the router in an overloaded state for a specified duration after a reboot, allowing other protocols (like BGP) to converge before it accepts transit traffic.
        - `wait-for-bgp`: The router sets the OL-bit until BGP signals that it has converged. There's typically a safety timeout (e.g., 10 minutes, though this can vary or be configurable) after which IS-IS might clear the bit even if BGP hasn't explicitly signaled.
        - The `suppress-interlevel` or `suppress-external` options (not detailed here) provide finer control over what prefixes are advertised when the OL-bit is set, relevant for LSP leaking scenarios.

Note: When the **Overload bit is set**, the **Attached bit is typically considered unset or ignored**. An overloaded router should not advertise itself as a default gateway for an L1 area.

IS-IS Routes Leaking

Route leaking in IS-IS is a mechanism where an L1/L2 router advertises routes learned via one IS-IS level into the other level. The most common scenario is leaking routes from the Level 2 backbone into a Level 1 area.

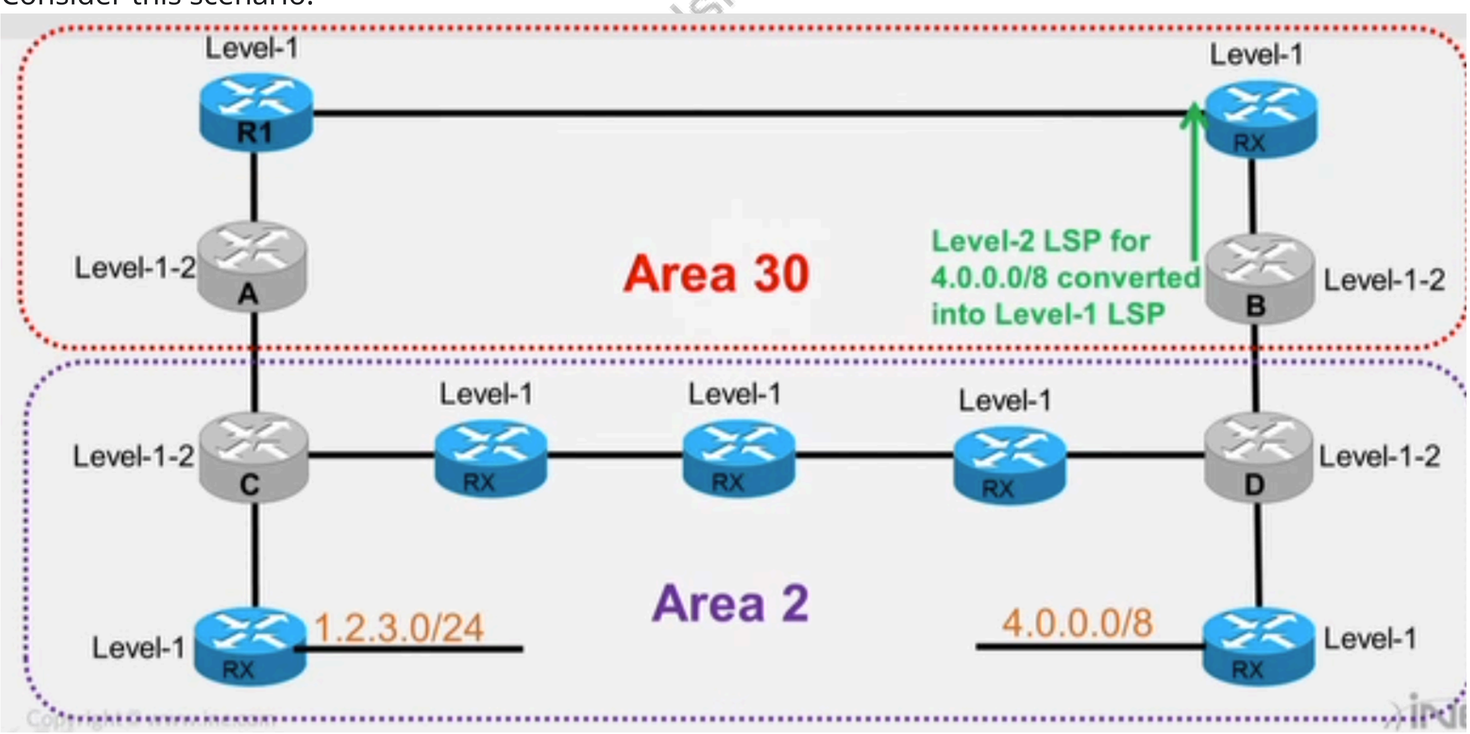
What is IS-IS Route Leaking?

Specifically, **Level 2 to Level 1 (L2->L1) route leaking** means an L1/L2 router takes specific prefixes it has learned via its Level 2 LSDB (typically from other areas or the backbone) and advertises them within its Level 1 LSP.

For routers within that L1 area, these leaked prefixes will appear as if they are originated by the leaking L1/L2 router and are reachable within the area, even though the actual destination lies in another area accessible via the L2 backbone. The leaking router essentially says, "You can reach these specific L2 prefixes through me, within this L1 area."

Why is Route Leaking Needed?

The primary reason for route leaking is to **avoid suboptimal routing paths**.
Consider this scenario:



- An L1-only router (R1) is in Area 30.
- Two L1/L2 routers, Router A and Router B, are also in Area 30 and connect to the L2 backbone.
- R1 has a default route (`0.0.0.0/0`) pointing to Router A because Router A is metrically closer.

- A specific prefix, say `4.0.0.0/8`, exists in Area 2 and is reachable via the L2 backbone. Router B has a much better (shorter) path through the L2 backbone to `4.0.0.0/8` than Router A does.

Without route leaking:

If R1 needs to send a packet to 4.0.0.0/8, it doesn't have a specific route for it in its L1 LSDB. R1 will use its default route via Router A. This traffic will take significantly longer path (e.g., 7 hops via A) to reach 4.0.0.0/8.

With route leaking:

If Router B is configured to "leak" the 4.0.0.0/8 prefix from its L2 knowledge into its L1 LSP for Area 30:

- R1 will now see a specific route for `4.0.0.0/8` via Router B within Area 30.
- Even if R1's default route still points to A, for this specific prefix, R1 can choose the more optimal path via Router B.

Route leaking provides more specific path information into an L1 area, allowing L1 routers to make better forwarding decisions for those particular prefixes instead of solely relying on a default route.

Configuring Route Leaking (L2--->L1)

You typically use a route-map (or ACL) to match the specific L2 prefixes you want to leak into L1.

IOS XE:

```
! First, define an ACL to match the prefix(es) to be leaked
! Source address = match network, Destination address = match mask
R1(config)# access-list 100 permit ip 4.0.0.0 0.255.255.255 any

! Optionally, use a route-map for more control (e.g., setting metric)
R1(config)# route-map LEAK_L2_TO_L1 permit 10
R1(config-route-map)# match ip address 100
R1(config-route-map)# set metric 50 // Optional: set a specific metric for the leaked route

R1(config)# router isis MY_PROCESS
R1(config-router)# redistribute isis level-2 into level-1 ip route-map LEAK_L2_TO_L1
! Or, using a distribute-list directly (less flexible):
! R1(config-router)# redistribute isis level-2 into level-1 ip distribute-list 100
```

IOS XR:

```
! Define a prefix-set and route-policy
RP/0/0/CPU0:CORE-P1(config)# prefix-set LEAK_PREFIXES
RP/0/0/CPU0:CORE-P1(config-pfx)# 4.0.0.0/8
RP/0/0/CPU0:CORE-P1(config-pfx)# end-set
```

```
RP/0/0/CPU0:CORE-P1(config)# route-policy LEAK_L2_TO_L1_RP
RP/0/0/CPU0:CORE-P1(config-rpl)# if destination in LEAK_PREFIXES then
RP/0/0/CPU0:CORE-P1(config-rpl-if)# set isis-metric 50 // Optional
RP/0/0/CPU0:CORE-P1(config-rpl-if)# pass
RP/0/0/CPU0:CORE-P1(config-rpl-if)# endif
RP/0/0/CPU0:CORE-P1(config-rpl)# end-policy

RP/0/0/CPU0:CORE-P1(config)# router isis MY_PROCESS
RP/0/0/CPU0:CORE-P1(config-isis)# address-family ipv4 unicast
RP/0/0/CPU0:CORE-P1(config-isis-af)# propagate level 2 into level 1 route-policy LEAK_L2_TO_L1_RP
```

Note on L1--->L2 Leaking: Routes from Level 1 are **leaked into Level 2 by default** by L1/L2 routers. You would typically only configure policy for L1--->L2 leaking if you need to *filter* or modify attributes of the routes being leaked upwards.

Metric of Leaked Routes (L2->L1)

When a route is leaked from L2 to L1:

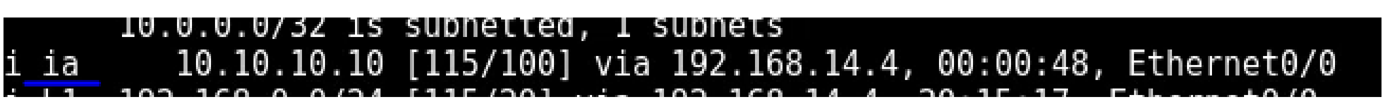
- **Default Behavior (No `set metric`):** The metric advertised for the leaked route into the L1 domain is typically the **path metric that the leaking L1/L2 router has in its L2 routing table** to reach that prefix.

- **Using `set metric` in Route-Map/Policy:** If you use a `set metric` command in your route-map (IOS XE) or route-policy (IOS XR), the specified metric will be used when the prefix is advertised into the L1 LSP.

This metric is what L1 routers within the area will use to calculate their path to the leaked prefix via the leaking L1/L2 router. The leaking router itself continues to use its original L2 path and metric to forward traffic to that destination.

Verifying Leaked Routes

- In the routing table of an L1 router, a leaked route will typically appear with a designation like `ia` (IS-IS Inter-Area), indicating it was learned from the L2 backbone via an L1/L2 router.


```
     10.0.0.0/32 is subnetted, 1 subnets
i ia     10.10.10.10 [115/100] via 192.168.14.4, 00:00:48, Ethernet0/0
```

- Examining the L1 LSP of the leaking router (`show isis database <LSP_ID_of_leaking_router_L1_LSP> detail`) will show the leaked prefix advertised, and the "up/down" bit in the prefix TLV will be set to indicate it's a prefix leaked "down" from L2.

Interaction with the Overload Bit (OL-bit)

The `set-overload-bit` command has `suppress` options that interact with route leaking:

- **IOS XE:**

```
R4(config-router)# set-overload-bit suppress interlevel
R4(config-router)# set-overload-bit suppress external
```

- **IOS XR:**

```
RP/0/0/CPU0:R4(config-isis)# set-overload-bit suppress inter-level-learn
RP/0/0/CPU0:R4(config-isis)# set-overload-bit suppress external-learn
```


- **`suppress interlevel` / `suppress inter-level-learn`:** If the router has its OL-bit set (e.g., due to low memory or `on-startup` condition), this option prevents it from leaking routes between IS-IS levels (L2--->L1 or L1--->L2). This is crucial because an overloaded router should not attract transit traffic by advertising paths it might not be able to handle.

- **`suppress external` / `suppress external-learn`:** If the OL-bit is set, this option prevents the router from advertising (redistributing) prefixes learned from *other routing protocols* (like BGP or EIGRP) into IS-IS.

You can use these options individually or together to control what routing information an overloaded IS-IS router advertises.

IS-IS on NBMA Networks

Simpler, but with Considerations

IS-IS generally simplifies network type considerations compared to OSPF.

- **OSPF Network Types:** OSPF has distinct behaviors for various network types like Broadcast, NBMA, Point-to-Point, Point-to-Multipoint (Broadcast and Non-Broadcast), affecting adjacency, DR/BDR election, and timers.

- **IS-IS Approach to NBMA:** IS-IS, by default, tends to treat NBMA environments (like Frame Relay multipoint interfaces) as **broadcast networks**. This means:
  - It expects to be able to form full adjacencies with all other routers on that logical segment.
  - It will attempt to elect a **DIS (Designated Intermediate System)** for each IS-IS level active on the segment.

The Challenge in Hub-and-Spoke NBMA

The default broadcast behavior for NBMA networks can lead to problems in a typical hub-and-spoke Frame Relay topology where spokes might not have direct PVCs (Permanent Virtual Circuits) to other spokes:

- **DIS Election:** If a spoke router (which cannot directly communicate with other spokes) is elected as the DIS, or if the hub is not the DIS, the logical broadcast domain assumed by IS-IS is broken.

- **Communication Issues:** Spoke routers might not receive CSNPs from a non-hub DIS, or LSPs flooded by one spoke might not reach another spoke if the DIS isn't the hub facilitating this communication. This can lead to inconsistent LSDBs and routing issues.

Solution:
The most straightforward solution in a hub-and-spoke NBMA environment is to ensure the hub router is always elected as the DIS. This is achieved by setting a higher IS-IS priority on the hub's multipoint interface for the relevant IS-IS level(s).

CLNS and DLCI Mapping in Frame Relay

A critical difference from OSPF in Frame Relay is how Layer 3 to Layer 2 addressing is handled for the routing protocol's own packets:

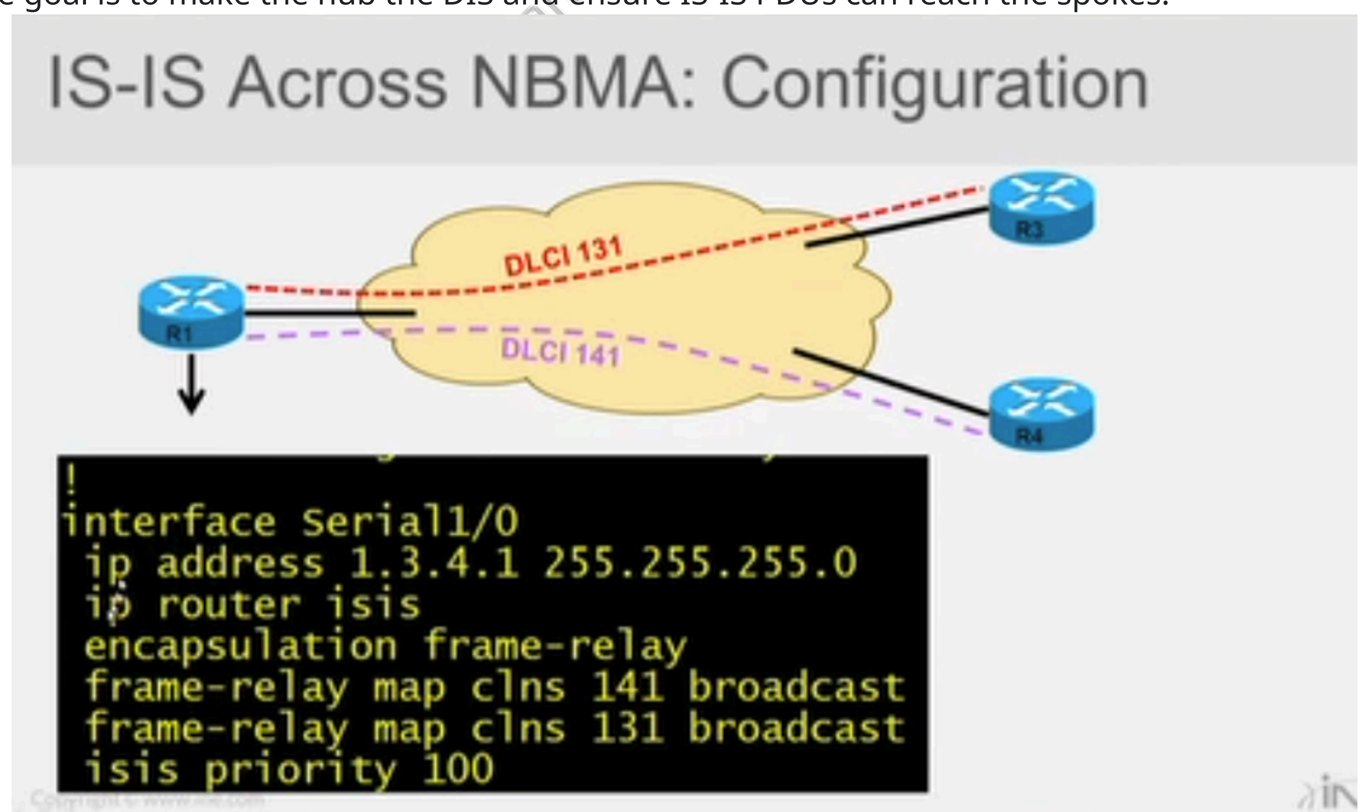
- **OSPF (IP-based):** OSPF uses IP. Inverse ARP (IARP) can often automatically discover the IP address of a remote router on a PVC and map it to the local DLCI. Manual `frame-relay map ip <ip_address> <dlci> [broadcast]` can also be used.

- **IS-IS (CLNS-based):** IS-IS PDUs are encapsulated directly over Layer 2 (e.g., LLC over Frame Relay), not within IP packets. Therefore, Inverse ARP (which works with IP) cannot be used for IS-IS's own CLNS-encapsulated PDUs.

    - You need to **manually configure mappings to enable CLNS traffic (and thus IS-IS PDUs) over specific DLCIs**, especially to simulate broadcast/multicast behavior needed for Hellos.

Recommended Configuration for an IS-IS Hub in Frame Relay

Here's how you might configure the hub router (e.g., R1) in a hub-and-spoke Frame Relay setup. The goal is to make the hub the DIS and ensure IS-IS PDUs can reach the spokes.



IOS XE Example for Hub Router (R1):

```
R1(config)# interface Serial0/0/0 // Or your Frame Relay interface/subinterface
R1(config-if)# encapsulation frame-relay
R1(config-if)# ip address <ip_address> <subnet_mask> // For IP data traffic

! Enable IS-IS on the interface
R1(config-if)# ip router isis MY_PROCESS

! Set IS-IS priority to ensure this hub becomes DIS (higher wins)
R1(config-if)# isis priority 127 level-1 // Set for L1, repeat for L2 if applicable
R1(config-if)# isis priority 127 level-2 // Example if hub is also L2

! Manually map CLNS to DLCIs for IS-IS PDUs to simulate broadcast to spokes
! This tells the router that CLNS "broadcasts" (like IS-IS multicasts)
! should be sent over these specific DLCIs.
R1(config-if)# frame-relay map clns 131 broadcast // DLCI to reach Spoke1
R1(config-if)# frame-relay map clns 141 broadcast // DLCI to reach Spoke2
! (You also need standard 'frame-relay map ip ...' for IP traffic)

R1(config)# router isis MY_PROCESS
R1(config-router)# net 49.0001.0000.0000.00R1.00 // Example NET
```

Explanation of Key Interface Commands:

- `encapsulation frame-relay`: Enables Frame Relay encapsulation.
- `ip router isis MY_PROCESS`: Enables the IS-IS process on the interface.
- `isis priority <value> [level-1 | level-2]`: Sets the DIS priority for the specified level. A higher value (0-127 range) makes the router more likely to become DIS. Setting it to the max (127) on the hub is a common practice.
- `frame-relay map clns <dlci> broadcast`: This command is crucial. It instructs the router that for the CLNS protocol (which IS-IS uses for its PDUs), any traffic that would normally be sent as a Layer 2 broadcast/multicast (like IS-IS Hello packets addressed to AllL1ISs or AllL2ISs) should be replicated and sent over the specified `<dlci>`. You need one such entry for each PVC leading to a spoke router with which you want to run IS-IS.

Note on Multipoint Sub interfaces:

IS-IS treats multipoint sub interfaces similarly to physical broadcast interfaces by default (i.e., it will attempt DIS election). If you have a multipoint sub interface and want to avoid DIS election (e.g., if you prefer to treat each PVC as a separate point-to-point link for IS-IS), you can change the IS-IS network type on the sub interface:

```
R1(config-subif)# isis network point-to-point
```

IS-IS Redistribution

Key Concepts and Rules

Redistributing routes from other routing protocols, static routes, or connected interfaces into IS-IS allows IS-IS to advertise these external prefixes throughout its domain.

Metric Handling: A Similarity with OSPF

- A key advantage of link-state IGPs (OSPF and IS-IS) is that you **do not need to supply a metric** when redistributing routes into them.
  - This contrasts with EIGRP, where you must define initial values for bandwidth, delay, reliability, load, and MTU for redistributed routes.
  - It also differs from RIP, where you must define an initial hop count.
- By default, when routes are redistributed into IS-IS on Cisco routers, they are typically assigned an initial **metric of 0**. These routes are then advertised as "external" IP prefixes within IS-IS LSPs.

IS-IS Redistribution Rules & Behavior

1. **Route Existence:** The route you intend to redistribute **must exist in the router's IP routing table** (RIB). IS-IS cannot redistribute a route it doesn't know about.

2. **L1-Only Routers:** If you are performing redistribution on an IS-IS router configured as `is-type level-1` (L1-only):
   - The redistributed routes will naturally be placed into the router's **Level 1 LSP**.
   - You still use the `level-1` keyword in the redistribution command f.

```
! On an L1-only router (IOS XE)
R1(config)# router isis MY_PROCESS
```

```
R1(config-router)# redistribute eigrp 100 level-1
```

- These routes are marked as "IP External" within the L1 LSP, typically with the default metric of 0 (unless modified).

3. **L2-Only Routers:** If the router is configured as **`is-type level-2-only`**:
   - Redistributed routes are, by default, injected into its **Level 2 LSP** and advertised throughout the L2 backbone.

4. **L1/L2 Routers (Default Behavior):** This is where careful attention is needed.
   - By default, if you redistribute routes on an L1/L2 router **without specifying a level** in the `redistribute` command, the routes are injected **only into its Level 2 LSP**. They are *not* automatically advertised into its L1 LSP for the local area.
   - To control where redistributed routes go on an L1/L2 router:
     - `redistribute <protocol> ... level-1`: Injects routes **only into the L1 LSP**.
     - `redistribute <protocol> ... level-2`: Injects routes **only into the L2 LSP** (this is the default if no level is specified).
     - `redistribute <protocol> ... level-1-2`: Injects routes into **both the L1 LSP AND the L2 LSP**.

5. **Metric Propagation:** The initial redistributed metric (default 0) is set by the redistributing router. As other routers calculate paths to these external prefixes, they will add their local IS-IS interface costs to reach the redistributing router. The original redistributed metric itself doesn't change hop by hop, but the total path cost to the external prefix will vary throughout the network.

Configuration Examples

IOS XE:

```
R1(config)# router isis MY_PROCESS
! Redistribute EIGRP routes into L2 only (default for L1/L2 router)
R1(config-router)# redistribute eigrp 100 metric 20 // Optional: sets default external metric

! Redistribute connected interfaces into L1 only
R1(config-router)# redistribute connected level-1 route-map CONN_TO_L1

! Redistribute static routes into both L1 and L2
R1(config-router)# redistribute static level-1-2
```

IOS XR:

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast

! Redistribute EIGRP 100 routes into L2 only (default for L1/L2 router)
RP/0/0/CPU0:R1(config-isis-af)# redistribute eigrp 100 metric 20 // Optional

! Redistribute connected interfaces into L1 only, using a route-policy
RP/0/0/CPU0:R1(config-isis-af)# redistribute connected level-1 route-policy CONN_TO_L1_RP

! Redistribute static routes into both L1 and L2
RP/0/0/CPU0:R1(config-isis-af)# redistribute static level-1-2
```

IS-IS Extra Config

IS-IS Default Route Injection

It's a common misconception that link-state IGPs like OSPF and IS-IS cannot redistribute a default route. They actually can. However, both protocols also provide a more specific and often preferred command, default-information originate, to explicitly advertise a default route into their domain.

Using `default-information originate` in IS-IS:

- **Unconditional by Default (IOS XE):** Unlike OSPF which often requires the `always` keyword to advertise a default route unconditionally, the `default-information originate` command in Cisco IOS XE IS-IS typically advertises the default route even if the route doesn't exist in the router's RIB.

- **Level of Injection:**
    - By default, on an L1/L2 router, a default route originated with `default-information originate` is injected **only into the Level 2 LSP**.
    - To inject the default route into Level 1 LSPs (or both L1 and L2) from an L1/L2 router, you generally need to influence its advertisement using route maps:

    ```
    R1(Config)# route-map <X> permit <Y>
    R1(Config-route-map)# Set level level-1
    R1(Config-router)# default-information originate route-map <X>
    ```

    - **IOS XR:**

    ```
    RP/0/0/CPU0:R1(config-isis-af)# default-information originate [route-policy <POLICY_NAME>]
    ```

- **Default Route via Attached Bit (ATT-bit):**
    - This is a separate mechanism. L1-only routers will automatically install a default route pointing to an adjacent L1/L2 router if that L1/L2 router sets the ATT-bit in its L1 LSP. The L1/L2 router sets the ATT-bit if it has connectivity to the L2 backbone (i.e., can reach other areas). This is a primary way L1 areas get default reachability.

IS-IS Passive Interface

The `passive-interface` command in IS-IS functions similarly to its counterparts in OSPF and EIGRP: it suppresses the sending and processing of IS-IS Hello packets on that interface, meaning no IS-IS adjacencies will be formed. This is useful for security (not forming adjacencies on LANs facing end-users) and optimization.

Key IS-IS Passive Interface Behavior (Cisco IOS XE):

1. **Interface Remains in IS-IS:** Using the `passive-interface <interface_name>` command under the `router isis` process **removes the IS-IS configuration** (like `ip router isis`) from the interface.

2. **Prefix Advertisement:** The network prefix configured on the passive interface **is still advertised** into IS-IS (into the appropriate L1 or L2 LSP) but metric automatically become zero.

Configuration:

- **IOS XE:**

```
R1(config)# router isis MY_PROCESS
R1(config-router)# passive-interface GigabitEthernet0/1
```

- **IOS XR:**

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# interface GigabitEthernet0/0/0/1
RP/0/0/CPU0:R1(config-isis-if)# passive
```

IS-IS Maximum Paths Feature

This feature controls Equal Cost Multi-Path (ECMP) load balancing, similar to other IGPs.

- It defines the maximum number of equal-metric paths IS-IS will install into the RIB for a given destination.
- The actual number of paths used also depends on the router's hardware/software capabilities and overall RIB limits.
- Setting `maximum-paths 1` disables ECMP load balancing for IS-IS routes.

Configuration:

- **IOS XE:**

```
R1(config)# router isis MY_PROCESS
R1(config-router)# maximum-paths <1-32_or_64_depending_on_platform>
```

- **IOS XR:**

```
RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/0/CPU0:R1(config-isis-af)# maximum-paths <1-64>
```

IS-IS Administrative Distance (AD)

The default Administrative Distance for IS-IS routes is **115**. You can modify this:

1. **Globally for all IS-IS Routes:**

   - **IOS XE:**

     ```
     R1(config)# router isis MY_PROCESS
     R1(config-router)# distance <1-255> ip
     ```

   - **IOS XR:**

     ```
     RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
     RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast
     RP/0/0/CPU0:R1(config-isis-af)# distance <1-255>
     ```

2. **No Simple AD Distinction Between L1 and L2 Routes:**

   Unlike OSPF where you can set different ADs for intra-area, inter-area, and external routes directly, IS-IS does not typically offer a simple built-in command to set different ADs based on whether a route is L1 or L2. All IS-IS derived routes (L1, L2, leaked) get the same AD assigned to the IS-IS process unless more specific overrides are used.

3. **Per-Prefix/Per-Source AD Modification:**

   You can change the AD for specific routes or routes from specific LSP originators, typically using an ACL to match prefixes and specifying the originating IS-IS router.

   - **IOS XE:**

     ```
     R1(config)# access-list 10 permit 192.168.1.0 0.0.0.255
     R1(config)# router isis MY_PROCESS
     R1(config-router)# distance <AD_value> <source_router> <wildcard> <standard_ACL_number_for_prefixes>
     ```

   - **IOS XR:**

     ```
     RP/0/0/CPU0:R1(config)# router isis MY_PROCESS
     RP/0/0/CPU0:R1(config-isis)# address-family ipv4 unicast
     ```

```
RP/0/0/CPU0:R1(config-isis-af)# distance <AD_value> <prefix/length> [<source_SystemID_as_dotted_hex>]
```

IS-IS Routes Summarization

Route Summarization in IS-IS

Route summarization in IS-IS, like in other link-state protocols (e.g., OSPF), is constrained by the need to maintain LSDB consistency within an area (or level). You can't summarize routes arbitrarily anywhere in the network. Summarization typically occurs at specific boundaries.

Where and How Can You Summarize in IS-IS?

There are two primary points where summarization is performed:

1. **On an ASBR (Autonomous System Boundary Router) - Router Performing Redistribution:**
    - When routes are redistributed from another routing protocol (e.g., BGP, EIGRP, OSPF) or from connected/static routes *into* IS-IS.
    - These redistributed routes are injected into IS-IS as either Level 1, Level 2, or both, based on the redistribution configuration and router level.
    - At this point of redistribution, you can configure IS-IS to advertise a summary address for these external prefixes into the specified IS-IS level(s).

2. **On a Level 1-Level 2 (L1/L2) Router - Inter-Level Summarization:**
    - An L1/L2 router acts as a border between an L1 and the L2 backbone.
    - **L1 to L2 Summarization:** This is the most common inter-level summarization. The L1/L2 router can summarize routes learned from its L1 area (via L1 LSPs in its L1 LSDB) when it advertises them into the L2 backbone (i.e., when it includes them in its L2 LSP).
    - **L2 to L1 Summarization (via Route Leaking):** If an L1/L2 router is configured to leak specific routes from the L2 backbone down into its L1 area, it can also summarize these leaked prefixes as they are advertised into the L1 LSP.

Configuration Examples

Summarizing Redistributed Routes (e.g., Connected interfaces into Level 1)

IOS XE:

```
R1(config)# router isis MY_PROCESS
R1(config-router)# redistribute connected level-1 // Redistribute connected into L1
R1(config-router)# summary-address 10.10.0.0 255.255.252.0 level-1 // Summarize these as they enter L1
```

IOS XR:

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# redistribute connected level-1
RP/0/RP0/CPU0:R1(config-isis-af)# summary-prefix 10.10.0.0/22 level-1
```

Summarizing L1 Routes into L2 (on an L1/L2 Router)

IOS XE:

```
R1(config)# router isis MY_PROCESS
R1(config-router)# is-type level-1-2 // Ensure router is L1/L2
R1(config-router)# summary-address 192.168.0.0 255.255.240.0 level-2
! This command tells the L1/L2 router to summarize its L1 area prefixes
! 192.168.0.0/20 when advertising them into the L2 backbone.
```


IOS XR:

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# is-type level-1-2
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# summary-prefix 192.168.0.0/20 level-2
! Summarizes L1 prefixes into L2.
```

Discard Route for Summaries

By default, IS-IS creates a discard route (a route pointing to the Null0 interface) on the summarizing router for the summary address it originates. This is a loop prevention mechanism. If the specific routes that make up the summary become unavailable, the discard route ensures that any traffic matching the summary (but not a more specific route) is dropped on the summarizing router rather than potentially being looped back.

No Summarization Within a Level/Area?

Link-state routing protocols like IS-IS and OSPF rely on all routers within a given area (or IS-IS level) having an **identical LSDB**. This identical view is necessary for consistent SPF (Shortest Path First) calculations and loop-free paths.

- Summarization inherently hides detailed topology information. If summarization were allowed *within* an area/level (e.g., an L1-only router summarizing its own prefixes within its L1 LSP before flooding it in the area), it would create inconsistencies in the LSDBs of other routers in that same area/level.
- Therefore, summarization is restricted to boundaries:
  - Where external routes enter IS-IS (redistribution).
  - Where routes cross between IS-IS levels (L1/L2 router).

Key Points:

- An **L1-only router cannot summarize** prefixes within its L1 LSP that is flooded *within its own L1 area*.

- An **L1/L2 router can summarize prefixes from its L1 area when it advertises them into its L2 LSP** (for the L2 backbone). It can also summarize L2 prefixes it leaks down into its L1 LSP.

- Once an LSP (L1 or L2) is created and flooded with detailed prefixes, **intermediate routers cannot summarize that LSP further** as it transits through them. Only the originator, at an appropriate boundary, can create a summary advertisement.

IS-IS Routes Filtering

Route filtering in IS-IS, like in other link-state protocols, adheres to the principle that all routers within a given level (L1 area or L2 backbone) must have an identical Link State Database (LSDB). This means **once an LSP is created and flooded, it cannot be filtered by intermediate routers within that same level**.
However, you can control which routes are:

1. Installed into the local router's Routing Information Base (RIB) from the LSDB.
2. Advertised between IS-IS levels (L1 to L2, or L2 to L1) on an L1/L2 router.
3. Redistributed into IS-IS from other routing protocols or sources.

---

1. Filtering Routes from LSDB into the RIB

This method prevents specified routes learned via IS-IS LSPs from being installed into the local router's IP routing table. It **does not stop the LSPs themselves from being flooded** or stored in the local LSDB. Other routers will still see these LSPs and potentially install the routes.

IOS XE:

```
R1(config)# router isis MY_PROCESS
R1(config-router)# distribute-list <ACL_NUMBER_OR_NAME | prefix-list PREFIX_LIST_NAME | route-map ROUTE_MAP_NAME> in [interface_type interfa
```

- You can use standard or extended ACLs, prefix-lists, or route-maps to define which prefixes to filter.
- When using an extended ACL for prefix matching: the `source` field of the ACL matches the network address, and the `destination` field matches the subnet mask.
- The `in` keyword is used because you are filtering routes coming *from* the IS-IS LSDB *into* the RIB.
- Specifying an interface is optional and would filter routes learned via that interface.
- **Note:** using this method to filter routes might result in traffic blackholing.

IOS XR:

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# distribute-list prefix-set MY_PREFIX_SET in
! Or using an ACL
RP/0/RP0/CPU0:R1(config-isis-af)# distribute-list <ACL_NAME> in
```

An alternative approach to prevent routes from being installed in the RIB is to set their administrative distance to 255 (untrusted):

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# distance 255 prefix-set MY_PREFIX_SET_TO_IGNORE
! Or using an ACL:
! RP/0/RP0/CPU0:R1(config-isis-af)# distance 255 access-list <ACL_NAME_MATCHING_PREFIXES>
```

This makes the specified IS-IS learned routes effectively unusable by the local router.

---

2. Filtering Routes Between Levels

This is done on an **L1/L2 router** and controls which routes are "leaked" or advertised from one level into another.

Filtering L1 routes from being advertised into L2:

By default, an L1/L2 router advertises all its learned L1 routes into its L2 LSP. You can filter this:

IOS XE:

```
R1(config)# router isis MY_PROCESS
R1(config-router)# redistribute isis level-1 into level-2 ip route-map FILTER_L1_TO_L2
! The route-map FILTER_L1_TO_L2 would permit only the desired L1 prefixes.
```

- The route-map can use extended ACLs or prefix-lists for matching.
- When using an extended ACL in the route-map: `source` matches the network, `destination` matches the mask.

IOS XR:

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# propagate level 1 into level 2 route-policy FILTER_L1_TO_L2_RP
```

---

3. Filtering Routes During Redistribution

This method controls which routes are injected into IS-IS from another routing protocol or source (e.g., connected, static). The filtering happens at the point of redistribution on the ASBR.

IOS XE:

```
R1(config)# router isis MY_PROCESS
R1(config-router)# redistribute connected level-1 route-map FILTER_CONNECTED
! The route-map FILTER_CONNECTED permits only specific connected routes.
R1(config-router)# redistribute ospf 100 level-2 route-map FILTER_OSPF
! The route-map FILTER_OSPF permits only specific OSPF routes.
```

IOS XR:

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv4 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# redistribute connected level-1 route-policy FILTER_CONNECTED_RP
RP/0/RP0/CPU0:R1(config-isis-af)# redistribute ospf 100 level-2 route-policy FILTER_OSPF_RP
```

IS-IS Timers

Timers, and Router Reloads

Understanding how IS-IS handles its Link State PDUs (LSPs) during normal operation and after events like a router reload is key, as are its various timers.

LSPs and Sequence Numbers

LSPs are fundamental to IS-IS. They carry the topology information, and each LSP is identified by an LSP ID and a **Sequence Number**.

- **Latest Information:** The sequence number ensures that routers always use the most current version of an LSP in their SPF calculations. A higher sequence number indicates a newer LSP.

- **Duplicate Prevention:** It prevents duplicate or outdated LSPs from being incorrectly processed or maintained in the LSDB.

LSP Behavior After a Router Reloads:

- When an IS-IS router reloads and its IS-IS process restarts, it will typically **originate its own new LSPs starting with a low sequence number** (e.g., 1), assuming it has no persistent state of its previous sequence numbers.

- Its neighbors might still hold copies of the LSPs this router originated *before* the reload, which could have higher sequence numbers.

- **Standard LSP Flooding Rules Apply:**
  - When the rebooted router sends out its new LSP (e.g., with SN=1), neighbors will compare it to any existing LSP they have from that same LSP ID.

  - If neighbors have an older version (e.g., SN=X, where X was the last sequence number before the reload), they will initially consider the newly received LSP (SN=1) to be older and might not immediately accept it if X > 1.

- However, the LSPs originated by the router *before its reload* are no longer being refreshed by that router. These old LSPs held by neighbors will eventually **age out** (their lifetime will reach zero).

- The rebooted router will quickly update and re-originate its LSPs as it forms new adjacencies and learns topology information, incrementing its sequence numbers. Eventually, its newly generated LSPs will have higher sequence numbers than any stale LSPs, or the stale LSPs will have aged out, leading to LSDB convergence.

- A router **does not "record" its old sequence number from neighbors** to then increment from there. It starts its origination process, and the standard LSP propagation and aging mechanisms handle the re convergence.

LSP Lifetime and Aging:

- Each LSP has a **remaining lifetime** (default is 1200 seconds / 20 minutes).

- This lifetime counts down. If it reaches zero before the LSP is refreshed by its originator, the LSP is considered outdated and is purged from the LSDB. This is the "count-to-zero" operation.

Key IS-IS Timers

- **IS-IS Hello Interval (IIH Interval):**
  - The frequency at which IS-IS routers send Hello packets.
  - Default on point-to-point links and for non-DIS routers on broadcast links: **10 seconds**.

  - **DIS Hello Interval:** On broadcast segments, the elected DIS typically sends Hellos more frequently. The default is often one-third of the regular Hello interval (e.g., approximately **3.3 seconds** if the standard interval is 10 seconds). This allows for faster detection of DIS failures.

- **IS-IS Hold Time (Dead Interval):**
  - The amount of time a router will wait to hear a Hello from a neighbor before declaring the adjacency down.

    - It's typically a multiple of the Hello interval (usually 3 times). So, if the Hello interval is 10 seconds, the default Hold Time is **30 seconds**. This timer does *not* need to match between neighbors.

- **CSNP Interval (Complete Sequence Number PDU):**
    - On broadcast networks, the DIS sends CSNPs periodically to help synchronize LSDBs.
    - Default interval: **10 seconds**.

- **LSP Refresh Interval:**
    - The interval at which an IS-IS router re-floods its self-originated LSPs, even if no changes have occurred. This prevents LSPs from aging out prematurely.
    - Default: **900 seconds (15 minutes)**.

- **Maximum LSP Lifetime (LSP Aging Timer):**
    - The maximum time an LSP can remain in an LSDB without being refreshed.
    - Default: **1200 seconds (20 minutes)**.

IS-IS Scalability

IS-IS Design Principles and Scalability

A well-organized addressing plan is the cornerstone of a scalable network because it enables effective **route summarization**. Hierarchical IP addressing allows large blocks of addresses to be represented by a single summary route.

When designing your IS-IS network, consider these points:

- **IP Addressing Plan:** A hierarchical IP addressing scheme is crucial for meaningful summarization.

- **NET Addressing Plan:** While IP addresses are for data traffic, Network Entity Titles (NETs) are for the IS-IS routing infrastructure itself. A logical NET addressing plan (Area IDs, System IDs) simplifies management.

- **Two-Level Hierarchy (L1/L2):** This is fundamental to IS-IS scalability.
    - It **limits the flooding scope of L1 LSPs** to within their own area, reducing the LSDB size on L1 routers.
    - It provides natural **opportunities for summarization** at the boundary between Level 1 areas and the Level 2 backbone.

- **L1/L2 Routers as Summarization Points:** Routers that connect an L1 area to the L2 backbone (L1/L2 routers) are the logical places to implement route summarization. They can summarize routes from their L1 area before advertising them into the L2 backbone, and similarly, can summarize L2 routes if leaking them into an L1 area.

- **Benefits of Summarization:** Saves router memory (smaller LSDBs and RIBs) and reduces CPU utilization (SPF calculations are faster on smaller LSDBs).

Why IS-IS is Often Considered More Scalable than OSPF

1. LSP Structure and Update Efficiency:

- **OSPF:** Tends to use many different types of LSAs (Link State Advertisements) for various pieces of information (router links, network segments, summaries, external routes). A change might trigger updates to multiple LSAs.

- **IS-IS:** A router typically groups its link-state information into a single L1 LSP and/or a single L2 LSP (plus pseudonode LSPs if it's a DIS). These LSPs contain multiple Type-Length-Value (TLV) structures, each describing a specific attribute (e.g., an adjacency, an IP prefix).

    - This can result in fewer distinct link-state packets to manage and flood for a given amount of topological information, potentially reducing the overhead on network resources as complexity increases. While the raw number of LSPs can be lower, the critical aspect is often the efficiency of updating information.

2. Extensibility via TLVs:

- **OSPF:** Extending OSPF to support new features or address families (like IPv6) often required defining new LSA types (e.g., OSPFv3 for IPv6, Opaque LSAs for MPLS-TE). This can introduce compatibility challenges.

- **IS-IS:** Its TLV-based architecture is much more flexible. Adding support for new functionalities (e.g., IPv6, MPLS-TE, new metrics) typically involves defining new TLVs. Existing routers that don't understand these new TLVs simply ignore them, making IS-IS easier to extend without breaking backward compatibility.

3. SPF Recalculation vs. PRC:

- **SPF Trigger:** In both IS-IS and OSPF, if there's a change in the router-to-router topology (a link goes down, an adjacency changes), a full Shortest Path First (SPF) calculation is typically run.

- **Partial Route Calculation (PRC) in IS-IS:** A significant advantage of IS-IS is its handling of IP prefix information.
    - The main SPF calculation in IS-IS determines reachability between Intermediate Systems (routers) based on IS-IS adjacency information (carried in IS Neighbor TLVs).
    - IP prefixes are advertised in separate IP Reachability TLVs.
    - If an IP prefix becomes unavailable (e.g., an interface with that IP goes down) but this event *does not change the underlying router-to-router connectivity*, IS-IS can often avoid

a full SPF recalculation. Instead, it can perform a Partial Route Calculation (PRC), which only updates the IP routing table entries related to the changed prefixes, leaving the main SPF tree intact. This is much less CPU-intensive than a full SPF run.

- In OSPF, information about IP subnets is more tightly coupled with the LSA types that define the topology, making it more likely that changes to IP prefix availability trigger a full SPF.

IS-IS Troubleshooting

Troubleshooting IS-IS Adjacency Issues

IS-IS adjacency problems typically stem from one of two sources:

1. **Configuration Errors:** These can sometimes be subtle and require careful verification of IS-IS parameters on both ends of the link.

2. **Link or Physical Layer Issues:** Failures at the physical or data-link layer will naturally prevent any IGP adjacency. These can often be identified using commands like `show interface`.

Common Causes of IS-IS Adjacency Failures

- **MTU Mismatch:**
    - While IS-IS Hello packets are small and usually not directly impacted by MTU for initial exchange, IS-IS LSPs can be large (up to the interface MTU).
    - If routers on a segment have mismatched MTUs, the adjacency might appear to form (Hellos are exchanged) but will then fail or flap during the LSDB synchronization phase when larger LSPs cannot be successfully exchanged.
    - **Best Practice:** Ensure consistent MTU settings on all interfaces participating in IS-IS on the same segment.

- **Circuit-Type / Level Mismatch:**
    - The `isis circuit-type` (IOS XE) or `circuit-type` (IOS XR under interface IS-IS config) command defines which type of Hellos (Level 1, Level 2, or both) are sent and processed on an interface.
    - An L1 adjacency requires both sides to be willing to form an L1 adjacency (i.e., one is L1-only and the other is L1-only or L1/L2; or both are L1/L2 configured for L1 on that link).
    - An L2 adjacency requires both sides to be willing to form an L2 adjacency.
    - **Example:** If Router A is configured for `circuit-type level-1` on an interface, and Router B (on the same link) is configured for `circuit-type level-2-only`, they will not form an adjacency.

- **Area ID Mismatch (for Level 1 Adjacencies):**
  - To form a **Level 1 adjacency**, routers **must** be in the same IS-IS area. The Area ID is part of the Network Entity Title (NET). If the Area ID portions of their NETs do not match, an L1 adjacency will not form.
  - This does not apply to L2 adjacencies, which can form between routers in different areas.

- **Authentication Mismatch:**
  - If IS-IS authentication is configured (for Hellos, LSPs, and/or SNPs), the authentication type (e.g., clear text, MD5) and the password/key **must match exactly** on both ends of the link. Any mismatch will prevent adjacency.

- **Network Type Mismatch:**
  - IS-IS interfaces can be configured as `broadcast` (default on Ethernet) or `point-to-point`.
  - If one router on a segment is configured for `broadcast` and the other for `point-to-point`, their Hello mechanisms (multicast vs. unicast expectations, PDU formats) will differ, and an adjacency will not form. The network type must be consistent.

- **Duplicate System ID:**
  - The System ID portion of the NET must be unique within an IS-IS routing domain, especially within the same area/level on a shared segment. If two routers on the same segment attempt to use the same System ID, it will prevent stable adjacency formation with each other and potentially with other routers.

- **Capability TLV Issues (Less Common):**
  - IS-IS uses TLVs (Type-Length-Value) to advertise capabilities (e.g., support for certain address families, new features).
  - While IS-IS is designed to be extensible (routers ignore TLVs they don't understand), a mismatch in *fundamental* operational capabilities advertised via TLVs could, in rare or specific scenarios (like incompatible mandatory features), lead to issues. However, minor capability differences usually don't prevent basic adjacency if levels and authentication match. It's more likely to affect the exchange or processing of certain types of information *after* adjacency.

Verification Commands

- `show isis neighbors`
    - The primary command to check the status of IS-IS adjacencies. It shows the neighbor's System ID (or hostname if dynamic hostname is enabled), local interface, state (Up, Init, Down), circuit type, and uptime.

- `show isis interface` / `show clns interface <interface>` **/** `show isis interface <interface>` =
    - Displays detailed IS-IS information for an interface, including its configured level(s), circuit ID (useful for identifying the DIS on broadcast segments), DIS priority, Hello timers, and whether it's up for IS-IS processing.

- `show isis topology`
    - Displays the IS-IS Shortest Path First (SPF) tree, showing reachable IS-IS routers (Intermediate Systems) and the cost to reach them. An empty or incomplete topology can indicate adjacency or LSP propagation problems.

- `show isis database`
    - Shows the contents of the IS-IS Link State Database (LSDB). Useful for checking if LSPs from neighbors are being received.

IS-IS with IPv6

Single vs. Multi-Topology

The Cisco IOS Software IS-IS implementation is versatile, supporting IPv6 routing for networks running only IPv6, as well as dual-stack (IPv4 and IPv6) environments. This can be achieved using either single-topology or multi-topology IS-IS.

What Does Multi-Topology IS-IS Mean?

- **Separate SPF Trees:** Multi-topology IS-IS (MT-ISIS) calculates **separate Shortest Path First (SPF) trees** for each configured address family (e.g., one for IPv4, one for IPv6). This means IPv6 traffic could take a completely different path through the network than IPv4 traffic, based on link capabilities and configured metrics for each topology.

- **Transition Flexibility:** It's particularly useful when transitioning to IPv6 or when some links in the network may not support IPv6. MT-ISIS specifically tracks which links can carry IPv6 traffic, building an IPv6-specific topology. This minimizes the risk of "black-holing" IPv6 traffic by trying to send it over IPv4-only paths.

- **IOS XR Default:** Multi-topology operation is the **default behavior** for IS-IS when IPv6 is enabled on **IOS XR**.

What Does Single-Topology IS-IS Mean?

- **Shared SPF Tree:** Single-topology IS-IS uses **one common SPF tree** for path calculation for all configured address families (e.g., both IPv4 and IPv6). Consequently, IPv4 and IPv6 traffic will follow the same paths through the network.

- **Homogeneous Network Required:** This mode assumes that the network is largely homogeneous, meaning the same links are capable of carrying both IPv4 and IPv6 traffic simultaneously and have consistent metric policies for both.

- **Simpler Administration:** It can be easier to administer if the network topology and link capabilities are identical for both protocols.

- **IOS XE Default:** Single-topology operation is the **default behavior** for IS-IS when IPv6 is enabled on **IOS XE**.

Adjacency Consistency Check

When migrating to a dual-stack environment or running IS-IS for multiple address families, IS-IS performs consistency checks on Hello packets.

- By default, an IS-IS router will **reject Hello packets from a neighbor if the set of configured address families does not match**. For example, a router running IS-IS for both IPv4 and IPv6 will not form an adjacency with a router configured to run IS-IS for only IPv4 or only IPv6.

- To facilitate smoother upgrades or allow adjacencies in mixed environments (though not generally recommended long-term without understanding the implications), these consistency checks can be disabled for IPv6.

Disabling Adjacency Check:

- **Cisco IOS XE:**

```
R1(config)# router isis MY_PROCESS
R1(config-router)# no adjacency-check
```

- **Cisco IOS XR:**

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv6 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# adjacency-check disable
```

HINT

This command typically suppresses the checks related to additional address families like IPv6. Fundamental IS-IS IPv4 processing will still expect IPv4 support from its neighbor. An IS-IS instance configured only for IPv4 will not form an adjacency with an IS-IS instance configured only for IPv6, regardless of this setting.

Mode Consistency and Transition

- **Crucial Consistency:** All routers within an IS-IS area or domain **must use the same mode of IPv6 support** either all single-topology or all multi-topology. Mixing modes will lead to inconsistent views of the IPv6 topology and likely cause routing holes.

- **Transition Mode:** To help migrate from a single-topology IPv6 deployment to the more flexible multi-topology approach.

Configuring IS-IS for IPv6

After deciding on single-topology or multi-topology operation, here's a basic outline for configuration:

IOS XE
(Default is single-topology for IPv6. metric-style wide is highly recommended.)

```
R1(config)# router isis MY_PROCESS
R1(config-router)# net 49.0001.AAAA.AAAA.AAAA.00
R1(config-router)# metric-style wide // Recommended for modern deployments
R1(config-router)# address-family ipv6 unicast
R1(config-router-af)# multi-topology // To enable multi-topology mode
R1(config-router-af)# exit-address-family

R1(config)# interface GigabitEthernet0/0/0
R1(config-if)# ipv6 address 2001:DB8:1:1::1/64
R1(config-if)# ipv6 enable // Enables IPv6, generates link-local
R1(config-if)# ipv6 router isis MY_PROCESS // Enable IS-IS for IPv6 on the interface
```

IOS XR:
(Default is multi-topology for IPv6. metric-style wide is highly recommended.)

```
RP/0/RP0/CPU0:R1(config)# router isis MY_PROCESS
RP/0/RP0/CPU0:R1(config-isis)# net 49.0001.BBBB.BBBB.BBBB.00
RP/0/RP0/CPU0:R1(config-isis)# address-family ipv6 unicast
RP/0/RP0/CPU0:R1(config-isis-af)# metric-style wide // Recommended
RP/0/RP0/CPU0:R1(config-isis-af)# single-topology // To change to single-topology mode
RP/0/RP0/CPU0:R1(config-isis-af)# exit

RP/0/RP0/CPU0:R1(config-isis)# interface GigabitEthernet0/0/0/0
RP/0/RP0/CPU0:R1(config-isis-if)# address-family ipv6 unicast
```

```
! IS-IS for IPv6 is enabled by configuring it under the AF on the interface
RP/0/RP0/CPU0:R1(config-isis-if-af)# exit
RP/0/RP0/CPU0:R1(config-isis-if)# exit

! Interface IP configuration is separate
RP/0/RP0/CPU0:R1(config)# interface GigabitEthernet0/0/0/0
RP/0/RP0/CPU0:R1(config-if)# ipv6 address 2001:DB8:1:1::1/64
```

New TLVs for IPv6 Support

IS-IS was extended to support IPv6 through the addition of new TLVs (as defined in RFC 5308):

1. **IPv6 Reachability TLV (Type 236 / 0xEC):**
    - Used to advertise IPv6 prefixes, their metrics, and associated options
    - This is equivalent to the IPv4 IP Internal/External Reachability TLVs (Type 128/130) and particularly the Extended IP Reachability TLV (Type 135).

2. **IPv6 Interface Address TLV (Type 232 / 0xE8):**
    - Used to advertise the IPv6 addresses assigned to an interface.
    - In Hello PDUs, it typically carries the link-local IPv6 address of the interface.
    - In LSPs, it can carry global unicast and other non-link-local IPv6 addresses of the router's interfaces.
    - This is equivalent to the IPv4 Interface Address TLV (Type 132).

These TLVs allow IS-IS to build a comprehensive view of the IPv6 topology and reachability.