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#CiscoLive

The bridge to possible

IS-IS Deployment in Modern Networks

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BRKENT-2007

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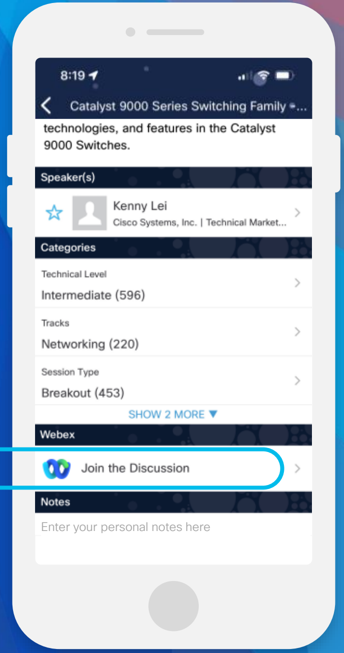

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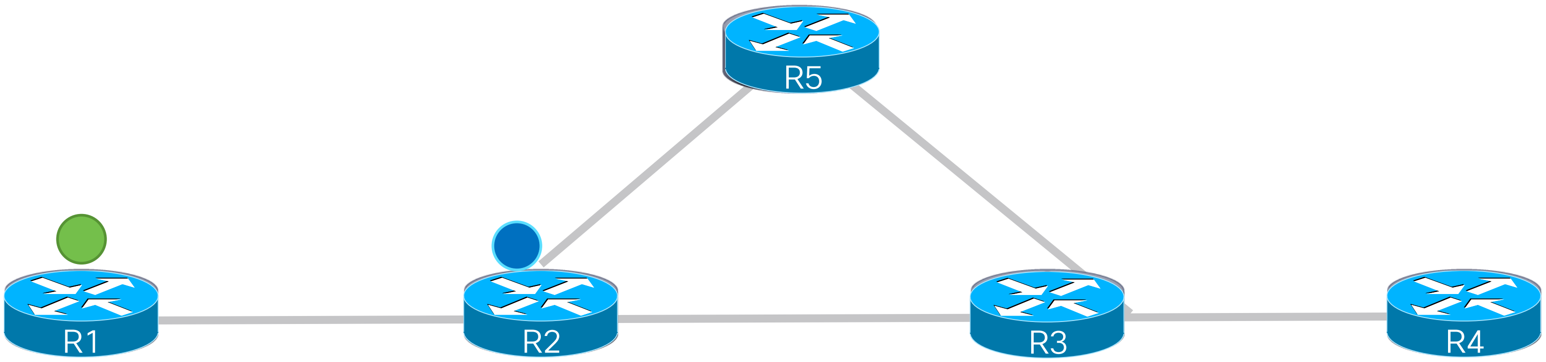
Agenda

- IS-IS Foundation
- IS-IS Configuration
- IS-IS Topology Constructs
- How a Router Builds an IS-IS Topology
- Route Advertisements and Metrics
- IPv6 Support
- Area Design

IS-IS Trivia Question

- How do you make the traffic between R1 and R4, take R5?
- How do you make the traffic between R2 and R3, take the direct link?



IS-IS Foundation

What is IS-IS?

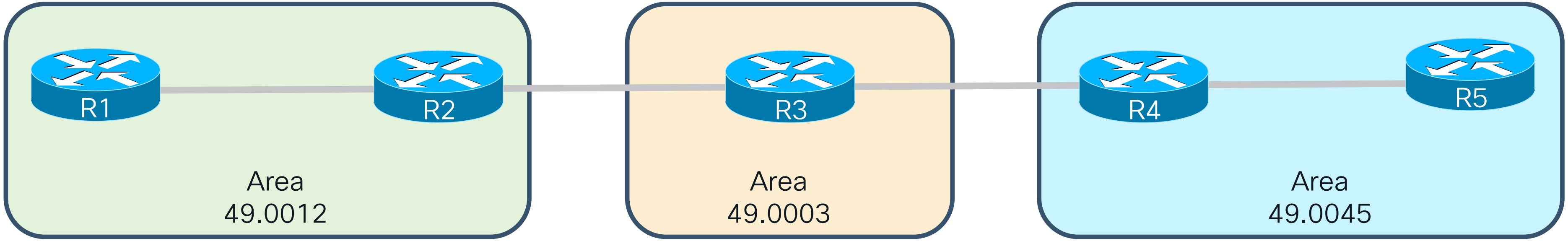
Intermediate System-to-Intermediate System (IS-IS) Overview

- IS-IS is a link-state routing protocol;
  - Offer Fast convergence
  - Excellent scalability
  - Flexibility in terms of tuning
- Adopted and published by International Organization for Standardization (ISO)... The guys who gave us the OSI model
- Easily extensible with Type/Length/Value (TLV) extensions;
  - IPv6 Address Family support (RFC 2308)
  - Multi-Topology support (RFC 5120)
  - MPLS Traffic Engineering (RFC 3316)

Hierarchy Levels

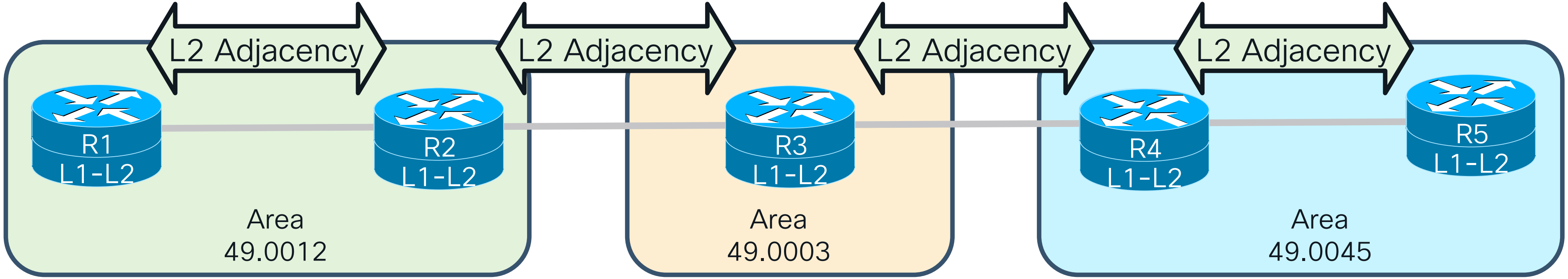
- IS-IS presently has a two-layer hierarchy
  - The backbone (level 2)
  - Non-backbone areas (level 1)

Routers, not interfaces are associated to an area



Hierarchy Levels

- IS-IS presently has a two-layer hierarchy
  - The backbone (level 2)
    - Formed between areas
    - Formed within an area



Hierarchy Levels

- IS-IS presently has a two-layer hierarchy
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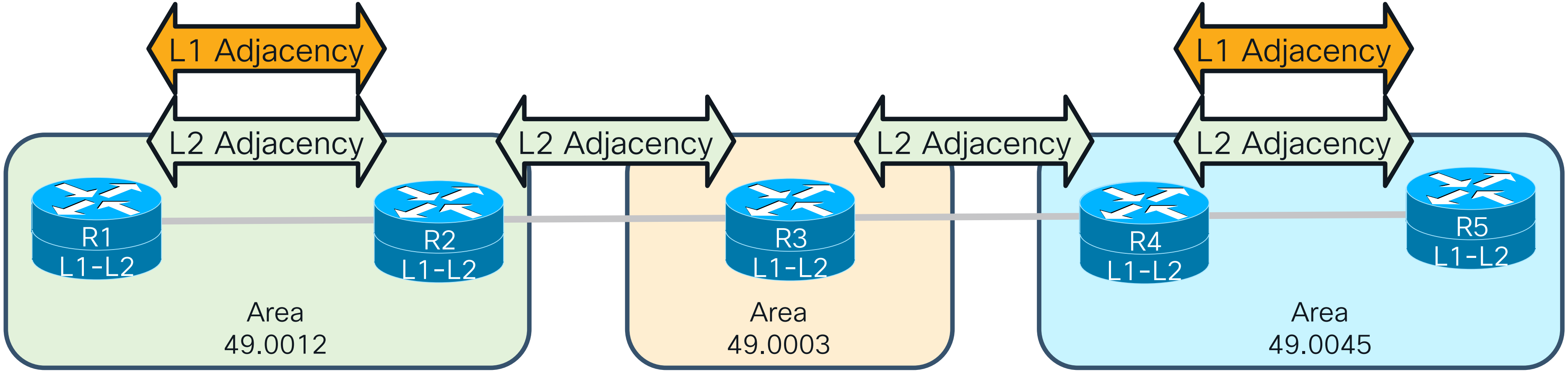
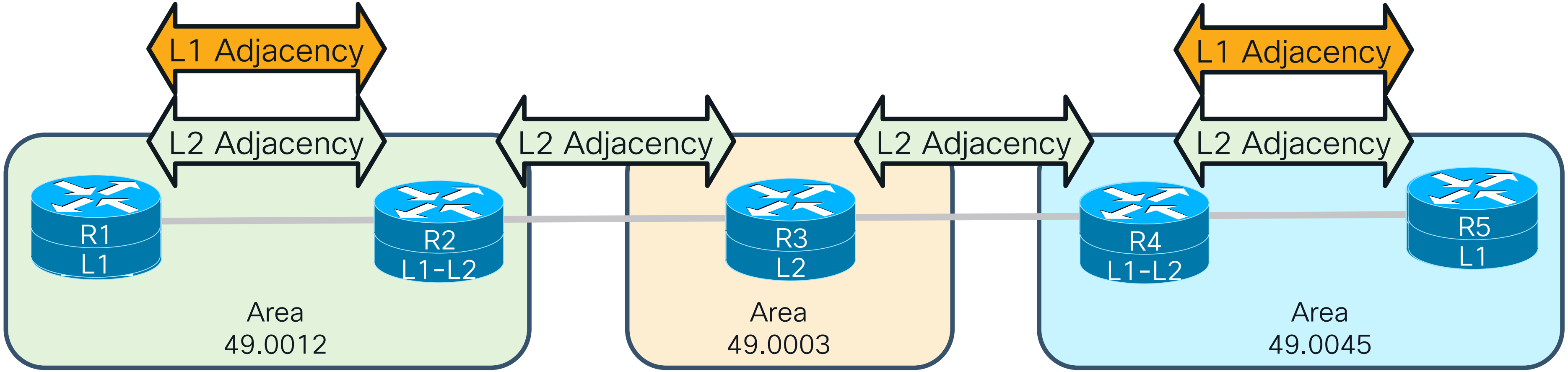


Hierarchy Levels (Routers)

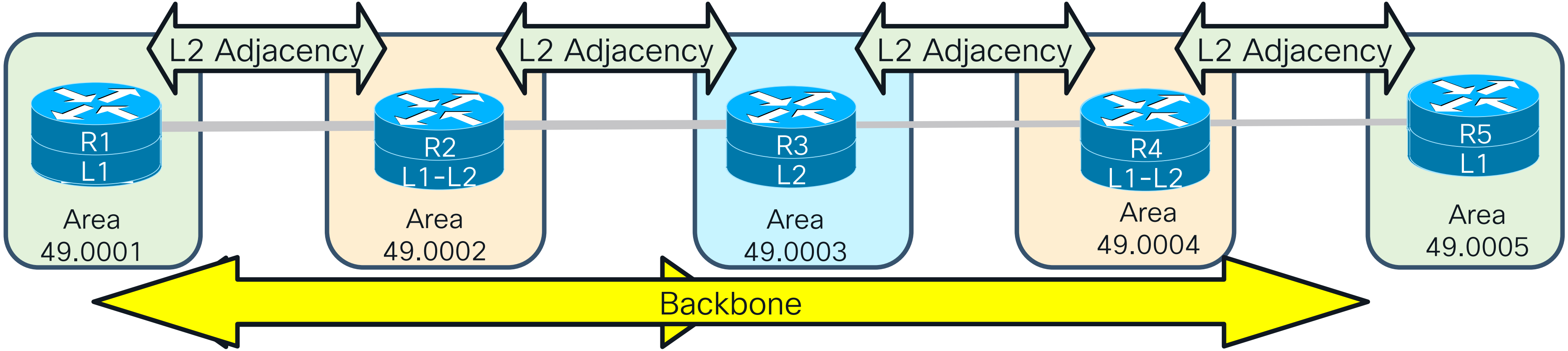
A router can be a:

- L1 only router (i.e. R1 & R5)
- L2 only router (i.e. R3)
- L1-L2 routers (i.e. R2 & R4)



The Backbone

- Connects Areas
- Responsible for taking routes from L1 routes and advertising to other domains
- Can cross multiple areas



IS-IS Communication

Based on OSI Layer 2 addresses (MAC addresses for Ethernet).

Name	Destination MAC Address
All L1 IS Devices	0180.c200.0014
All L2 IS Devices	0180.c200.0015
All IS Devices	0900.2b00.0005

- Does not work on IP based tunnels
- Does work on GRE tunnels
- Does not work on DMVPN tunnels

IS-IS Packet Types

IS-IS has three types of PDUs (packets)

- **IS-IS Hello (IIH) Packets** – Used to establish/monitor neighbors
- **Link State Packets (LSPs)** – used to build a topology and share routes
- **Sequence Number Packets (SNPs)** – used to synchronize LSPs

Type, Length, Value (TLV) Tuples

- This is the true magic of IS-IS. Provides the ability to support multiple protocols in the same architecture.
- TLVs provide variable modules, and support nesting.
- A TLV is assigned a numerical value which directly correlates to a function.
- When a router receives an IS PDU and detects an unrecognizable TLV, it just skips the TLV and continues to the next TLV in that packet.
- TLVs are not modified in transit.

IS-IS Packet Structure

IIS-IS Hello (IIH), LSPs, SNPs all contain these fields in every packet:

- Protocol Descriptor – 0x83 for IS-IS
- PDU Length
- PDU Type – Defines if it is an IIH, LSP, or SNP
- Reserved – Identifies the level of a packet (L1 or L2)
- Max Areas – Maximum number of areas a router will support

```
ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
    Intra Domain Routing Protocol Discriminator: ISIS (0x83)
    PDU Header Length: 27
    Version (==1): 1
    System ID Length: 0
    PDU Type           : L1 HELLO (R:000)
    Version2 (==1): 1
    Reserved (==0): 0
    Max.AREAs: (0==3): 0
```

IS-IS LSP Structure

```
⊟ ISO 10589 ISIS Link State Protocol Data Unit
    PDU length: 111
    Remaining lifetime: 1200
    LSP-ID: 0000.0000.0001.00-00
    Sequence number: 0x00000003
  ⊞ Checksum: 0xcbf3 [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.. = Overload bit: Not set
      .... ..11 = Type of Intermediate System: Level 2 (3)
  ⊟ Area address(es) (4)
      Area address (3): 47.0012
  ⊟ Protocols supported (1)
      NLPID(s): IP (0xcc)
  ⊟ Hostname (3)
      Hostname: XR1
  ⊞ IP Interface address(es) (4)
  ⊟ IS Reachability (12)
      IsNotVirtual
    ⊞ IS Neighbor:  0000.0000.0002.03
  ⊟ IP Internal reachability (48)
    ⊞ IPv4 prefix: 10.1.1.0/24
    ⊞ IPv4 prefix: 10.11.11.0/24
    ⊞ IPv4 prefix: 10.12.1.0/24
    ⊞ IPv4 prefix: 192.168.1.1/32
```

Remaining Lifetime

Sequence Number

Attribute Fields

TLV#128 – IP Internal Reachability

Common LSP TLVs

TLV #	Function
1	List of area addresses on router
2	List of IS Neighbors (Narrow Metrics)
10	Authentication
22	Extended IS Neighbors (Wide Metrics)
128	IP network and metric from advertising router (Narrow Metrics)
130	External networks and metrics when redistributed
132	IP Addresses on transmitting interface (includes secondary interfaces) (Narrow Metrics)
135	IP Addresses on transmitting interface (includes secondary interfaces) (Wide Metrics)
137	Router hostname (Allows correlation of name to System ID
232	IPv6 Interface Address
236	IPv6 Reachability Information
237	Multi Topology Reachable IPv6 Prefix

IS-IS Interfaces

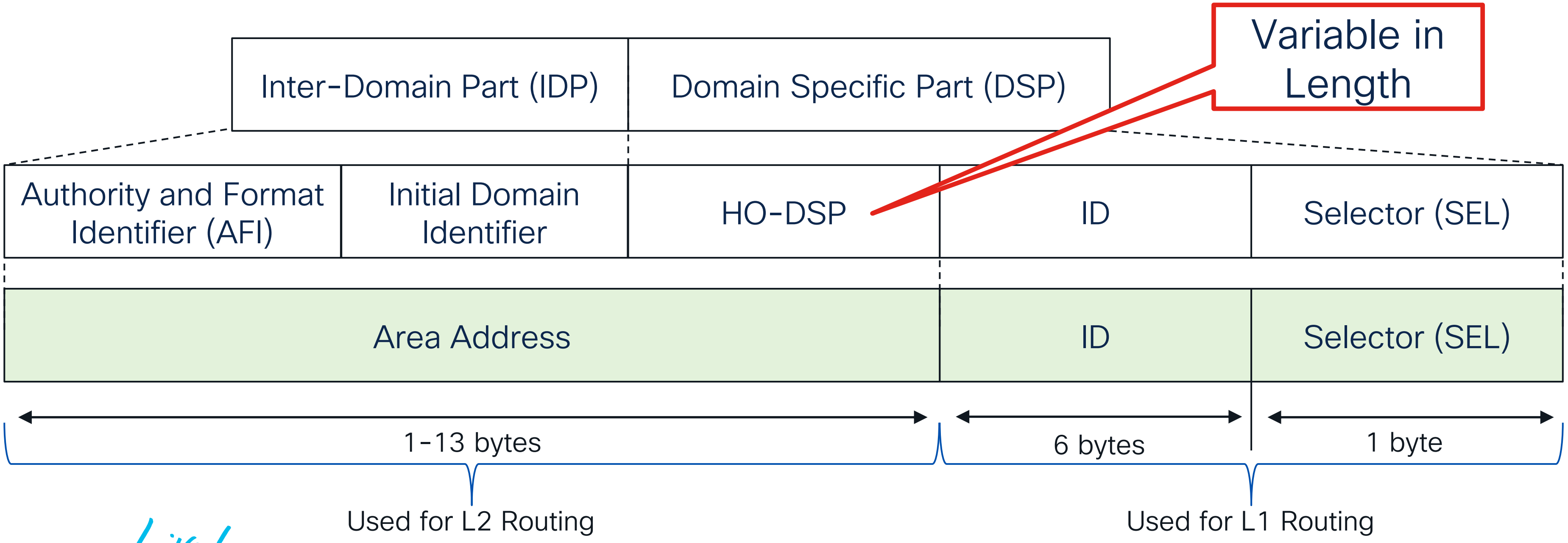
There are two types of interface in IS-IS:

- **Broadcast** – This is the default. Allows for more than one neighbor to connect on this medium. Requires the election of a pseudonode called a Designated Intermediate System (DIS)
- **Point-to-Point** – Used to reduce some of the overhead mechanisms with broadcasts networks if only 2 devices exist on a segment.

IS-IS Addressing

Anatomy of a NET Address

- Each IS-IS router is identified with a Network Entity Title (NET)



IS-IS Addressing

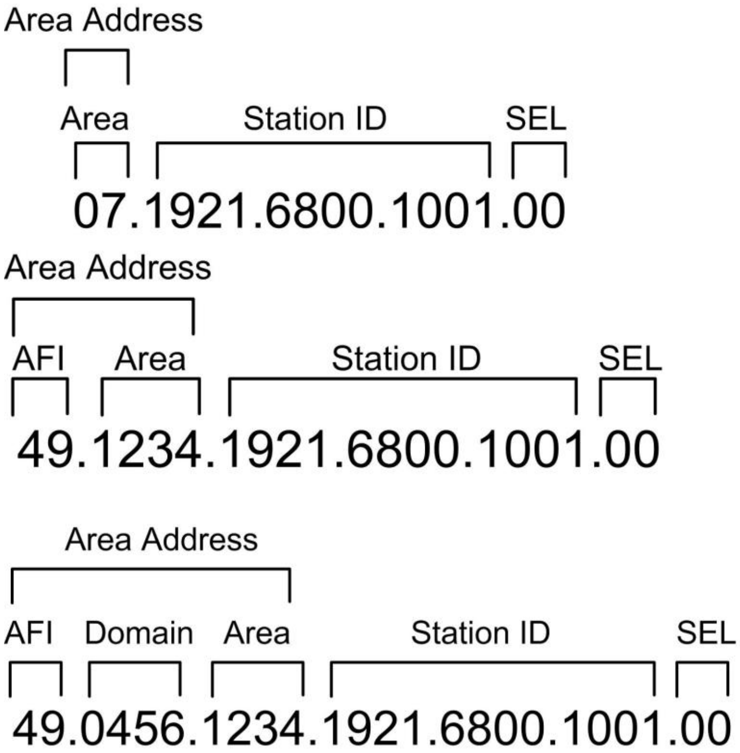
Reading the NET Address

- Start from Right work your way back:
  - Final 8 bits – zero
  - Next 48 bits – router identifiter
  - Next 16 bits – area
  - First 8 bits – pick a number (49 is the private AFI family)

Authority and Format Identifier (AFI)	Initial Domain Identifier	HO-DSP	ID	Selector (SEL)
Area Address			ID	Selector (SEL)

IS-IS Addressing

Sample NET Addresses



8-byte Area ID/System ID

10-byte Private AFI/
Area ID/System ID

OSI NSAP Format

IS-IS Addressing

Sample NET Addresses

Notice the SEL is always 00

Area Address

Area | Station ID | SEL

07.1921.6800.1001.00

8-byte Area/System ID

Area Address

AFI | Area | Station ID | SEL

49.1234.1921.6800.1001.00

10-byte Private AFI/ Area ID/System ID

Area Address

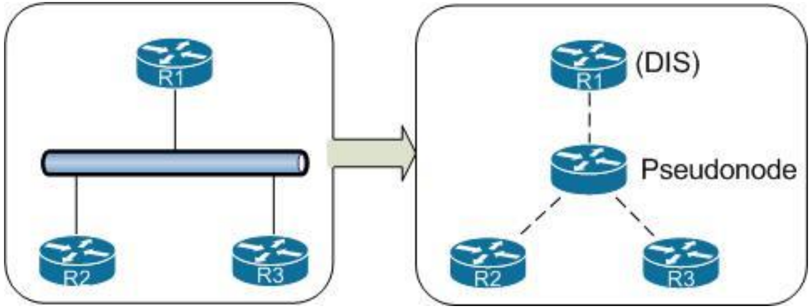
AFI | Domain | Area | Station ID | SEL

49.0456.1234.1921.6800.1001.00

OSI NSAP Format

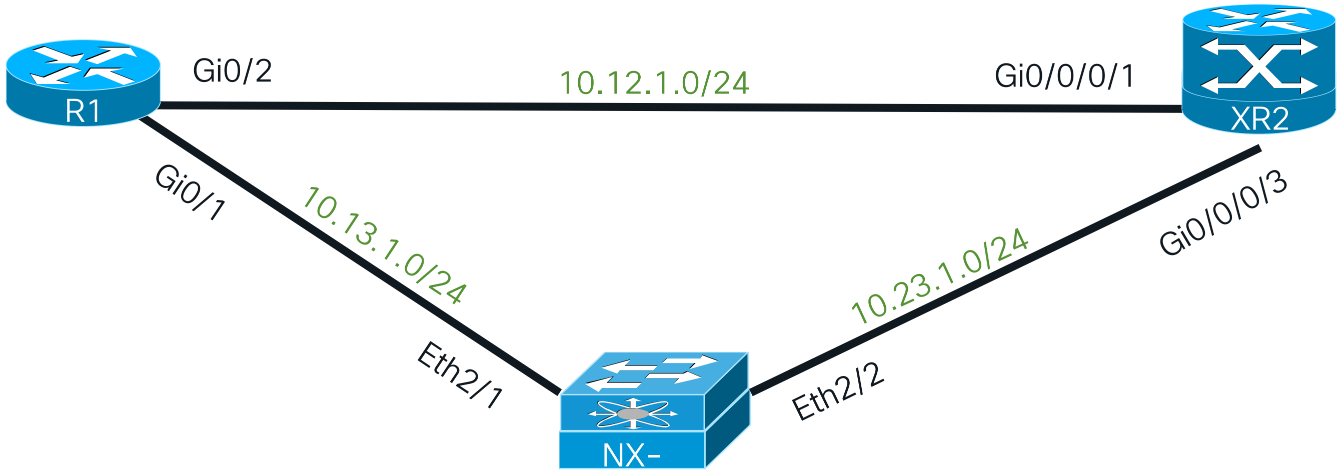
Designated Intermediate System (DIS)

- Broadcast networks support more than two routers which could cause scalability problems with IS-IS
- IS-IS overcomes this inefficiency by creating a pseudonode to manage synchronization issues that arise on the broadcast network segment. A DIS exist for each IS-IS level (L1 and L2).
- By inserting the logical pseudonode into a broadcast segment, the multi-access network segment is converted into multiple P2P networks in the LSPDB



IS-IS Configuration

Topology for Configuration



IS-IS Configuration: IOS XE

- Initialize the routing protocol

  router isis [*process-id*]

- Enable Adjacency Logging (Optional)

  log-adjacency-changes

- Define the NET Address

  net *area-systemid.sel*

- Enable IS-IS on the interface

  interface *interface-id*

  ip router isis [*process-id*]

  ipv6 router isis [*process-id*]

IS-IS Configuration: IOS XE

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router isis CISCOLIVE
R1(config-router)# log-adjacency-changes
R1(config-router)# net 49.0123.0001.0001.0001.00
R1(config-router)#interface gi0/2
R1(config-if)#  ip router isis CISCOLIVE
R1(config-if)#  ipv6 router isis CISCOLIVE
R1(config-if)#interface gi0/3
R1(config-if)#  ip router isis CISCOLIVE
R1(config-if)#  ipv6 router isis CISCOLIVE
03:38:39.967: %CLNS-5-ADJCHANGE: ISIS: Adjacency to 0002.0002.0002 (GigabitEthernet0/2)
Up, new adjacency
03:38:41.967: %CLNS-5-ADJCHANGE: ISIS: Adjacency to 0002.0002.0002 (GigabitEthernet0/2)
Up, new adjacency
```

IS-IS Configuration: IOS XR

- Initialize the routing protocol

  router isis *process-id*

- Enable Adjacency Logging (Optional)

  log-adjacency-changes

- Define the NET Address

  net *area-systemid.sel*

- Initialize IPv6 Address family (optional)

  address-family ipv6 unicast

- Enable IS-IS on the interface

  interface *interface-id*

  address-family ipv4 unicast

  address-family ipv6 unicast

IS-IS Configuration: IOS XR

```
RP/0/0/CPU0:XR2#conf t
RP/0/0/CPU0:XR2(config)#router isis CISCOLIVE
RP/0/0/CPU0:XR2(config-isis)# log-adjacency-changes
RP/0/0/CPU0:XR2(config-isis)# net 49.0123.0002.0002.0002.00
RP/0/0/CPU0:XR2(config-isis)# interface gi0/0/0/1
RP/0/0/CPU0:XR2(config-isis-if)#  address-family ipv4 unicast
RP/0/0/CPU0:XR2(config-isis-if)#  address-family ipv6 unicast
RP/0/0/CPU0:XR2(config-isis-[illegible]f)# interface gi0/0/0/3
RP/0/0/CPU0:XR2(config-isi[illegible])#  address-family ipv4 unicast
RP/0/0/CPU0:XR2(config-[illegible]if)#  address-family ipv6 unicast
RP/0/0/CPU0:XR2(confi[illegible]s-if-af)#commit
RP/0/0/CPU0:May  8 [illegible]:37.226 : isis[1010]: %ROUTING-ISIS-6-INFO_STARTUP_START : Cold
controlled start[illegible]ing
[illegible].996 : isis[1010]: %ROUTING-ISIS-5-ADJCHANGE : Adjacency to
[illegible]gabitEthernet0/0/0/1) (L1) Up, New adjacency
[illegible]2.015 : isis[1010]: %ROUTING-ISIS-5-ADJCHANGE : Adjacency to
49.0123.0001.0001.0001 (GigabitEthernet0/0/0/1) (L2) Up, New adjacency
```

Notice the config is under isis process

IS-IS Configuration: NX-OS

- Enable the IS-IS feature

  feature isis

- Initialize the routing protocol

  router isis *process-id*

- Enable Adjacency Logging (Optional)

  log-adjacency

- Define the NET Address

  net *area-systemid.sel*

- Enable IS-IS on the interface

  interface *interface-id*

  ip router isis *process-id*

  ipv6 router isis *process-id*

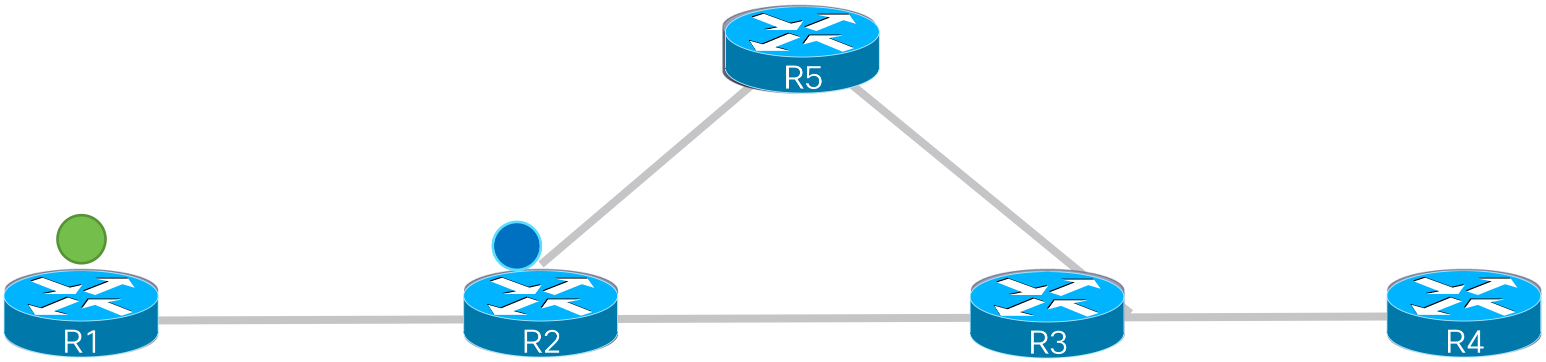
IS-IS Configuration: NX-OS

```
NX-3(config)# feature isis
NX-3(config)# router isis CISCOLIVE
NX-3(config-router)# net 49.0123.0003.0003.0003.00
NX-3(config-router)# log-adjacency
NX-3(config-router)# interface ethernet2/1
NX-3(config-if)# ip router isis CISCOLIVE
NX-3(config-if)# ipv6 router isis CISCOLIVE
NX-3(config-if)# interface ethernet2/2
NX-3(config-if)# ip router isis CISCOLIVE
NX-3(config-if)# ipv6 router isis CISCOLIVE
03:55:40 NX-3 %ISIS-5-ADJCHANGE:  isis-CISCOLIVE [9333]  LAN adj L1 0001.0001.0001 over
Ethernet2/1 - INIT (New) on MT--1
03:55:41 NX-3 %ISIS-5-ADJCHANGE:  isis-CISCOLIVE [9333]  LAN adj L2 0001.0001.0001 over
Ethernet2/1 - INIT (New) on MT--1
03:55:41 NX-3 %ISIS-5-ADJCHANGE:  isis-CISCOLIVE [9333]  LAN adj L2 0001.0001.0001 over
Ethernet2/1 - UP on MT-0
03:55:41 NX-3 %ISIS-5-ADJCHANGE:  isis-CISCOLIVE [9333]  LAN adj L1 0001.0001.0001 over
Ethernet2/1 - UP on MT-0
```

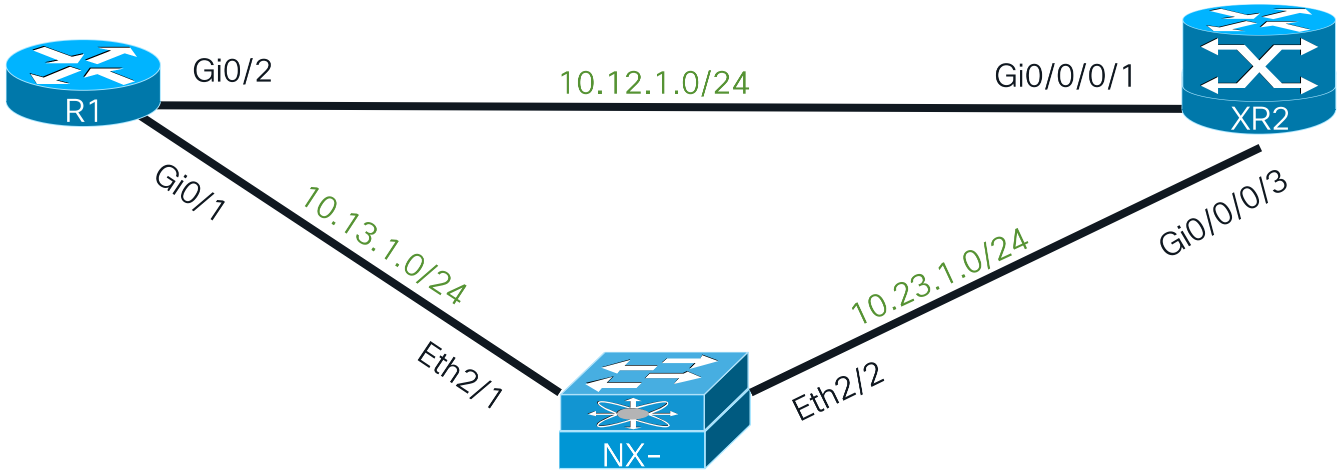
Trivia Question Hint

- How do you make the traffic between R1 and R4, take R5?
- How d… e direct link?

HINT!
One command on Four Routers



Checking for Neighbor Adjacencies



Viewing IS-IS Neighbors

IOS XE

```
R1#show isis neighbors
Tag CISCOLIVE:
System Id       Type Interface     IP Address      State Holdtime Circuit Id
XR2             L1   Gi0/2         10.12.1.2       UP    22       R1.02
XR2             L2   Gi0/2         10.12.1.2       UP    26       R1.02
NX-3            L1   Gi0/3         10.13.1.3       UP    26       R1.01
NX-3            L2   Gi0/3         10.13.1.3       UP    27       R1.01
```

Viewing IS-IS Neighbors

IOS XE

```
R1#show isis neighbors
Tag CISCOLIVE:
System Id       Type Interface     IP Address      State Holdtime Circuit Id
XR2             L1   Gi0/2         10.12.1.2       UP    22       R1.02
XR2             L2   Gi0/2         10.12.1.2       UP    26       R1.02
NX-3            L    Gi0/3         10.13.1.3       UP    26       R1.01
NX-3            L2   Gi            10.13.1.3       UP    27       R1.01
```

How did R1 find out the system ID for XR2 and NX-3?

Was it CDP?

Is it DNS?

Viewing IS-IS Neighbors

IOS XE

No! It is TLV#137

```
R1#show is

Tag CISCOLIVE:

System Id
XR2
XR2
NX-3
NX-3
```

```
⊟ ISO 10589 ISIS InTRA Domain Routeing Information Exchange Protocol
    Intra Domain Routing Protocol Discriminator: ISIS (0x83)
    PDU Header Length: 27
    Version (==1): 1
    System ID Length: 0
    PDU Type           : L1 LSP (R:000)
    Version2 (==1): 1
    Reserved (==0): 0
    Max.AREAs: (0==3): 0
  ⊟ ISO 10589 ISIS Link State Protocol Data Unit
      PDU length: 97
      Remaining lifetime: 1199
      LSP-ID: 0001.0001.0001.00-00
      Sequence number: 0x0000000b
    ⊞ Checksum: 0xec74 [correct]
    ⊞ Type block(0x03): Partition Repair:0, Attached bits:0, Overload bit:0, IS type:3
    ⊞ Area address(es) (4)
    ⊞ Protocols supported (1)
    ⊟ Hostname (2)
        Hostname: R1
    ⊞ IS Reachability (23)
    ⊞ IP Interface address(es) (4)
    ⊞ IP Internal reachability (24)
```

Hostname to LSP ID Conversion Can Be Disabled

IOS XE and NX-OS

- no hostname dynamic

IOS XR

- hostname dynamic disable

IOS XE

```
R1#show isis neighbors
Tag CISCOLIVE:
System Id        Type Interface        IP Address        State Holdtime Circuit Id
0002.0002.0002   L1   Gi0/2            10.12.1.2         UP    22       R1.02
0002.0002.0002   L2   Gi0/2            10.12.1.2         UP    26       R1.02
0003.0003.0003   L1   Gi0/3            10.13.1.3         UP    26       R1.01
0003.0003.0003   L2   Gi0/3            10.13.1.3         UP    27       R1.01
```

Viewing IS-IS Neighbors

IOS XE

```
R1#show isis neighbors
Tag CISCOLIVE:
System Id       Type Interface     IP Address      State Holdtime Circuit Id
XR2             L1   Gi0/2         10.12.1.2       UP    22       R1.02
XR2             L2   Gi0/2         10.12.1.2       UP    26       R1.02
NX-3            L1   Gi0/3         10.13.1.3       UP    26       R1.01
NX-3            L2   Gi0/3         10.13.1.3       UP    27       R1.01
```

IOS XR

```
RP/0/0/CPU0:XR2#show isis neighbors
IS-IS CISCOLIVE neighbors:
System Id      Interface        SNPA           State Holdtime Type IETF-NSF
R1             Gi0/0/0/1        fa16.3eac.7a9b Up    9        L1L2 Capable
NX-3           Gi0/0/0/3        fa16.3e00.0002 Up    21       L1L2 Capable
```

Viewing IS-IS Neighbors

NX-OS

```
NX-3# show isis adjacency
IS-IS process: CISCOLIVE VRF: default
IS-IS adjacency database:
Legend: '!': No AF level connectivity in given topology
System ID       SNPA            Level  State  Hold Time  Interface
R1              fa16.3e69.d5fc  1      UP     00:00:10   Ethernet2/1
R1              fa16.3e69.d5fc  2      UP     00:00:10   Ethernet2/1
XR2             fa16.3e1f.787e  1      UP     00:00:08   Ethernet2/2
XR2             fa16.3e1f.787e  2      UP     00:00:07   Ethernet2/2
```

Settings that are required for an IS-IS Adjacency

- IS-IS Interface is Active
- IS-IS Interface shares a common subnet
- Protocols match (IPv4, IPv6) per topology
- Circuit types match (General or Point to Point)
- Router levels are compatible
  - L1 adjacencies require the area address to matches
  - The system ID must be unique within the same area address
- IS-IS Hello Authentication matches
- MTU Matches

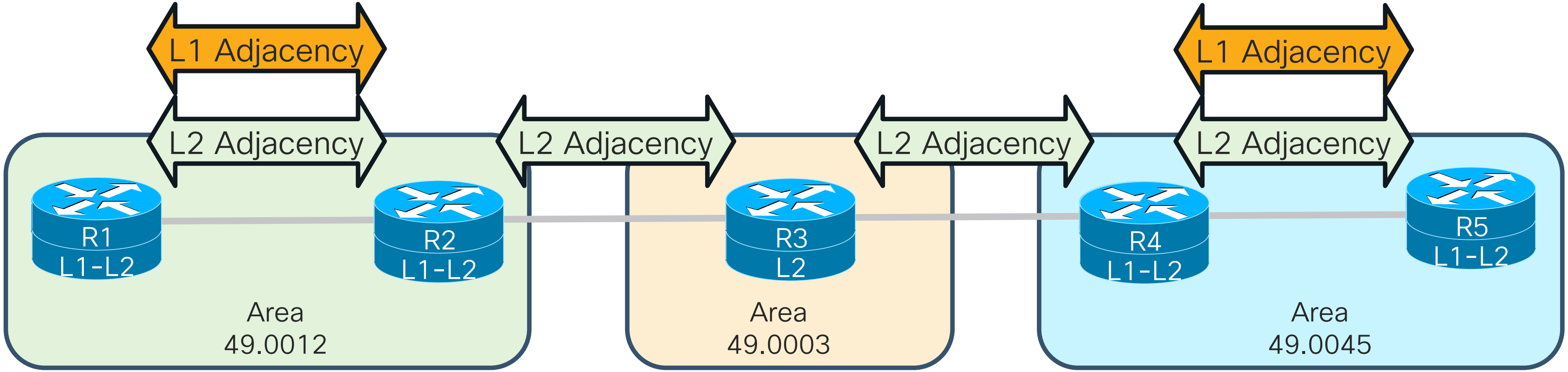
IS-IS Topology Constructs

IS-IS Topologies

IS-IS maintains a copy of all the LSPs in a database for a Level

An LSP database per Level can be thought of as a topology.

How many topologies do you see?



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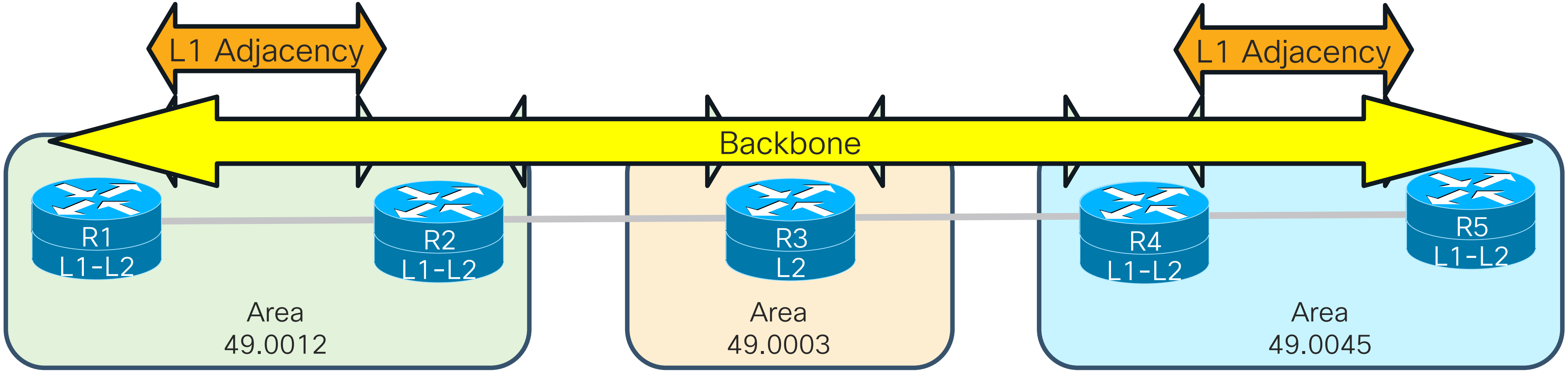

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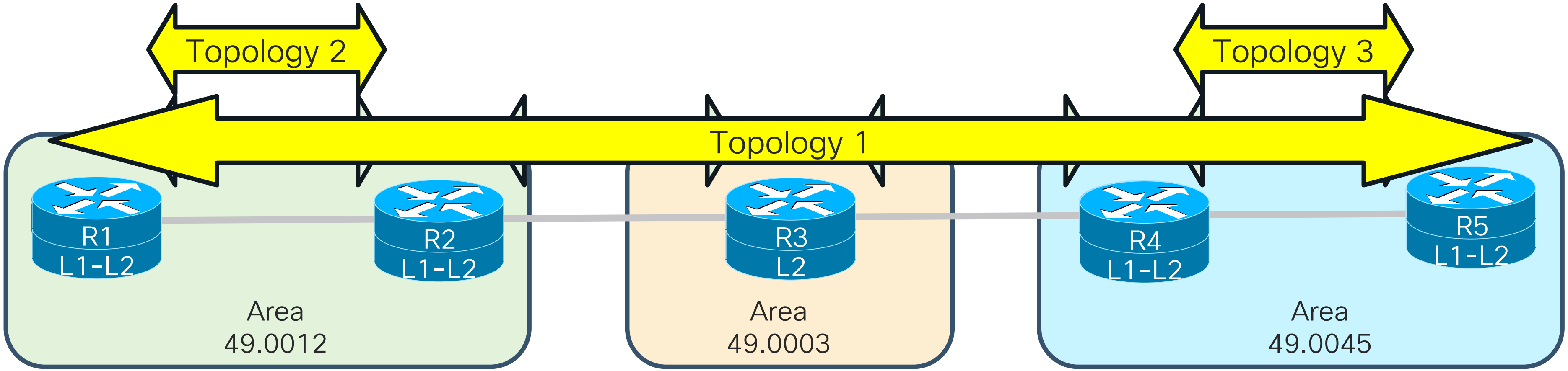


Viewing an IS-IS Topology (IOS XE)

```
R1#show isis topology


Tag CISCOLIVE:
IS-IS TID 0 paths to level-1 routers
System Id          Metric     Next-Hop            Interface    SNPA
R1                 --
R2                 10         R2                  Gi0/2        fa16.3ed4.04f5

IS-IS TID 0 paths to level-2 routers
System Id          Metric     Next-Hop            Interface    SNPA
R1                 --
R2                 10         R2                  Gi0/2        fa16.3ed4.04f5
R3                 20         R2                  Gi0/2        fa16.3ed4.04f5
R4                 30         R2                  Gi0/2        fa16.3ed4.04f5
R5                 40         R2                  Gi0/2        fa16.3ed4.04f5
```

Viewing an IS-IS Topology (IOS XR)

```
RP/0/0/CPU0:XR1#show isis topology

IS-IS CISCOLIVE paths to IPv4 Unicast (Level-1) routers
System Id       Metric  Next-Hop        Interface       SNPA
XR1             --
XR2             10      XR2             Gi0/0/0/2       *PtoP*

IS-IS CISCOLIVE paths to IPv4 Unicast (Level-2) routers
System Id       Metric  Next-Hop        Interface       SNPA
XR1             --
XR2             10      XR2             Gi0/0/0/2       *PtoP*
XR3             20      XR2             Gi0/0/0/2       *PtoP*
R4-XR           30      XR2             Gi0/0/0/2       *PtoP*
R5-XR           40      XR2             Gi0/0/0/2       *PtoP*
```

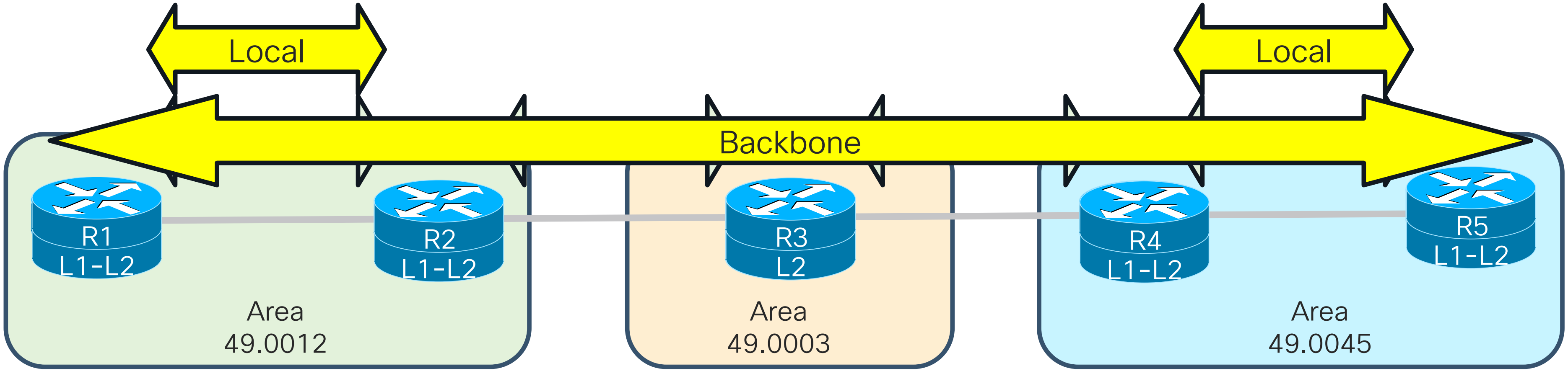

Viewing an IS-IS Topology (NX-OS)

```
NX-1# show isis topology
IS-IS process: CISCOLIVE
VRF: default
IS-IS Level-1 IS routing table
NX-2.00, Instance 0x00000006
   *via NX-2, Ethernet2/2, metric 40

IS-IS Level-2 IS routing table
NX-2.00, Instance 0x00000009
   *via NX-2, Ethernet2/2, metric 40
NX-3.00, Instance 0x00000009
   *via NX-2, Ethernet2/2, metric 80
R4-NX.00, Instance 0x00000009
   *via NX-2, Ethernet2/2, metric 120
R4-NX.01, Instance 0x00000009
   *via NX-2, Ethernet2/2, metric 120
R5-NX.00, Instance 0x00000009
   *via NX-2, Ethernet2/2, metric 130
```

Optimizing an Area

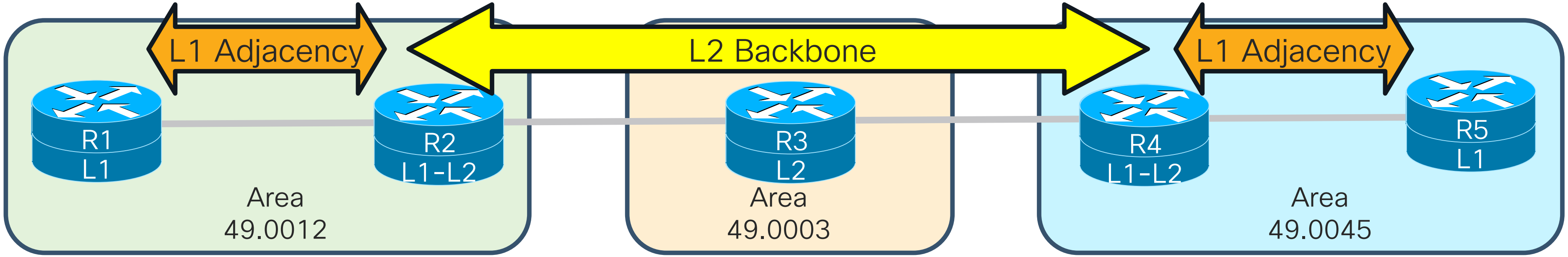
So currently R1 can reach R5 using just the L2 Backbone

What happens when the backbone shrinks between to R2 to R4?



Understanding Route Advertisement

- IS-IS builds the topology using TLV#2.
- Routes are built using TLV#128 and/or TLV#135
- All routers in the same L1/L2 area have the same LSPDBs for that Level



Setting IS-IS Adjacencies with Hierarchy Levels

Checking Interface IS-Setting

Router Level Commands

IOS XE, IOS XR

is-type {level-1 | level-1-2 | level-2-only}

NX-OS

is-type {level-1 | level-1-2 | level-2}

Interface Level Commands

IOS XE

is-type {level-1 | level-1-2 | level-2-only}

IOS XR

circuit-type {level-1 | level-1-2 | level-2-only}

NX-OS

Isis circuit-type {level-1 | level-1-2 | level-2}

Viewing an IS-IS Topology (IOS XE)

```
R1#show isis topology
Tag CISCOLIVE:
IS-IS TID 0 paths to level-1 routers
System Id            Metric     Next-Hop              Interface    SNPA
R1                   --
R2                   10         R2                    Gi0/2        fa16.3ed4.04f5
```

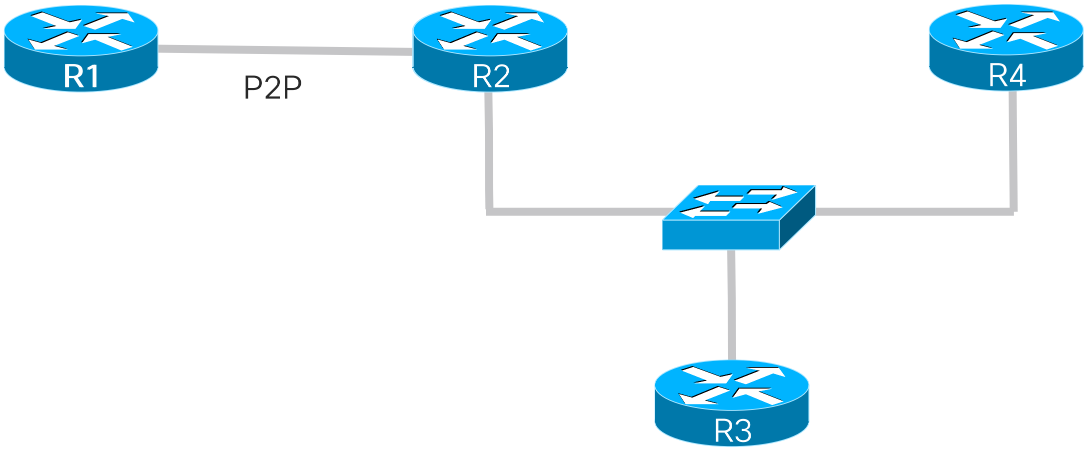
```
R2#show isis topology
Tag CISCOLIVE:
IS-IS TID 0 paths to level-1 routers
System Id            Metric     Next-Hop              Interface    SNPA
R1                   10         R1                    Gi0/1        fa16.3e5c.91c1
R2                   --
IS-IS TID 0 paths to level-2 routers
System Id            Metric     Next-Hop              Interface    SNPA
R2                   --
R3                   10         R3                    Gi0/3        fa16.3e94.673d
R4                   20         R3                    Gi0/3        fa16.3e94.673d
R5                   30         R3                    Gi0/3        fa16.3e94.673d
```

R1 is no longer present in L2 Topology/Database

How a Router Builds an IS-IS Topology

Understanding How the Topology is Built

- Topology is built off of TLV#2 (IS-Neighbors) and the LSP-ID
- LSP-IDs that end with 00 are those of routers themselves
    - Remember the SEL being set to 00 back from the NET addressing?
- LSP-IDs that DO NOT end with 00 are those of DIS (pseudonode)

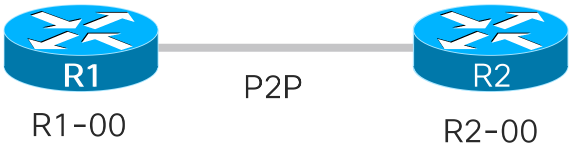


Understanding How the Topology is Built

show isis database [LSP-ID] [level-1|level-2] [detail]

- Displays all the LSPs from a specific router (or DIS), Sequence Number, Holdtime, Attribute fields (Partition, Attached/Overload/Router Type)

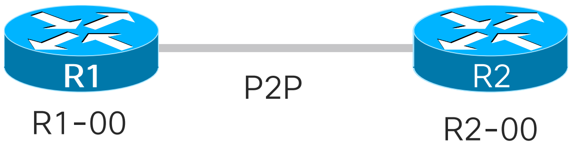
```
R1#show isis database
Tag CISCOLIVE:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime/Rcvd      ATT/P/OL
R1.00-00            * 0x00000007   0x3E7A                 757/*         0/0/0
R2.00-00              0x0000000A   0x40A6                 576/1199      0/0/0
```



Understanding How the Topology is Built (P2P)

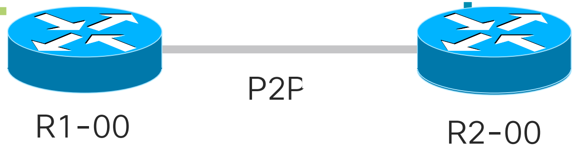
show isis database [LSP-ID] [level-1|level-2] [detail]

```
R1#show isis database detail
Tag CISCOLIVE:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime/Rcvd      ATT/P/OL
R1.00-00            * 0x00000007   0x3E7A                335/*          0/0/0
  Area Address: 49.1234
  NLPID:        0xCC 0x8E
  Hostname: R1
  Metric: 10         IS R2.00
  IP Address:   192.168.1.1
  Metric: 10         IP 10.12.1.0 255.255.255.0
  Metric: 10         IP 10.1.1.0 255.255.255.0
R2.00-00              0x0000000C   0xF0BB                939/1199       0/0/0
..
```

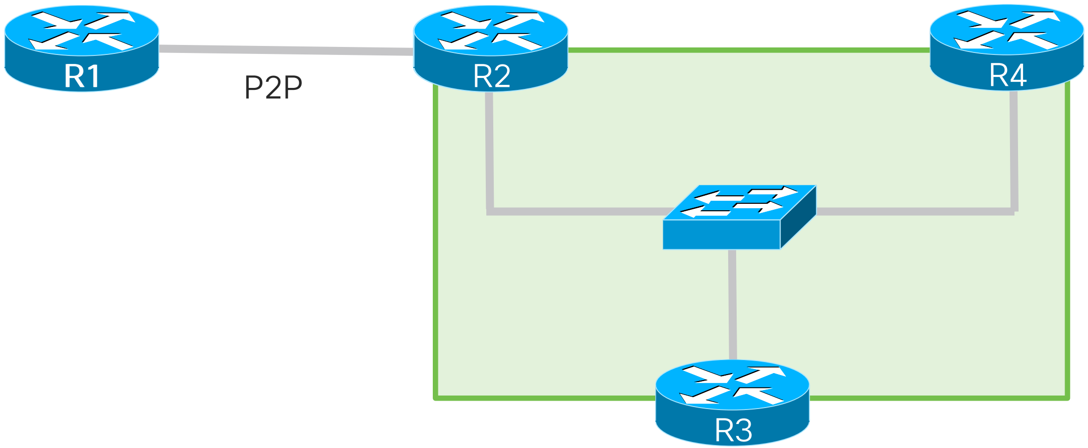


Understanding How the Topology is Built (P2P)

```
R1#show isis database detail | exclude IP|PID|Area


Tag CISCOLIVE:
IS-IS Level-1 Link State Database:
R1.00-00             * 0x0000000A   0x7BEC               1038/*         0/0/0
  Hostname: R1
  Metric: 10            IS R2.00
R2.00-00               0x0000000C   0xF0BB                791/1199      0/0/0
  Hostname: R2
  Metric: 10            IS R1.00
```



Understanding How the Topology is Built (Multi)

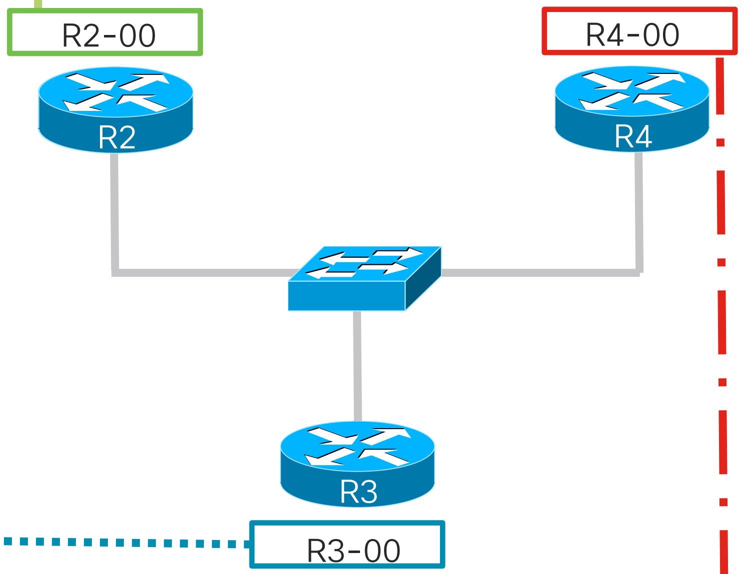


Understanding How the Topology is Built (Multi)

```
R2#show isis database detail | exclude IP|PID|Area
..
R2.00-00              0x0000017E   0x52E6               1130/1199      0/0/0
  Hostname: R2
  Metric: 10         IS R4.01
R3.00-00              0x00000173   0xE6AF               1121/1198      0/0/0
  Hostname: R3
  Metric: 10         IS R4.01
R4.00-00              0x0000017D   0x823F               1120/1198      0/0/0
  Hostname: R4
  Metric: 10         IS R4.01
R4.01-00              0x00000172   0xB040               1130/1198      0/0/0
  Metric: 0          IS R4.00
  Metric: 0          IS R2.00
  Metric: 0          IS R3.00
```

Understanding How the Topology is Built (Multi)

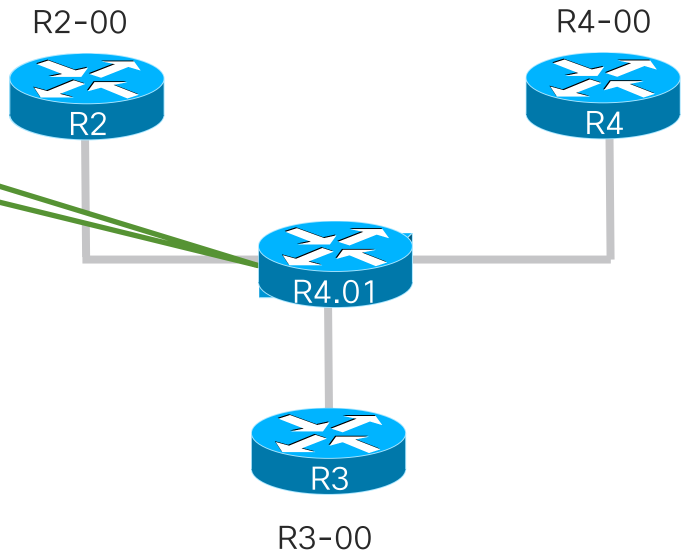
```
R2#show isis database detail | exclude IP|PID|Area

..
R2.00-00                 0x0000017E
  Hostname: R2
  Metric: 10            IS R4.01
R3.00-00                 0x00000173
  Hostname: R3
  Metric: 10            IS R4.01
R4.00-00                 0x0000017D
  Hostname: R4
  Metric: 10            IS R4.01
R4.01-00                 0x00000172
  Metric: 0             IS R4.00
  Metric: 0             IS R2.00
  Metric: 0             IS R3.00
```



Understanding How the Topology is Built (Multi)

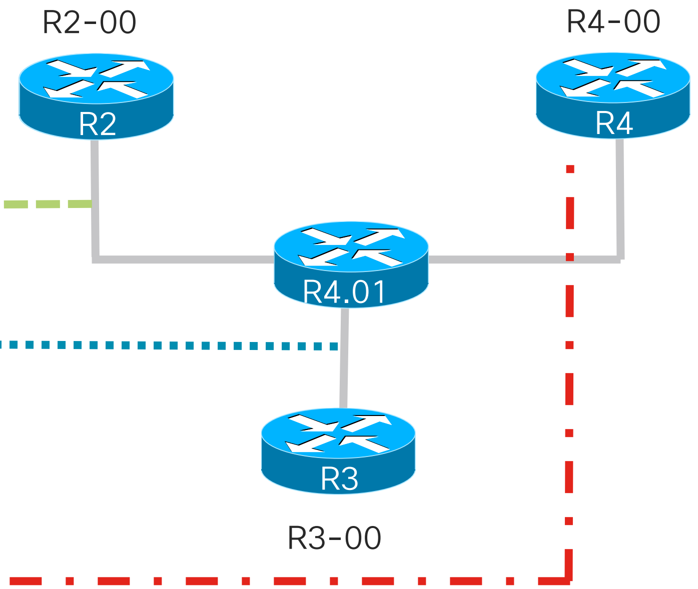
```
R2#show isis database detail | exclude IP|PID|Area
..
R2.00-00                   0x0000017E
  Hostname: R2
  Metric: 10
R3.00-00
  Hostname: R3
  Metric: 10           IS R4.01
R4.00-00                   0x0000017D
  Hostname: R4
  Metric: 10           IS R4.01
R4.01-00                   0x00000172
  Metric: 0            IS R4.00
  Metric: 0            IS R2.00
  Metric: 0            IS R3.00
```

R4.01-00 must be the DIS



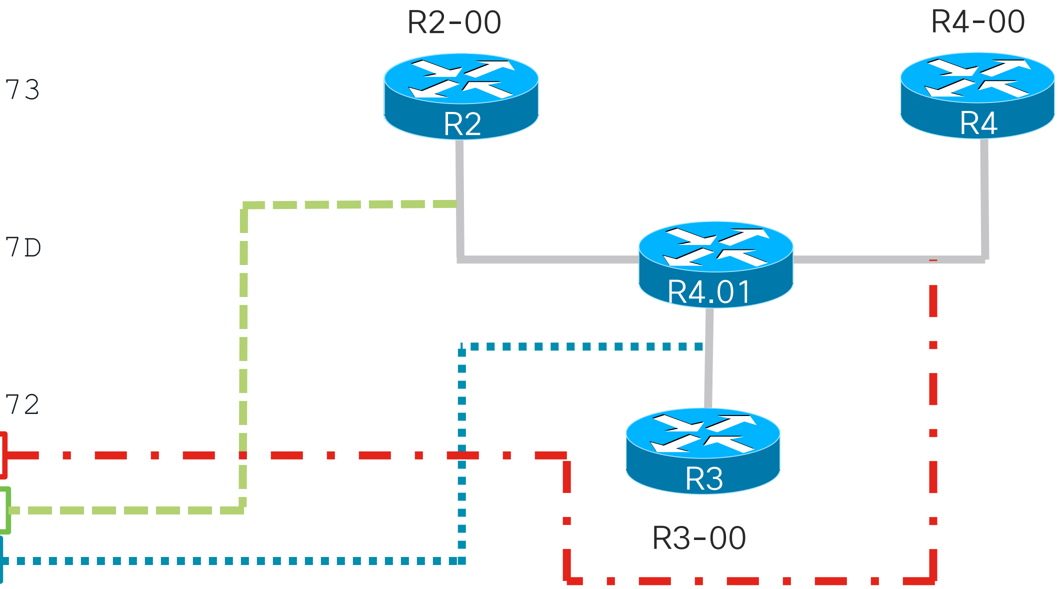
Understanding How the Topology is Built (Multi)

```
R2#show isis database detail | exclude IP|PID|Area
..
R2.00-00                    0x0000017E
  Hostname: R2
  Metric: 10               IS R4.01
R3.00-00                    0x00000173
  Hostname: R3
  Metric: 10               IS R4.01
R4.00-00                    0x0000017D
  Hostname: R4
  Metric: 10               IS R4.01
R4.01-00                    0x00000172
  Metric: 0                IS R4.00
  Metric: 0                IS R2.00
  Metric: 0                IS R3.00
```



Understanding How the Topology is Built (Multi)

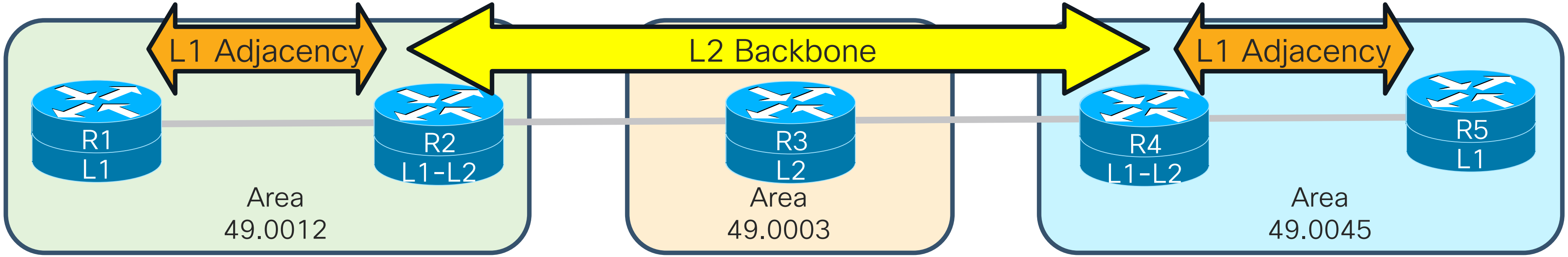
```
R2#show isis database detail | exclude IP|PID|Area
..
R2.00-00                     0x0000017E
  Hostname: R2
  Metric: 10                IS R4.01
R3.00-00                     0x00000173
  Hostname: R3
  Metric: 10                IS R4.01
R4.00-00                     0x0000017D
  Hostname: R4
  Metric: 10                IS R4.01
R4.01-00                     0x00000172
  Metric: 0                 IS R4.00
  Metric: 0                 IS R2.00
  Metric: 0                 IS R3.00
```



Route Advertisements

Understanding Route Advertisement

- IS-IS builds the topology using TLV#2.
- Routes are built using TLV#128 and/or TLV#135
- All routers in the same L1/L2 area have the same LSPDBs for that Level



Viewing Routes in the LSPDB

```
R1#show isis database R2.00-00 level-1 detail
Tag CISCOLIVE:

IS-                       -00
LSP                       SP Seq Num   LSP Chec              vd        ATT/P/OL
R2.00-                   0x0000000E    0x2BD0                99        1/0/0
  Area A     ess: 49.0012
Hostname:     2
  Metric: 10             IS R1.00
  IP Address:   192.168.2.2
  Metric: 10             IP 10.12.1.0 255.255.255.0
  Metric: 10             IP 10.23.1.0 255.255.255.0
  Metric: 10             IP 192.168.2.2 255.255.255.255
  IPv6 Address: 2001:2:2::
  Metric: 10             IPv6 2000:12::/64
  Metric: 10             IPv6 2000:23::/64
  Metric: 10             IPv6 2001:2:2::/128
```

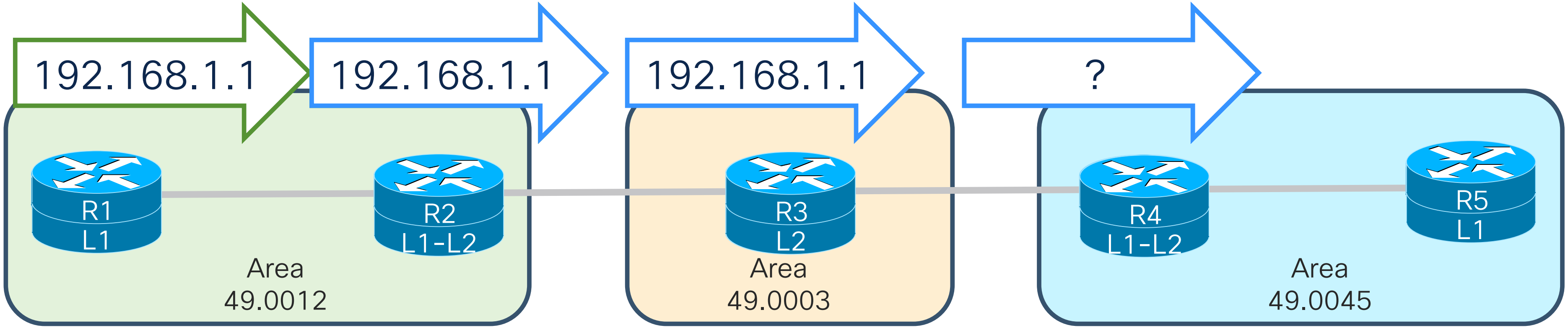
Metric for the topology

Connected IPv4 Networks

Connected IPv6 Networks

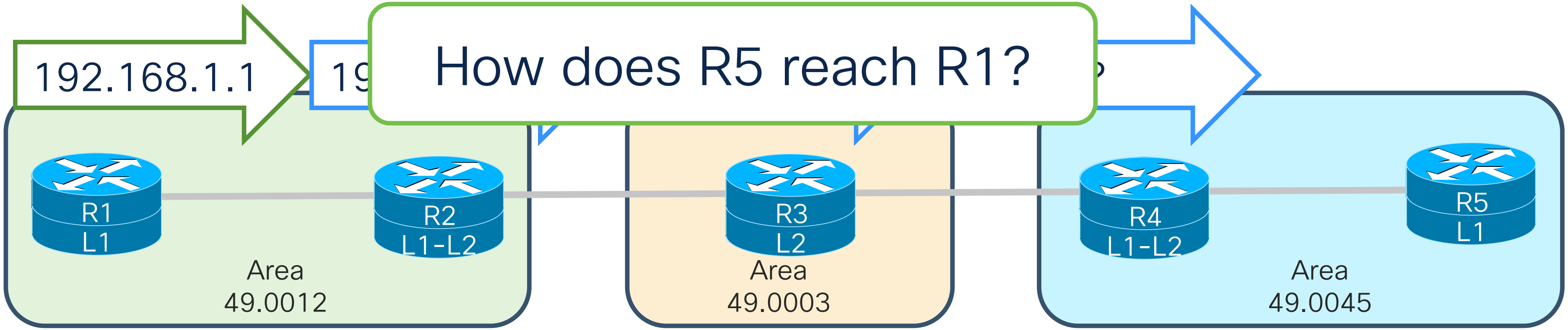
Understanding Route Advertisement

- L1 advertises the router 192.168.1.1 within Area 49.0012 via L1
- R2 takes the L1 route and places it into the L2 router as its own
- R2's L2 LSP is Forwarded to R3 and R4
- Does R4 advertise 192.168.1.1 into Area 49.0045?
- No, it does not!



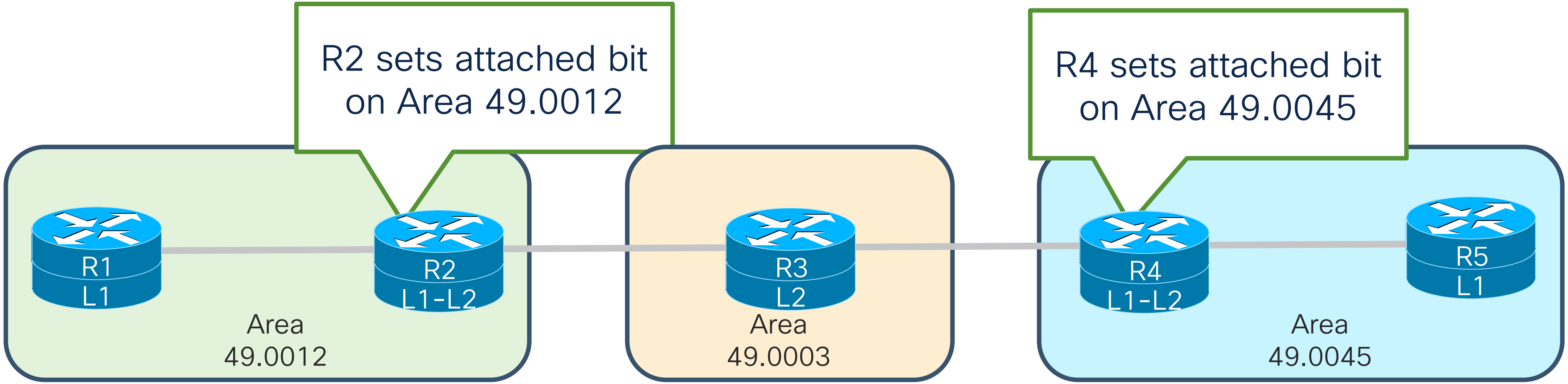
Understanding Route Advertisement

- L1 advertises the router 192.168.1.1 within Area 49.0012 via L1
- R2 takes the L1 route and places it into the L2 router as its own
- R2's L2 LSP is Forwarded to R3 and R4
- Does R4 advertise 192.168.1.1 into Area 49.0045?
- No, it does not!



The Attached Bit

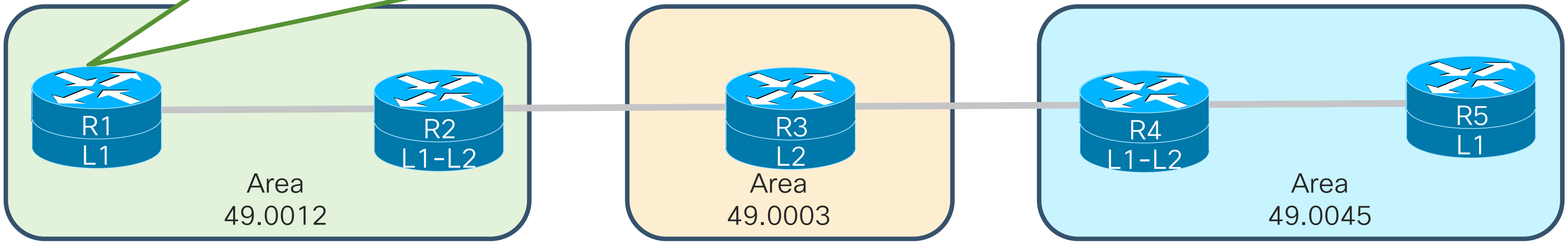
- L1 routers use the attach bit to locate their nearest L1-L2 router
  - That L1-L2 router must contain LSPs from a different area.
- The L1-L2 router acts as a gateway
- L1 routers translate the Attach bit as the default gateway



The Attached Bit

- Can be viewed by looking examining Attribute fields

```
R1#show isis database
Tag CISCOLIVE:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime/Rcvd      ATT/P/OL
R1.00-00            * 0x0000002E   0xB3D2               1174/*          0/0/0
R2.00-00              0x0000002C   0xF6DE               932/1199        1/0/0
```



The Attached Bit

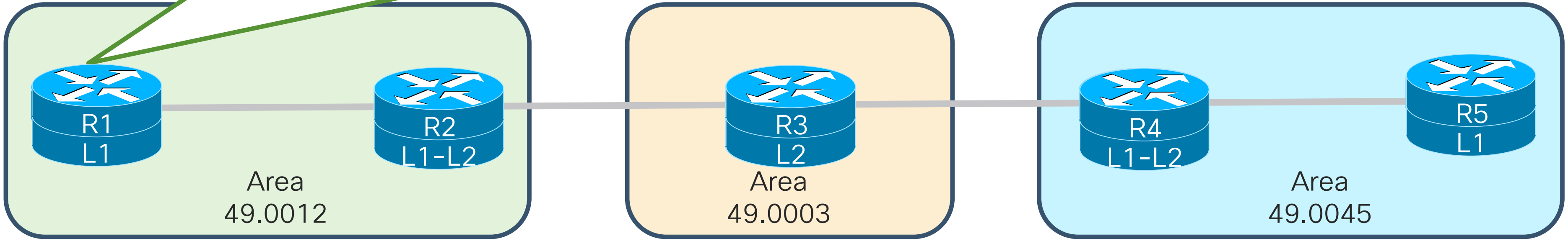
- Can be seen by viewing an explicit router's LSP too

```
R1#show isis database detail R2.00-00
IS-IS Level-1 LSP R2.00-00
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime/Rcvd      ATT/P/OL
R2.00-00              0x0000002E   0xF2E0                 725/1199      1/0/0
  Area Address: 49.0012
  NLPID:        0xCC 0x8E
  Hostname: R2
  Metric: 10         IS R1.00
  IP Address:   192.168.2.2
  Metric: 10         IP 10.12.1.0 255.255.255.0
  Metric: 10         IP 10.23.1.0 255.255.255.0
  Metric: 10         IP 192.168.2.2 255.255.255.255
```

The Attached Bit

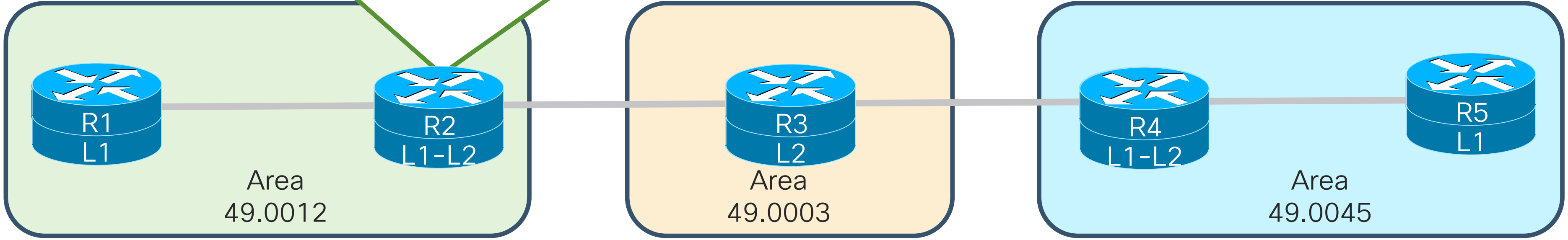
- Translating it to the Routing Table

```
R1#show ip route isis
i*L1  0.0.0.0/0 [115/10] via 10.12.1.2, 00:03:18, GigabitEthernet0/2
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
i L1     10.23.1.0/24 [115/20] via 10.12.1.2, 00:03:18, GigabitEthernet0/2
      192.168.2.0/32 is subnetted, 1 subnets
i L1     192.168.2.2 [115/20] via 10.12.1.2, 00:03:18, GigabitEthernet0/2
```



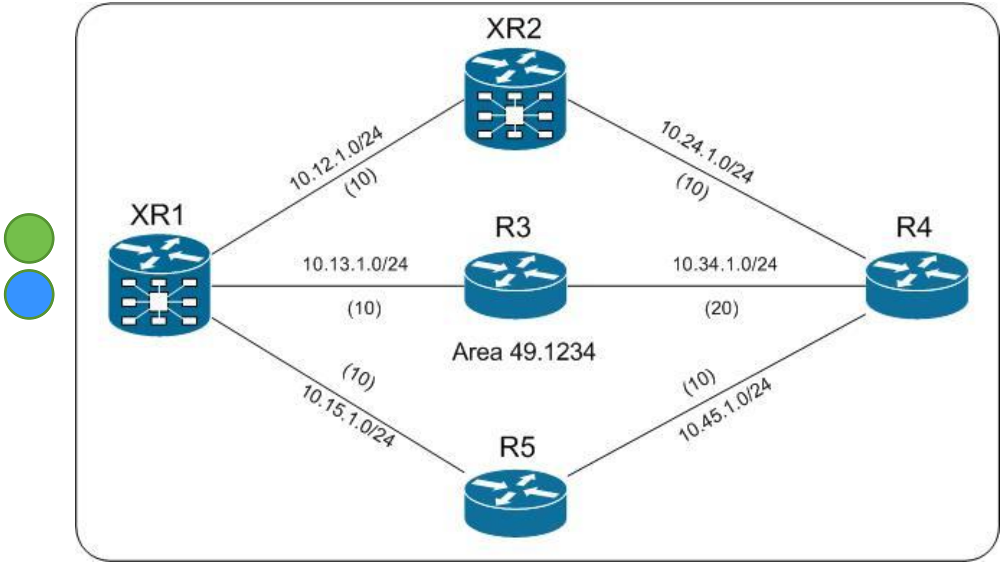
Viewing the Backbone Routing Table

```
R2#show ip route isis | ex subnet
i L2      10.34.1.0/24 [115/20] via 10.23.1.3, 00:18:41, GigabitEthernet0/3
i L2      10.45.1.0/24 [115/30] via 10.23.1.3, 00:18:41, GigabitEthernet0/3
i L1      192.168.1.1 [115/20] via 10.12.1.1, 07:54:35, GigabitEthernet0/1
i L2      192.168.3.3 [115/20] via 10.23.1.3, 00:18:41, GigabitEthernet0/3
i L2      192.168.4.4 [115/30] via 10.23.1.3, 00:18:41, GigabitEthernet0/3
i L2      192.168.5.5 [115/40] via 10.23.1.3, 00:18:41, GigabitEthernet0/3
```



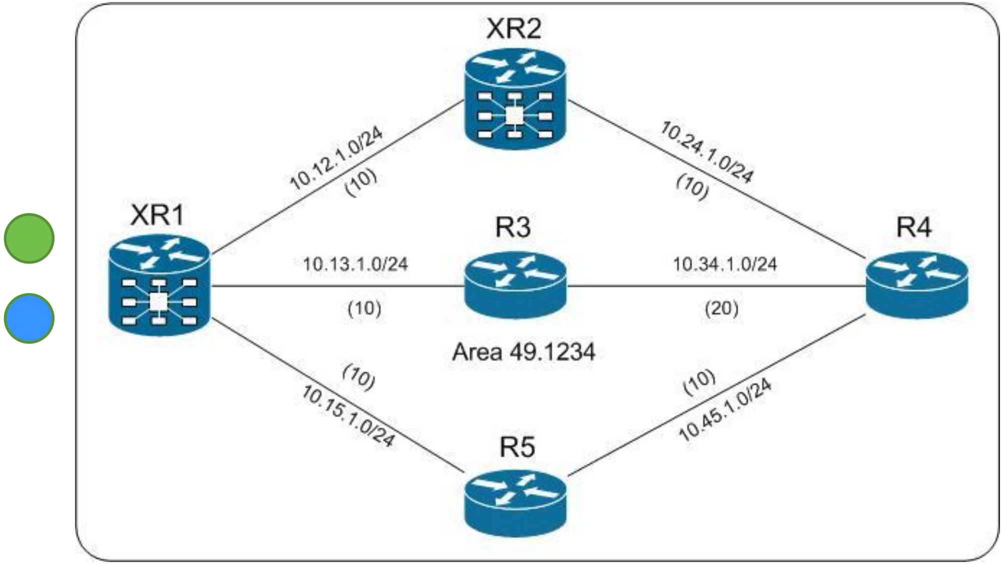
Overload Bit

Normal traffic flow between XR1 and R4 would be between XR2 and R5 based on metric calculations



Overload Bit

Traffic flow taken across links that have higher metric are not normal.

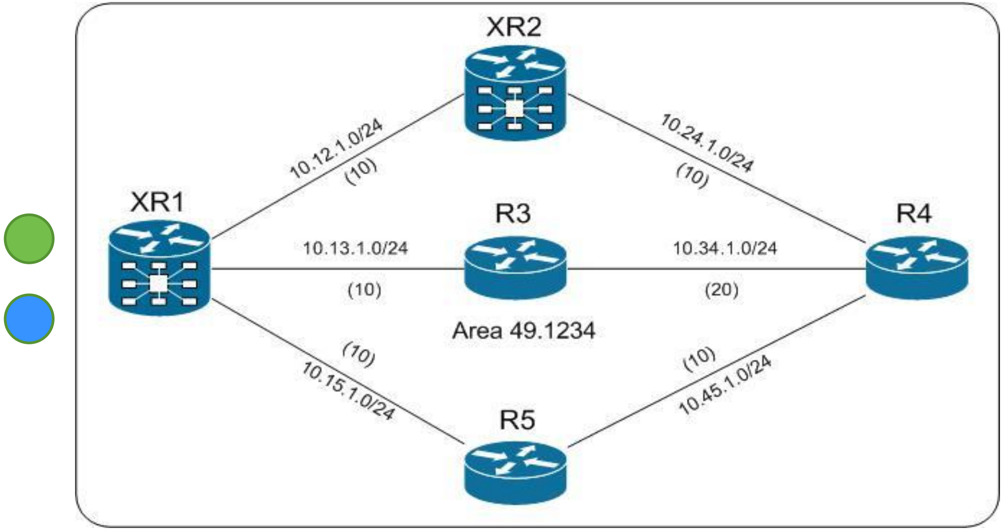


Overload Bit

- The overload bit indicates a router in an overloaded condition.
- Routers avoid sending traffic through routers that set the overload bit.
- Upon recovery, the router advertises a new LSP without the overload bit, and the SPF calculation occurs normally without avoiding routes through the previously overloaded node.

Overload Bit

```
RP/0/0/CPU0:XR1#show isis database
IS-IS ISIS (Level-1) Link State Database
LSPID                    LSP Seq Num  LSP Checksum  LSP Holdtime  ATT/P/OL
XR1.00-00              * 0x00000007   0x71d6        1046            0/0/0
XR2.00-00                0x0000000c   0x2557        1124            0/0/1
R3.00-00                 0x00000009   0x5564        1031            0/0/0
R4.00-00                 0x0000000c   0x8baa        1065            0/0/0
R5.00-00                 0x00000009   0xa406        1155            0/0/1
R5.03-00                 0x00000003   0x7ccc        1124            0/0/0
```



Overload Bit

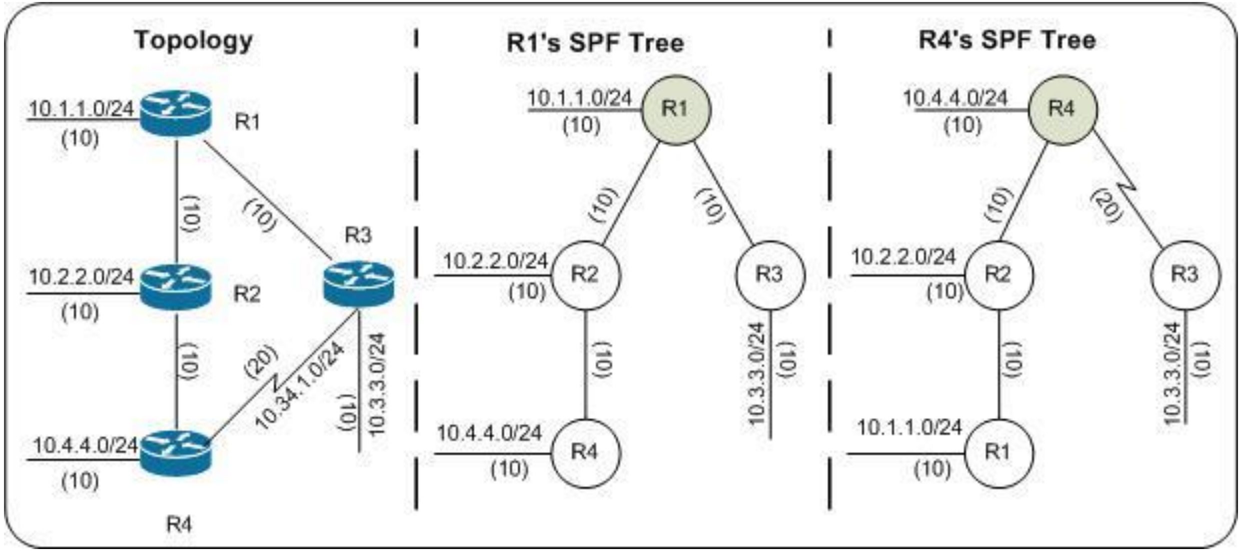
- Originally, the overload bit signified memory exhaustion, but current routers have a significant amount of memory making those situations very rare.
- Setting the overload bit on a router during maintenance windows is a common technique to route traffic around the nodes being worked on.
- Newer IS-IS functionality allows a router to set the overload bit when it first starts up for a specific amount of time, or until BGP sessions have stabilized.

Route Metrics

Path Computation

After a router has built a topology of routers and their connecting interfaces, it runs a Shortest Path First Computation

The local router is the top of SPF Tree. All other routers are a branch. Calculations are made based off of interface cost

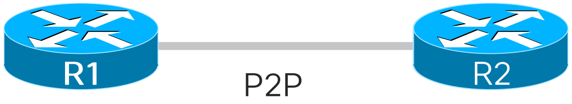


Interface Metrics

RFC 1195 provides a 6-bit field supporting values 1-63

- Stored in TLV# 128
- Industry standard is that all interfaces are statically set to 10 by default

```
R1#show isis database detail
..
R1.00-00              * 0x00000007   0x3E7A                335/*        0/0/0
  Area Address: 49.1234
  NLPID:        0xCC 0x8E
  Hostname: R1
  Metric: 10          IS R2.00
```



Interface Metrics

RFC 1195 provides a 6-bit field supporting values 1-63

- Stored in TLV# 128
- Industry standard is that all interfaces are statically set to 10 by default
  - Value are changed as needed statically as needed
  - Except Nexus uses a reference bandwidth of 40 Gbps by default
    - 10-Gigabit Interfaces are set to 4
    - Gigabit Interfaces are set to 40

Interface Wide Metrics

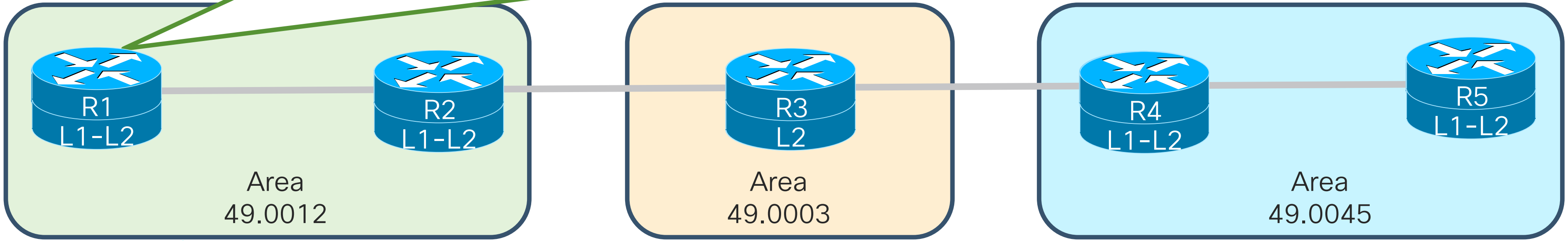
Some network engineers thought that 6-bits is not enough to tune a network

- RFC 5305 introduced a new TLV# 135 that supported 32-bit values
- Allows for wide scale of metrics to reflect values from T1 interfaces to 100Gb interfaces
- Does not impact the way a topology is built, using TLV #2

What's Wrong?

```
R1#show isis topology level-2

IS-IS TID 0 paths to level-2 routers

System Id            Metric     Next-Hop              Interface    SNPA
R1                   --
R2                   10         R2                    Gi0/2        fa16.3ed4.04f5
R3                   **
R4                   **
R5                   **
```

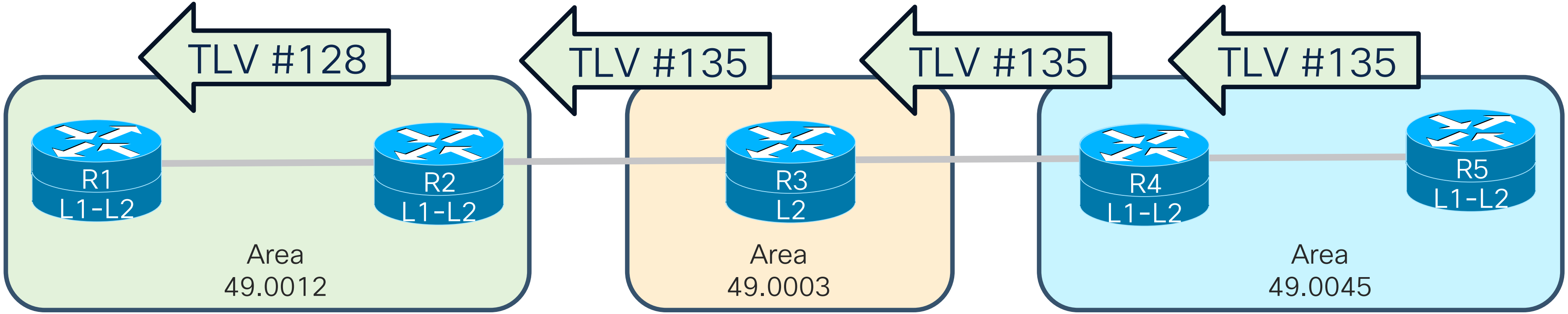
IS-IS builds the topology on TLV #2.



Mismatch Metric Types

- TLVs are transmitted as long as they are recognized
- When a router does not recognize a TLV it drops it.

IOS XE and IOS XR use Narrow Metrics by Default
NX-OS uses Wide Metrics by default



Checking Metric Style

IOS XE

```
R1#show isis protocol | i narrow|wide
  Generate narrow metrics: level-1-2
  Accept narrow metrics:   level-1-2
  Generate wide metrics:   none
  Accept wide metrics:     none
  Generate narrow metrics: level-1-2
  Accept narrow metrics:   level-1-2
  Generate wide metrics:   none
  Accept wide metrics:     none
```

Checking Metric Style

IOS XR

```
RP/0/0/CPU0:XR1#show isis protocol | i "Level-|style"
Level-1
        Metric style (generate/accept): Narrow/Narrow
      Level-2
        Metric style (generate/accept): Narrow/Narrow
```

NX-OS

```
NX-1# show isis protocol | i Metric
  Metric-style : advertise(wide), accept(narrow, wide)
```

Narrow vs. Wide Metrics

A router can use Narrow, Wide, or Transition Metrics (Both)

IOS XE

```
router isis CISCOLIVE
metric-style {narrow | transition | wide}
```

IOS XR

```
router isis CISCOLIVE
 address-family ipv4 unicast
   metric-style {narrow | transition | wide}
```

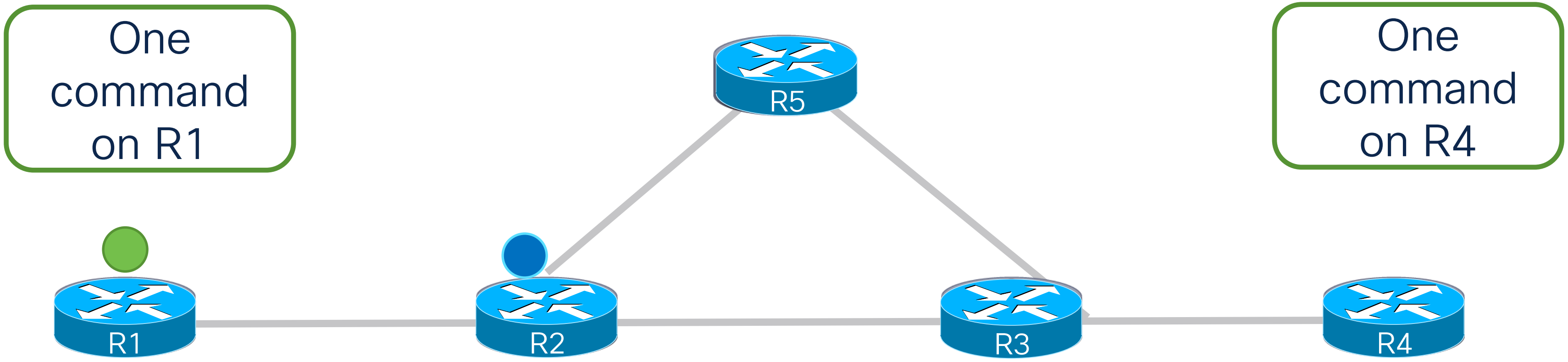
NX-OS

```
router isis CISCOLIVE
  metric-style transition
```

Needs to be consistently Narrow or Wide (Exception is Transition)

Trivia Question Hint

- How do you make the traffic between R1 and R4, take R5?
- How do you make the traffic between R2 and R3, take the direct link?



IPv6 Support

IS-IS for IPv6

- IPv6 Address Family support (RFC 2308)
- 2 new Tag/Length/Values added to introduce IPv6 routing
  - IPv6 Reachability TLV#236:
    - Equivalent to IP Internal/External Reachability TLV’s
  - IPv6 Interface Address TLV #232
    - For Hello PDUs, must contain the link-local address
    - For LSP, must contain the non-link local address
- IPv6 NLPID (Network Layer Protocol Identifier) TLV#232 is advertised by IPv6 enabled routers

IS-IS for IPv6

Restrictions with Single Topology

- In Single topology IS-IS for IPv6 uses the same SPF for both IPv4 and IPv6.
  - Remember that the protocol must match for an adjacency to form? IPv4 and IPv6 topologies MUST match exactly
  - Cannot run IS-IS IPv6 on some interfaces, IS-IS IPv4 on others.
  - An IS-IS IPv6-only router will not form an adjacency with an IS-IS IPv4/IPv6 router (Exception is over L2-only interface)

IS-IS for IPv6

Multi-Topology IS-IS extensions

- Multi-Topology IS-IS solves the restrictions of Single topology
  - Two independent topology databases maintained
  - IPv4 uses Multi-Topology ID (MTID) zero(0)
  - New Multi-Topology ID (MTID #2) for IPv6
- Multi-Topology IS-IS has updated packets
  - Hello packets marked with MTID #0 or MTID #2
  - New TLV attributes introduced
  - Each LSP is marked with the corresponding MTID
- Miss-Matched MTID values
  - No effect on broadcast segments, adjacency will form
  - Point-to-point segments, adjacency will not form

IS-IS for IPv6

Choosing Single or Multi-Topology IS-IS

Use Single-Topology for:

- No planned differences in topology between IPv4 and IPv6
- Each interface has the same IPv4 and IPv6 router Level

Use Multi-Topology for:

- Incremental roll-out of IPv6 on an IPv4 topology
- If you plan for differences in topology between IPv4 and IPv6

The optional keyword transition may be used for transitioning existing IS-IS IPv6 single Topology mode to Multi-Topology IS-IS

IS-IS for IPv6

Transition to Multi-Topology IS-IS – Wide Metrics

- Ensure “Wide metric” is enabled
  - Mandatory for Multi-Topology to work
  - When migrating from narrow to wide metrics, care is required
  - Narrow and wide metrics are NOT compatible with each other

- Migration is a two stage process
  - Step 1: make use of the transition keyword

```
router isis
  metric-style transition
```

→

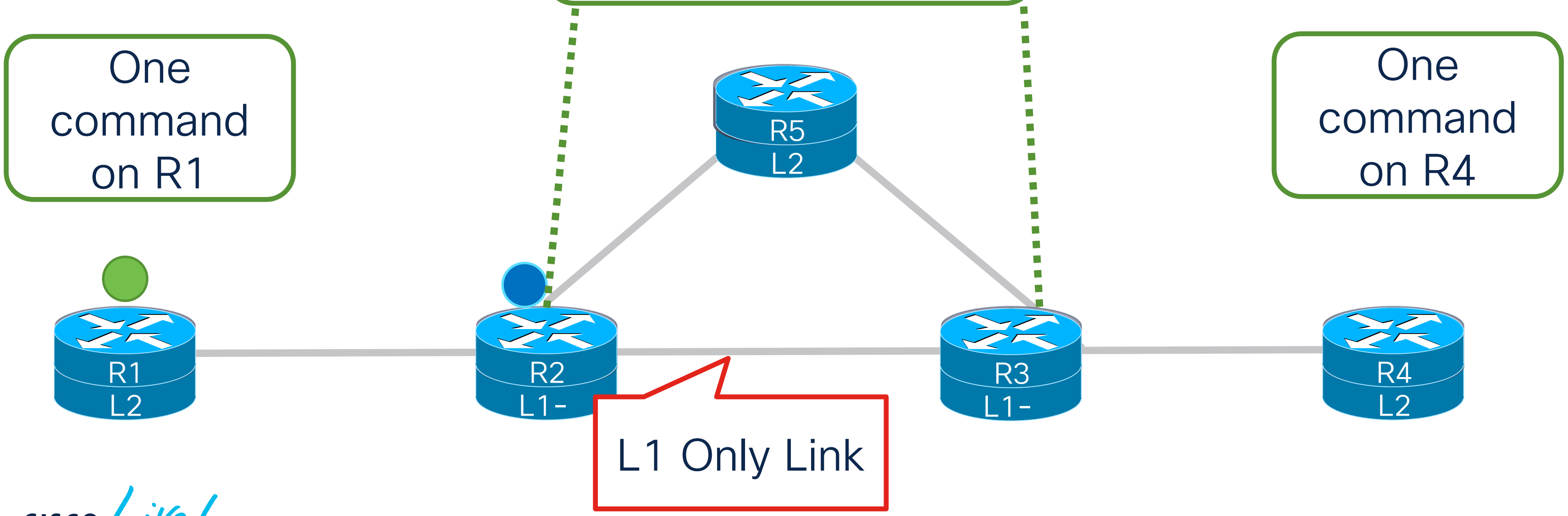
```
router isis
  metric-style wide
```

  - Step 2: Once the whole network is changed to transition support, the metric style can be changed to wide

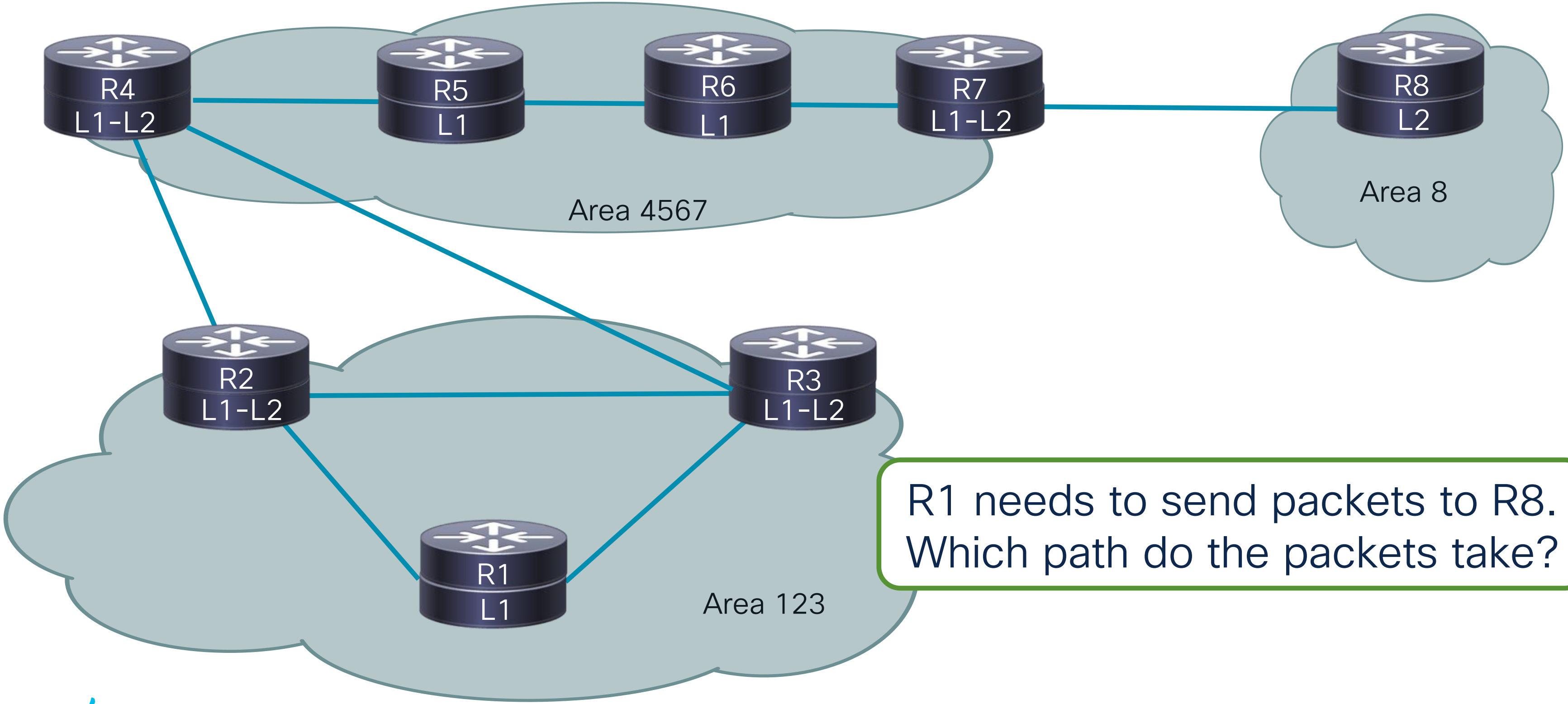
Trivia Question: ANSWER

Trivia Question Answer

- How do you make the traffic between R1 and R4, take R5?
- How do you make the One command on R2 or R3 d R3, take the direct link?

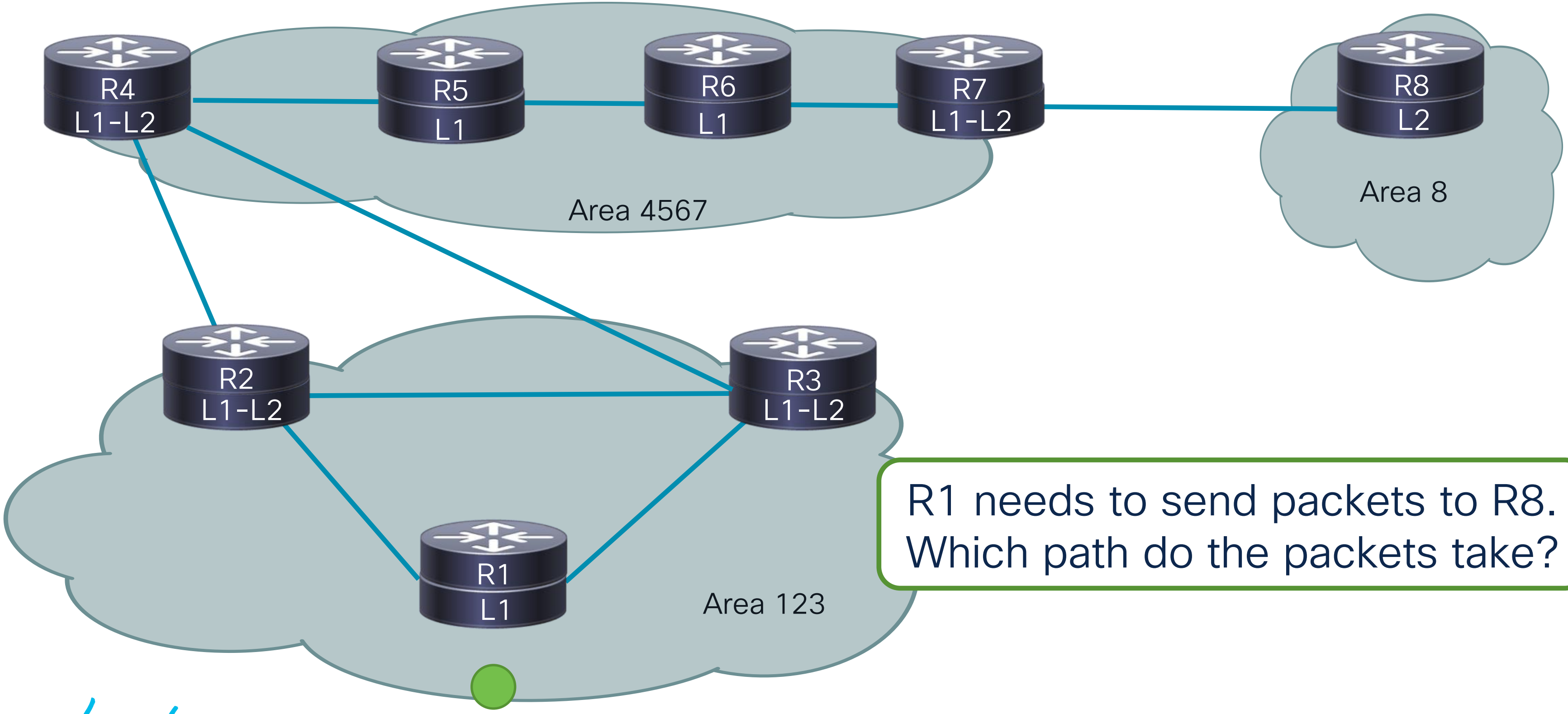


Area Design



R1 needs to send packets to R8. Which path do the packets take?

Area Design



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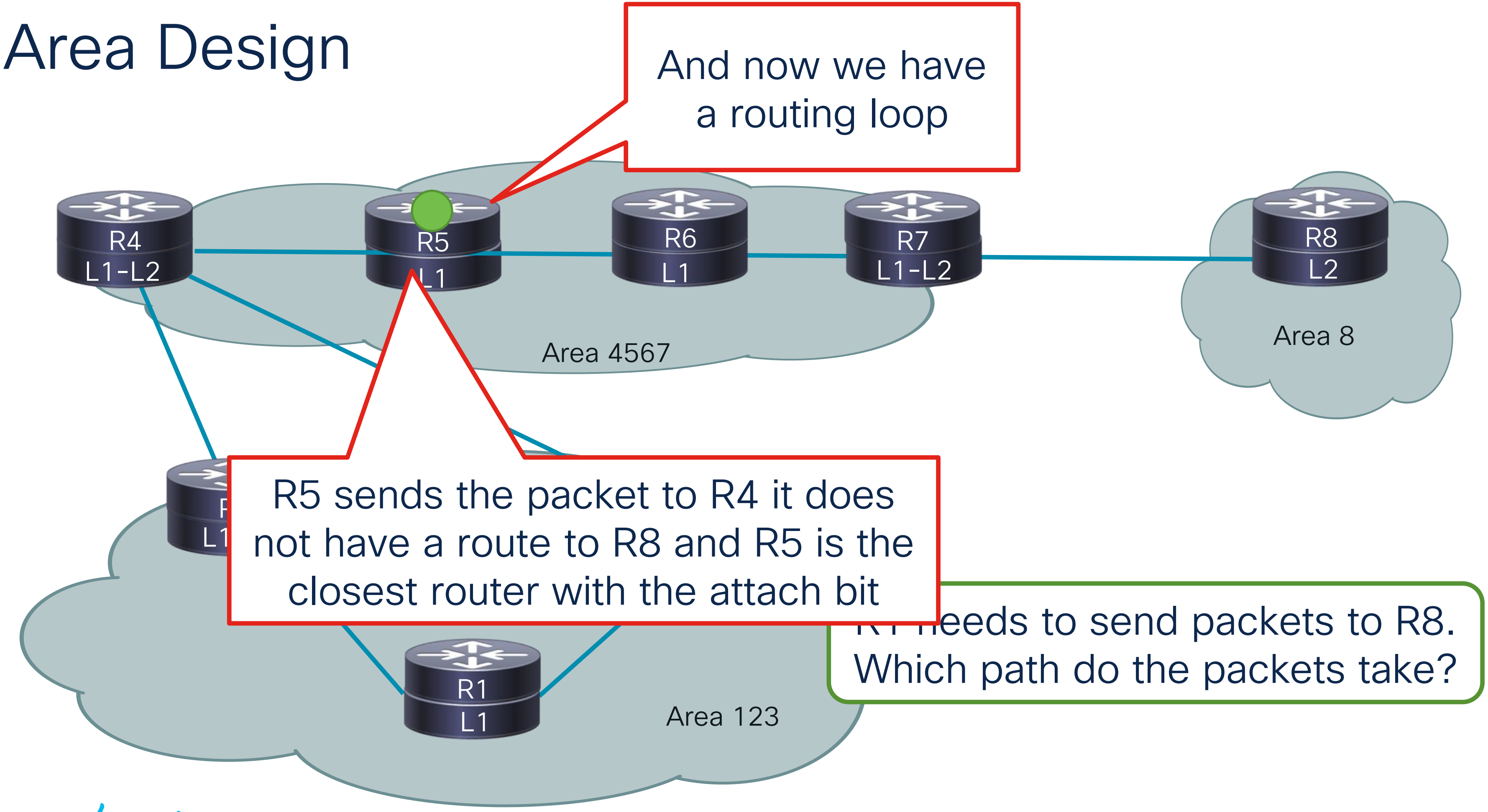
Area Design

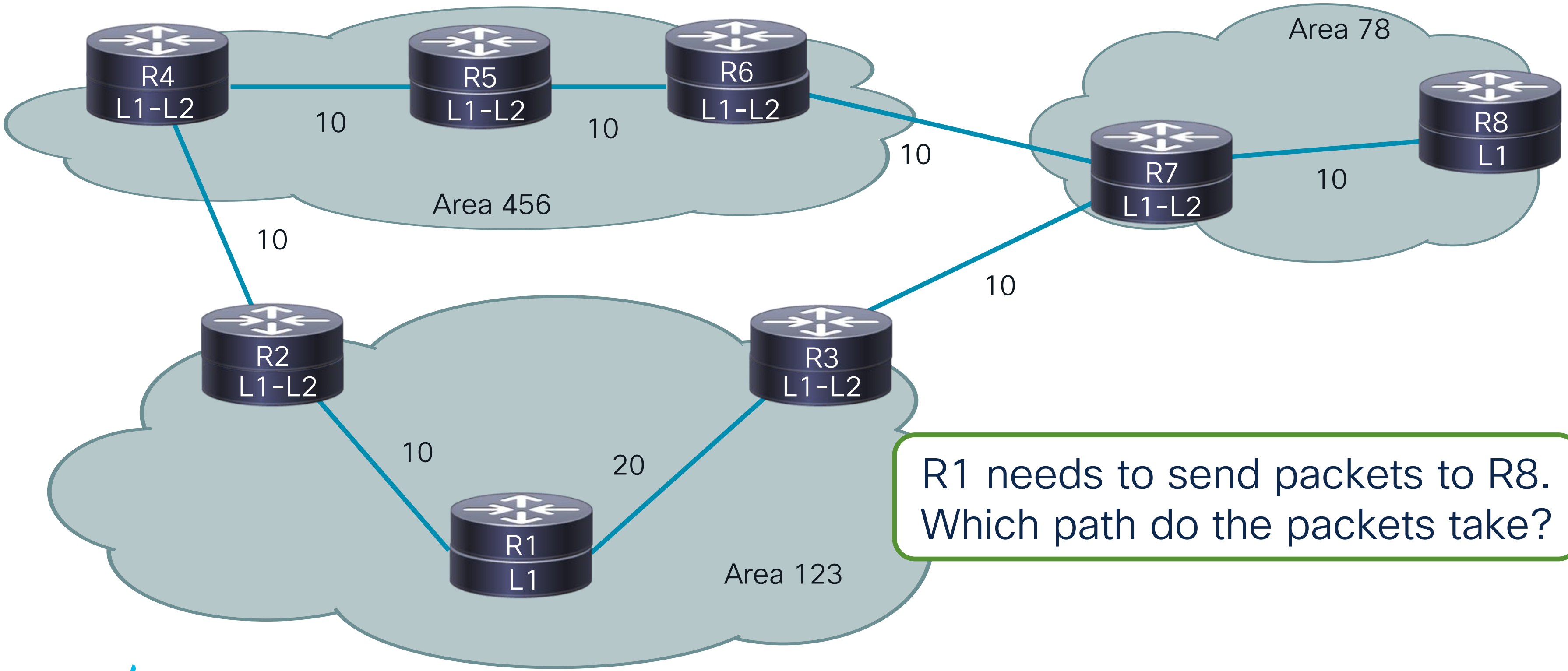


And now we have a routing loop
R4
L1-L2
R5
L1
R6
L1
R7
L1-L2
R8
L2
Area 4567
Area 8
R5 sends the packet to R4 it does not have a route to R8 and R5 is the closest router with the attach bit
needs to send packets to R8.
Which path do the packets take?
R1
L1
Area 123

Sup-Optimal IS-IS Routing

– Area design

Areas and Suboptimal Routing



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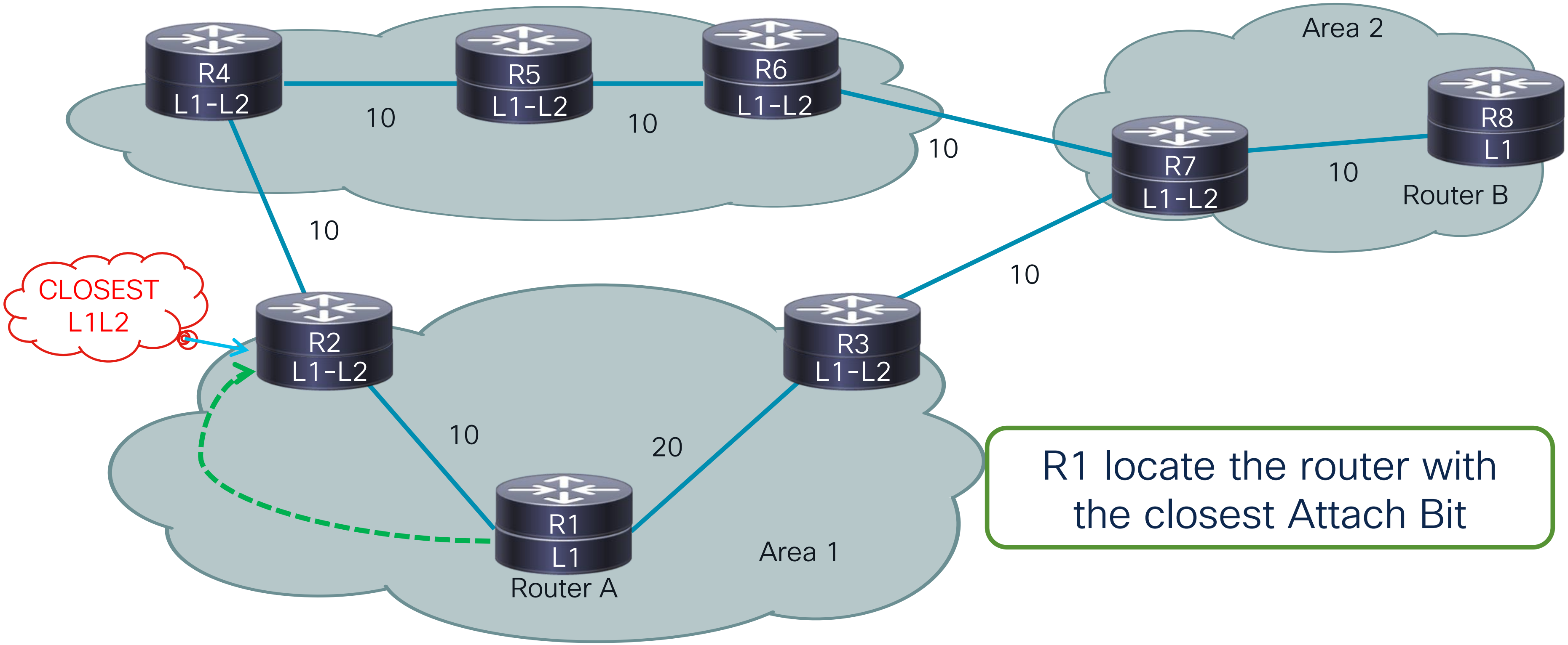
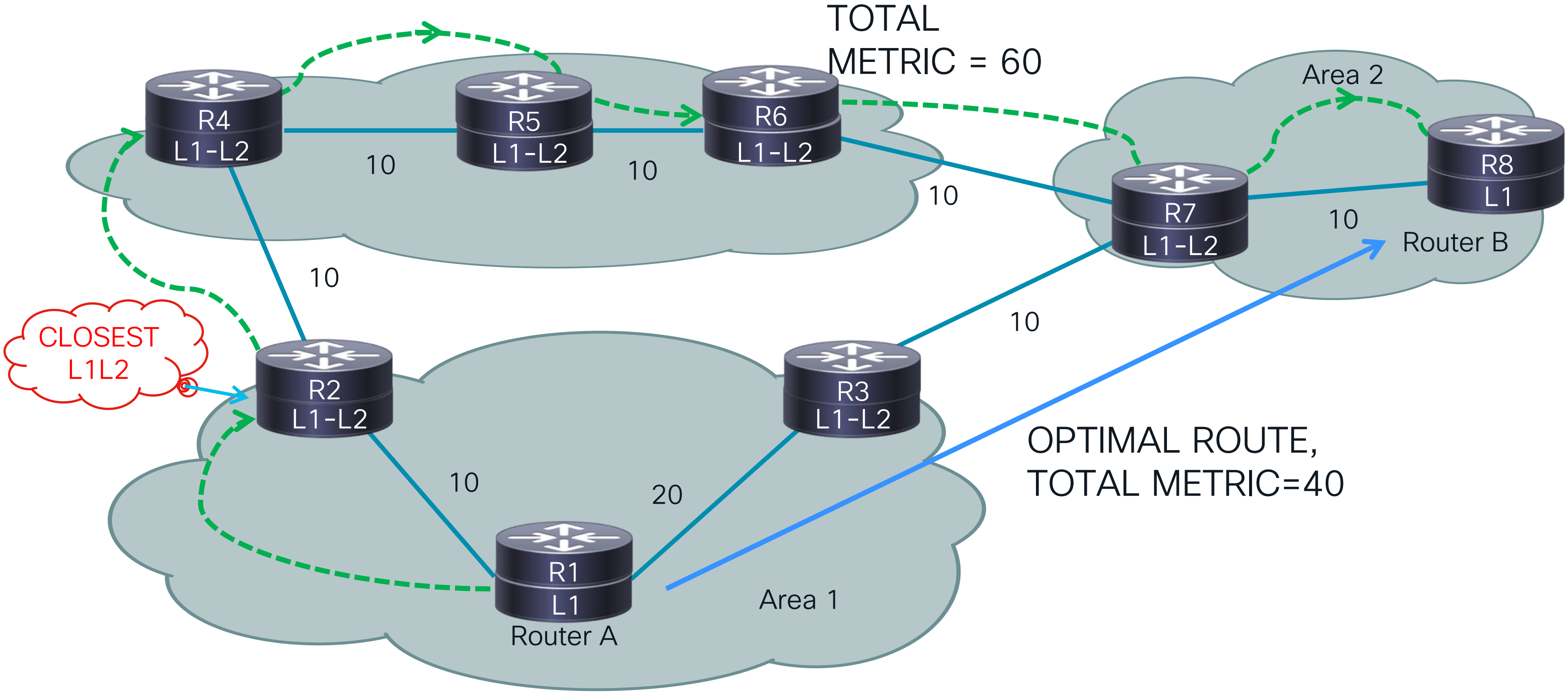
Areas and Suboptimal Routing



R1 locate the router with the closest Attach Bit

Areas and Suboptimal Routing



Overcoming Areas and Suboptimal Routing

- All the L1-routers in a given pop will receive the ATT bit set by the L1L2 router at the edge of the POP
    - L1 routers install a default route based on the ATT bit
    - This will cause sub-optimal routing in reaching the prefixes outside the POP by the local routers
- This can be overcome by Leaking more explicit L2 routes into the L1 area

L2 → L1 Leaking Configuration

IOS XE

```
R1#conf t
R1(config)#router isis CISCOLIVE
R1(config)#redistribute isis ip level-2 into level-1
```

IOS XR

```
RP/0/0/CPU0:XR2#conf t
RP/0/0/CPU0:XR2(config)#router isis CISCOLIVE
RP/0/0/CPU0:XR2(config-isis)#address-family ipv4 unicast
RP/0/0/CPU0:XR2(config-isis-af)# propagate level 2 into level 1
```

NX-OS

```
R1#conf t
NX-3(config)# router isis CISCOLIVE
NX-3(config-router)# distribute level-2 into level-1 all
```

L2 → L1 Leaking Configuration (Conditions)

IOS XE

```
R1#conf t
R1(config)#router isis CISCOLIVE
R1(config)#redistribute isis ip level-2 into level-1 route-map CONDITIONAL
```

IOS XR

```
RP/0/0/CPU0:XR2#conf t
RP/0/0/CPU0:XR2(config)#router isis CISCOLIVE
RP/0/0/CPU0:XR2(config-isis)#address-family ipv4 unicast
RP/0/0/CPU0:XR2(config-isis-af)# propagate level 2 into level 1 route-policy CONDITIONAL
```

NX-OS

```
R1#conf t
NX-3(config)# router isis CISCOLIVE
NX-3(config-router)# distribute level-2 into level-1 route-map CONDITIONAL
```

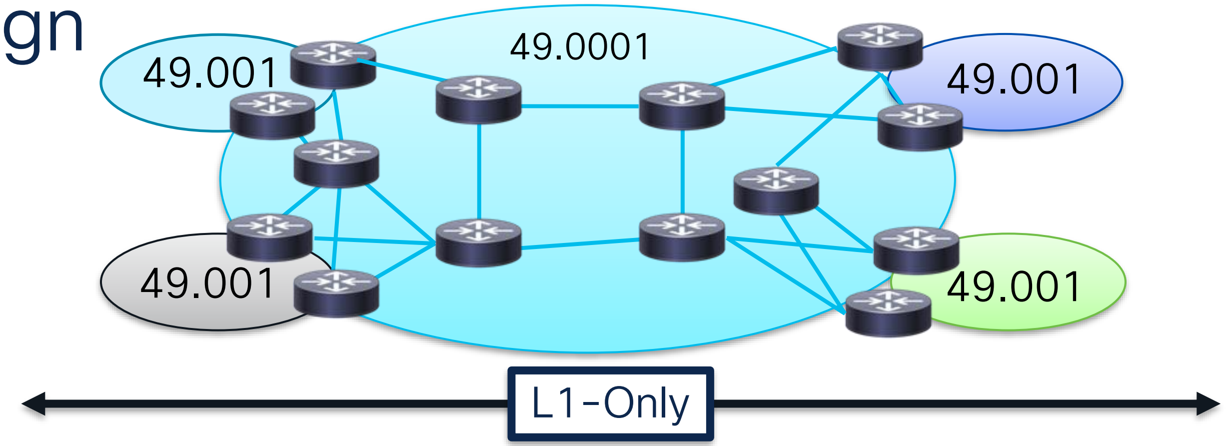
Area and Scaling

Areas vs. single area

- ISIS supports a large number of routers in a single area
  - More than 400 routers in the backbone is possible
- Starting with L2-only everywhere is a good choice
  - Backbone continuity is ensured from the start
  - Future implementation of level-1 areas will be easier
- Use areas in places where sub-optimal routing is acceptable
  - areas with a single exit point is a better choice from an optimal routing standpoint

Area Design

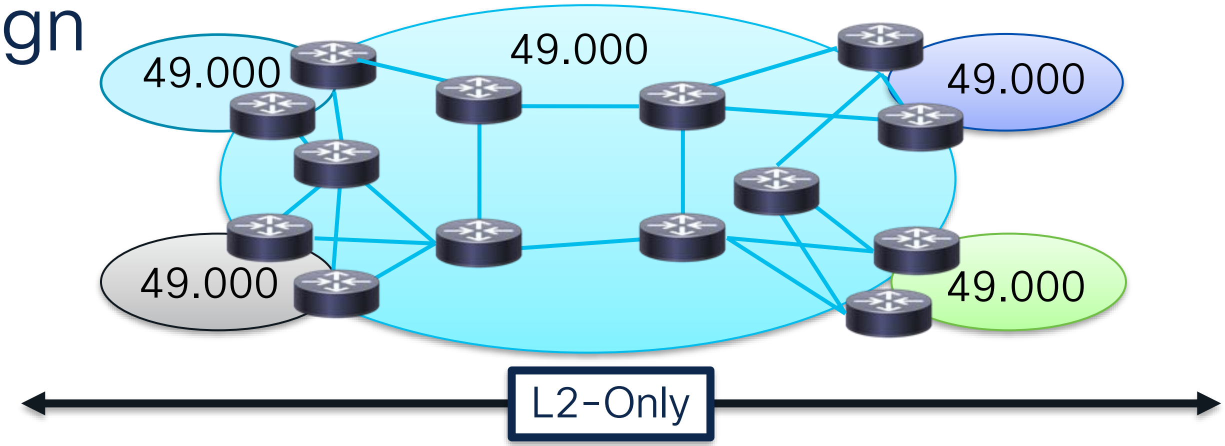
L1-Only POP



- In this design, all the routers will be running in one area and are all doing L1-only routing
- This design is flat with a single L1-only database running on all the routers
- If you have a change in the topology, the SPF computation will be done in all the routers as they are in the L1-only domain
- SPs picked L1-only to avoid sub-optimal routing problems

Area Design

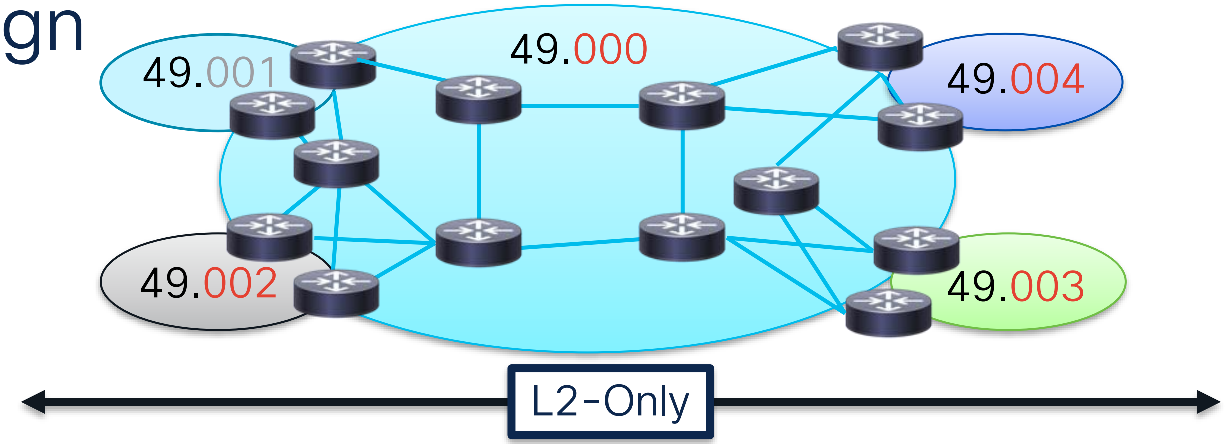
L2-Only POP



- In this design, all the routers will be running L2-Only in the network
  - With the <u>same</u> Area in all the POPs
- Optimal routing with L2-only database
- Traffic-engineering support with no restrictions, just like L1-only

Area Design

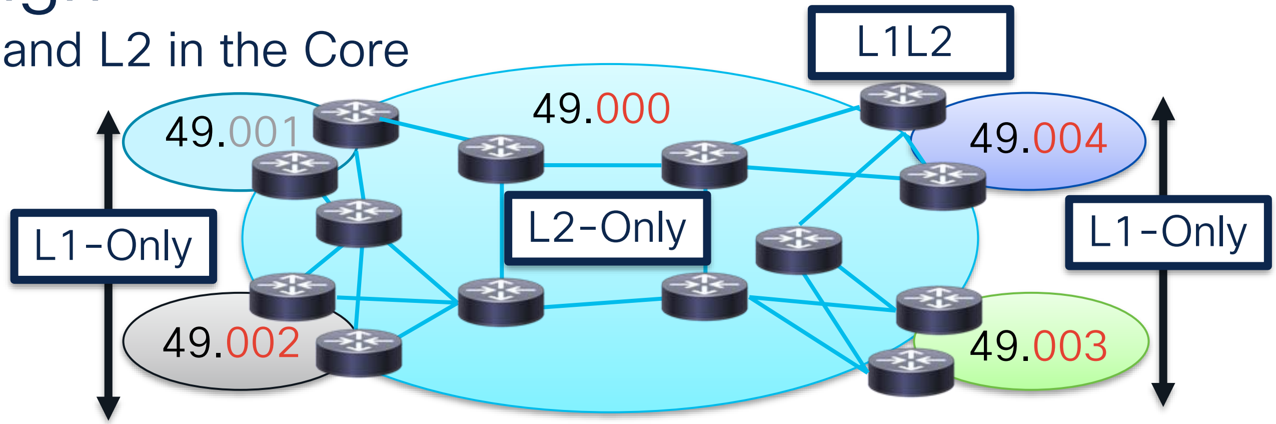
L2-Only POP



- In this design, all the routers will be running L2-Only in the network
  - With the different Area in all the POPs
  - No summarization and No route-leaking
- All the routers in L2 will share all the LSPs and provides optimal routing (similar to L1-Only POPs)
- As the network grows, easy to bring the L1-only POPs/sub-networks for easy migration

Area Design

L1 in the POP and L2 in the Core

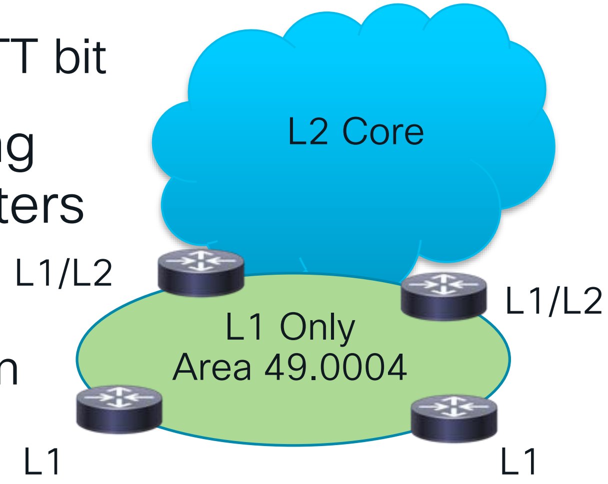


- Within a given local pop—all the routers will be in a separate area
- The L1-L2 routers at the edge of the POPs will be running
  - L1-adj going into the POP
  - L2-adj into the core with the rest of the L1-L2 routers
- The SPF computations will be limited to the respective L1-areas only

Area Design

L1 in the POP and L2 in the Core

- All the L1-routers in a given pop will receive the ATT bit set by the L1L2 router at the edge of the POP
  - L1 routers install a default route based on the ATT bit
- This will cause sub-optimal routing in reaching the prefixes outside the POP by the local routers
- Summarization at the L1L2 boundary
  - potential sub-optimal inter-area routing in certain failure conditions
  - potential black-holing of traffic
  - potential breaking of MPLS LSP among PEs



L1-L2 Router at Edge of POP

Route-Leaking

- It is recommended to configure the L1-L2 routers at the edge of the pop with route-leaking capabilities
- Leak BGP next-hops and summarize physical link
- Hence the L1 routers will be able to take the right exit/entry router based on the metric of the leaked IP-prefix
  - Optimal Inter-Area Routing
- Ensure 'metric-style wide' is configured when leaking routes e.g. MPLS-VPN (PEs Loopback Reachability and LSP binding)

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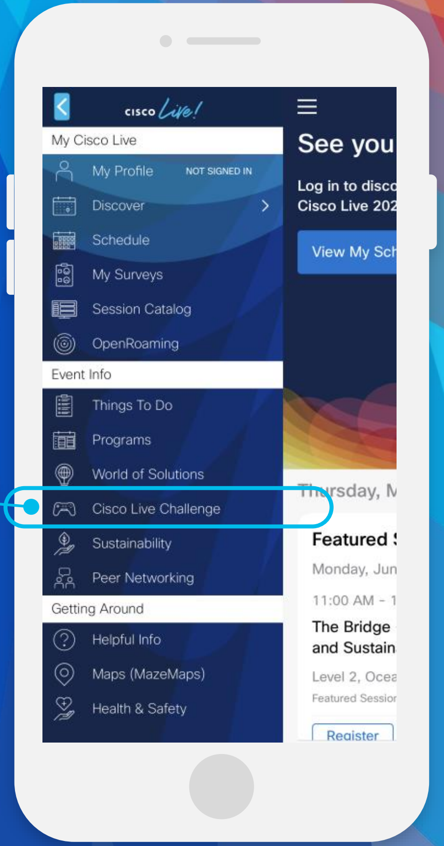

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Let's go