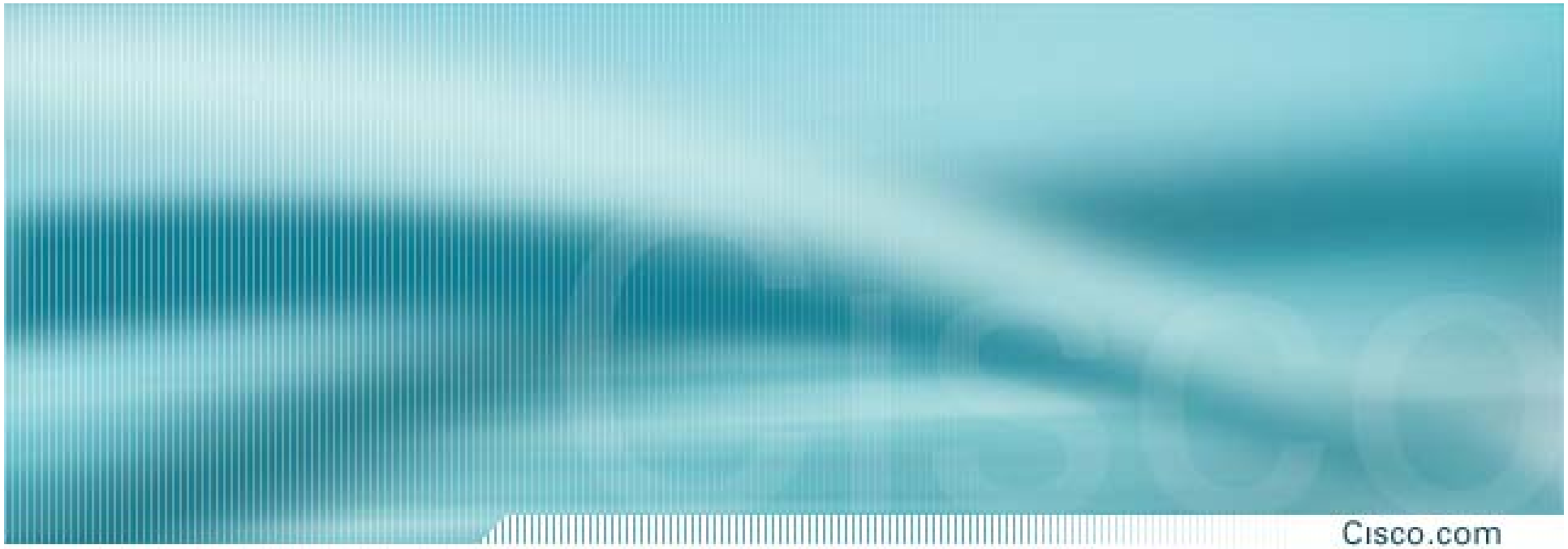

IS-IS for IPv6

Khalid Raza

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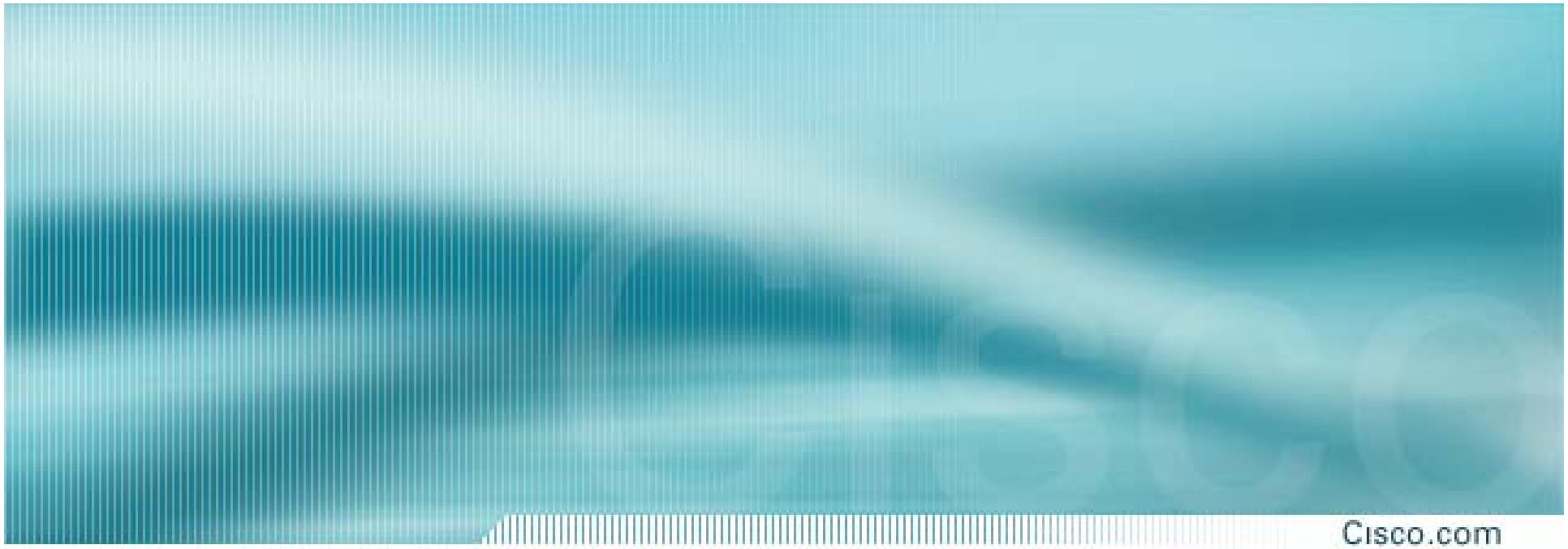


Refresher on Fundamentals

ISIS basics

- ISO laid foundation for seven layer model
- Defined connection less network service (CLNS)
- CLNS provides datagram service
- This service is supported by three protocols
  1. Connectionless Networks Protocol (CLNP)
  2. End system to Intermediate system
  3. Intermediate system to Intermediate system

ISIS basics

- Each of them is a separate network layer protocol
- They can coexist at layer 3
- Each of them run directly on top of datalink layer (FEFE)
- They are differentiated by the protocol identifier

  CLNP: 0x81

  IS-IS: 0x83

  ES-IS: 0x82

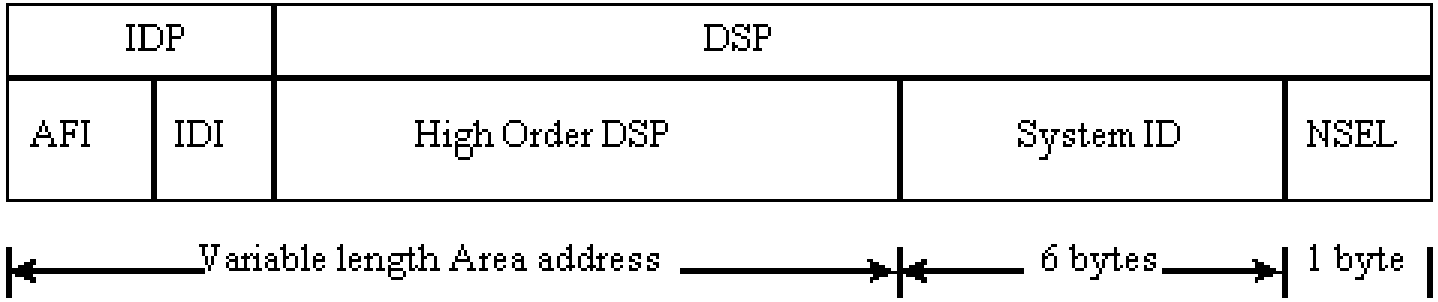
ISIS basics

- **IS-IS as routing protocol**
  - **Designed to run as intradomin routing protocol (IGP)**
  - **Link state protocol**
  - **Provide fast convergence**
  - **Extended to provide routing service to IP network (RFC1195)**

ISIS Fundamentals

- **IS-IS addressing**
- **NSAP: Network Service Access Point**
- **An NSAP has an address that consists of 3 parts**
  - **Variable length area-address**
  - **6 Byte system ID**
  - **1 Byte n-selector (indicating transport layer)**
- **Total length between 8 and 20 bytes**

ISIS Fundamentals



- **ISO/IEC 10589 distinguishes only 3 fields in the NSAP address format**

Area Address: variable length field composed of high order octets of the NSAP excluding the SystemID and SEL fields

SystemID: defines an ES or IS in an area. Cisco implements a fixed length of 6 octets for the SystemID

NSEL: selector, also designated as N-selector. It is the last byte of the NSAP and identifies a network service user (transport entity or the IS network entity itself)

IS-IS fundamentals

- **Fundamentally 3 types of packet**
  1. **Hello**
  2. **Link State Packets**
  3. **Sequence number packets**

IS-IS fundamentals

- **ISIS packet format**

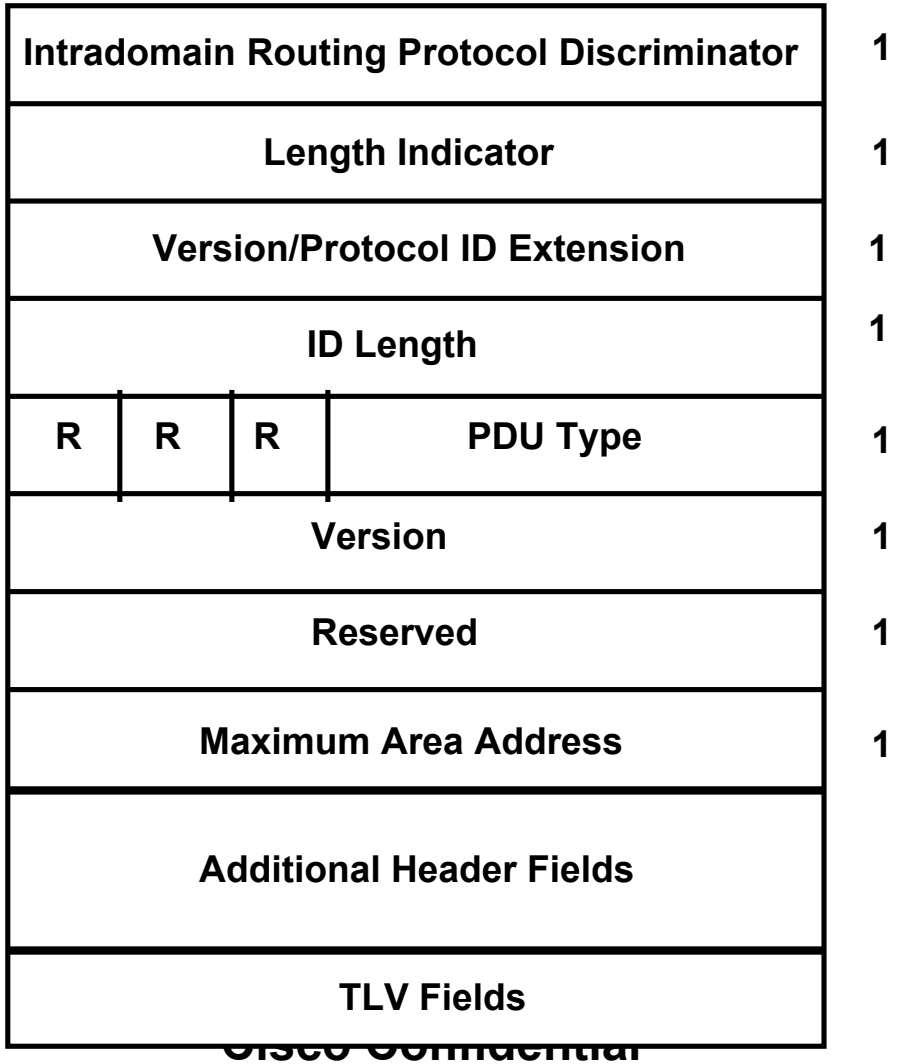
  Each ISIS packet is made up of a header and a number of optional variable length TLV's

  Typically the value is composed of repeated blocks of similar information

  Different types of ISIS packets have slightly different composition of header except for the first 8 bytes each one byte long.

IS-IS fundamentals

- **ISIS Header**



ISIS Fundamentals

- **Intradomain Routing Protocol Discriminator**

  Indicates the network layer protocol, ISIS is 0x83, CLNP is 0x81

- **Length Indicator: Length of Header fields in octet**
- **Version Protocol ID Extension: Currently set to 1**
- **ID Length: Indicates the length of system ID if set to 0 then the length is 6 bytes (Cisco has this fixed)**
- **PDU Type: Type of ISIS packet, Hello, LSP, SNP**
- **Version: This value is 1**
- **Reserved: Unused, set to 0**
- **Maximum Area Address: A value of 0 indicates that maximum 3 address per area**

ISIS Fundamentals

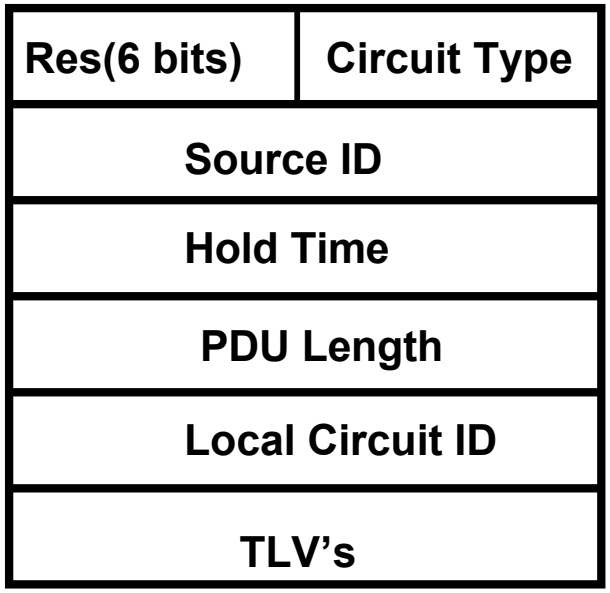
TLV	Type	Description
IP Internal Reachability Information	128	Intradomain ISIS routes
Protocol Supported	129	Supported network layer protocol
IP External Reachability Information	130	Routes redistributed into ISIS
IP Interface address	132	IP address of outgoing interface
IPv6 Reachability	236	Equivalent to IP Internal/ External Reachability TLV's
IPv6 Interface Address	232	IPv6 address of outgoing interface

ISIS Fundamentals

- **Hello Packet in ISIS**
  1. **Point-to-Point IIH (local Circuit id) PDU 17**
  2. **Level 1 LAN IIH (LAN id, priority) PDU 15**
  3. **Level 2 LAN IIH PDU 16**

ISIS Fundamentals

- **Additional header fields for Point-to-Point hello**



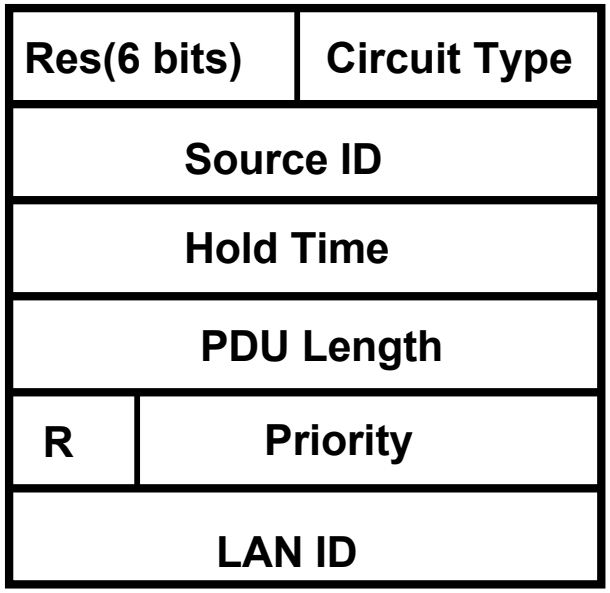
Circuit Type: Level 1 or Level 2
Source ID: System ID of generating router
Holding Time: Maximum time between two consecutive hellos
PDU Length: Length of PDU including the header
Local Circuit ID: Unique Identifier

ISIS fundamentals

- **Hello packets carries**
  1. **TLV 129 Protocols supported**
  2. **TLV 132 IP interface address**

ISIS Fundamentals

- **Additional Header fields for LAN hello**



Priority: 7 bits long to decide who will be DIS
LAN ID: System ID of DIS plus an octet long unique identifier assigned by the DIS

ISIS-Fundamentals

- Level 1 link state packet (PDU 18)
- Level 2 link state packet (PDU 20)

ISIS Fundamentals

- **Link State Packets**

Remaining Lifetime: Time remaining for LSP to expire

LSP Identifier: System ID of the source + PSN ID + LSP number

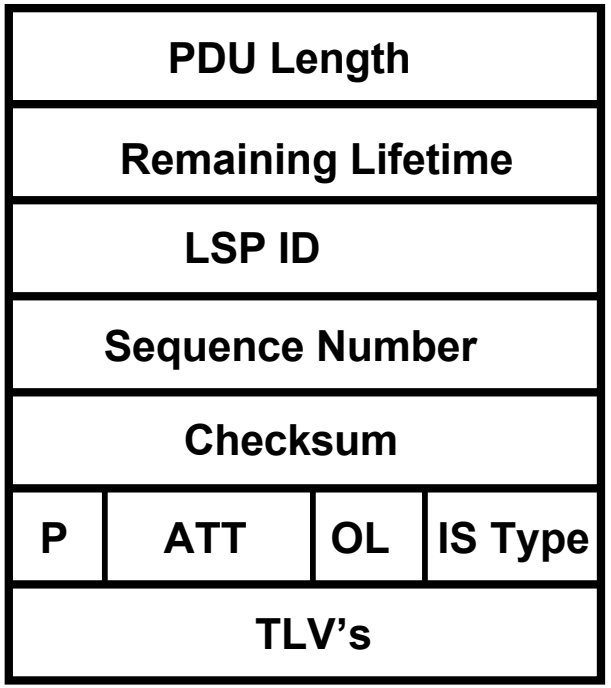
Sequence Number: Sequence number of LSP

Partition: Bit 8, used to indicate support for partition repair

Attached: Bit 4-7 L2 router to indicate attachment to another area

Overload: Bit 3 Indicates that source is overloaded

IS Type: Bits 1 and 2 to indicate if it is L1 or L2



ISIS Fundamentals

- **IP Internal Reachability information (TLV 128)**
  - **Stores lists of directly connected IP prefixes**
  - **Each prefix is assigned a metric value, which is that of the link over which the IP prefix is configures**
  - **Value is 12 bytes: 4 bytes metric, 4 byte IP prefix, 4 byte mask**

ISIS Fundamentals

- **IP Internal Reachability information (TLV 128)**

Default Metric: Value of the metric for link, these are 6 bits and bit 7 is for Internal/External bit 8 is reserved, its 0.

Delay Metric: This is the value of delay to reach the neighbor, if not supported then S bit is set R is reserved bit, set to 0 on transmission and ignored on reception

0	I/E	Default metric
S	R	Delay Metric
S	R	Expense Metric
S	R	Error Metric
IP Address		
Subnet Mask		

Expense: Relates to the financial cost of the link

Error: Error probability of the link

ISIS Fundamentals

- **Protocol Supported TLV 129**
  - **Defines the supported layer 3 protocols**
  - **This appears in LSP number 0**
  - **Currently supported protocols**

CLNP	0x81
IPv4	0xCC
IPv6	0x8E

ISIS Fundamentals

- IP Interface Address TLV 132
- Depending upon the type of packet its function differs slightly
  - IP interface address of the outgoing interface
  - One or more IP address associated with the router, in current Cisco IOS this is highest loopback address of the router

ISIS Fundamentals

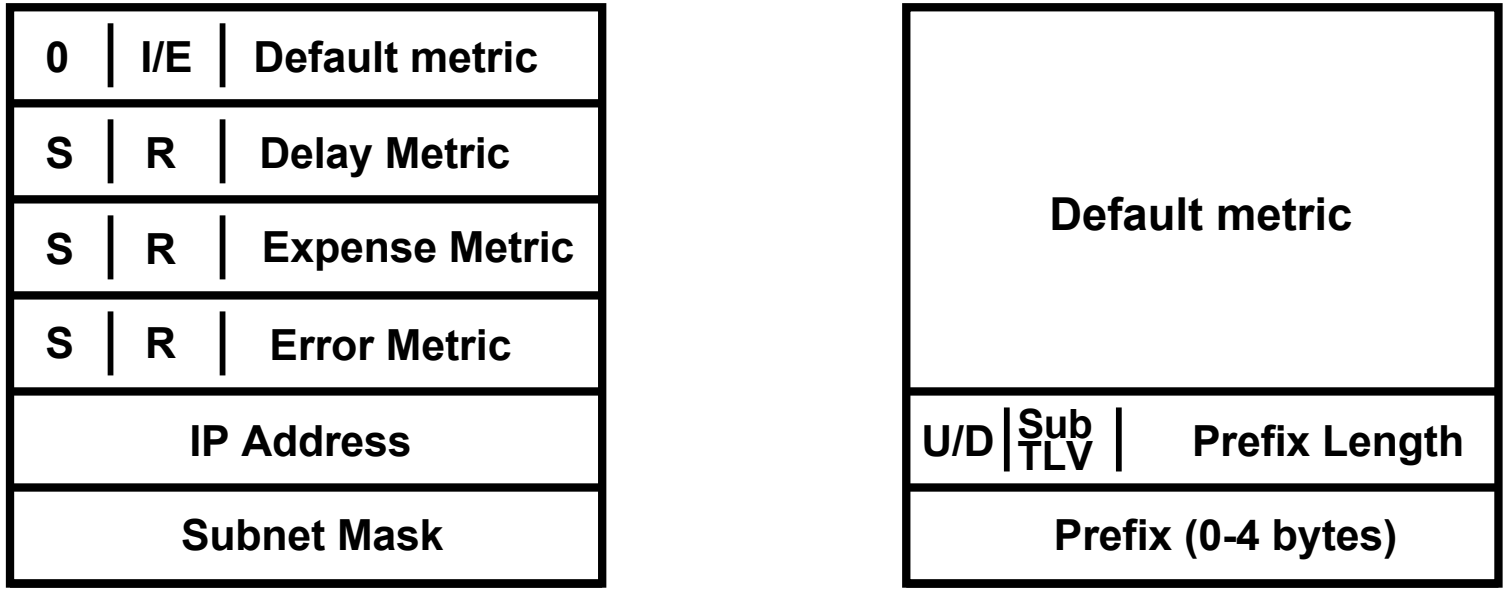
- **IP External Reachability Information TLV 130**
  - **All routes redistributed into ISIS, source is from other routing protocols**
  - **Only allowed in level 2 but we allow is for L1 as well**
  - **We only support default metric**

ISIS Fundamentals

- **Extended IP Reachability TLV 135**

  Delay, Expense and Error were for QOS for CLNP packet header, these were optional path selection service for network

  TLV is used to extend the metric from 6 to 32 bits



IPv6 New TLV's

- **IPv6 Reachability TLV 236**

  Defines both IPv6 Internal and External reachability information

  Metric is still 32 bits

  U: Up/Down

  X: External origin bit

  S: Sub-TLV present

  Prefix length: Length of prefix 8 bits

  Prefix: Number of octet is calculated depending on the prefix length

IPv6 New TLV's

- **IPv6 address TLV 232**

  Modified to carry IPv6 address

  For hello PDU interface address must use link local IPv6 address assigned to the interface

  For LSP non-link local address must be used

IS-IS for IPv6

- 2 Tag/Length/Values added to introduce IPv6 routing
- IPv6 Reachability TLV (0xEC)

  External bit

  Equivalent to IP Internal/External Reachability TLV's
- IPv6 Interface Address TLV (0xE8)

  For Hello PDUs, must contain the Link-Local address

  For LSP, must only contain the non-Link Local address
- IPv6 NLPID (0x8E) is advertised by IPv6 enabled routers

Agenda

- IS-IS standardization
- Cisco IOS IS-IS for IPv6
- Cisco IOS Multi-Topology IS-IS

Cisco IOS IS-IS for IPv6

- IS-IS for IPv6 was introduced across Cisco IOS releases
  - Since 12.2(8)T, now on 12.3M and 12.3T on Cisco 2600 to Cisco 7500 series
  - 12.0(22)S and above on Cisco 12000
  - 12.2(14)S and above on Cisco 7x00 series and Cat.6K [12.2SX]
  - Images are –p and –js as CLNS is required for IS-IS
- A single SPF runs per level for OSI, IPv4 and IPv6
  - All routers in an area must run the same set of protocols [IPv4-only, IPv6-only, IPv4-IPv6]
  - L2 routers may not be configured similarly but no routing hole must exist

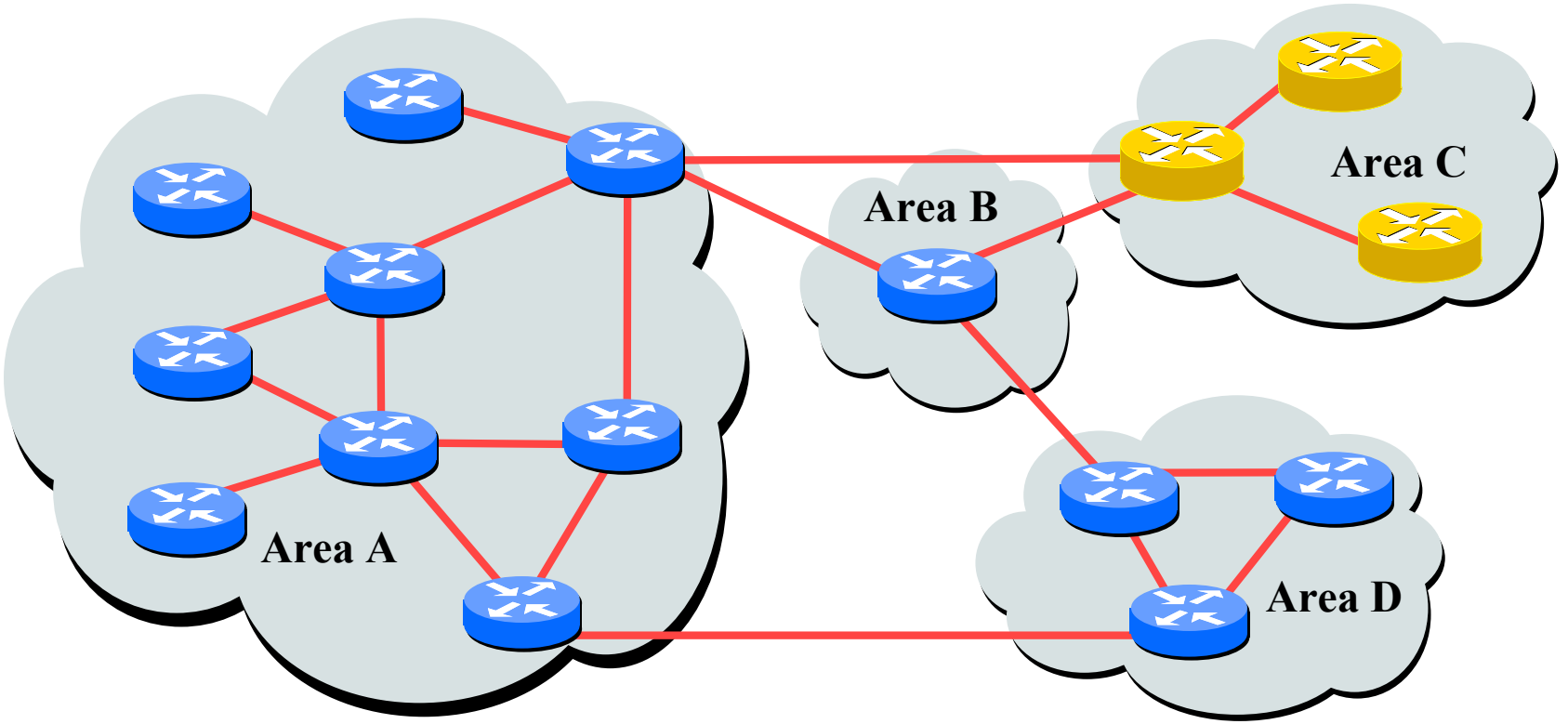
Single SPF rules

- If IS-IS is used for both IPv4 and IPv6 in an area, both protocols must support the same topology within this area.
  - Could set “no adjacency-check” between L2 routers, but must be used with caution
- All interfaces configured with IS-ISv6 must support IPv6
  - Can’t be configured on DPT as it is not yet supported
  - Can’t be configured on MPLS/TE since IS-ISv6 extensions for TE are not yet defined
- All interfaces configured with IS-IS for both protocols must support both of them
  - IPv6 configured tunnel won’t work, GRE should be used in this configuration
- Otherwise, consider Multi-Topology IS-IS (separate SPF)

Single SPF IS-IS for IPv6 Restrictions

- IS-IS for IPv6 uses the same SPF for both IPv4 and IPv6. Therefore:
- Not really suitable for an existing IPv4 IS-IS network where customer wants to turn on scattered IPv6 support.
- If using IS-IS for both IPv4 and IPv6 then the IPv4 and IPv6 topologies MUST match exactly. Cannot run IS-IS IPv6 on some interfaces, IS-IS IPv4 on others.
- Will only form adjacencies with similarly-configured routers. E.g. An IS-IS IPv6-only router will not form an adjacency with an IS-IS IPv4/IPv6 router. (Exception is over L2-only interface)
- Cannot join two IPv6 areas via an IPv4-only area. L2 adjacencies will form OK but IPv6 traffic will black-hole in the IPv4 area.

IS-IS Hierarchy & IPv6 example



IPv4-IPv6 enable router

IPv4-only enable router

Configuring IS-IS for IPv6 on Cisco IOS

- **Configure generic IS-IS interface attributes**

  Eg., circuit type, priority, etc

- **Configure IS-IS for IPv6 on interfaces**

  Interface must be IPv6 enabled, eg. IPv6 address set

- **Configure IS-IS router mode attributes**

  Some router-mode commands have no effect on IPv6, eg. Metric-style, mpls, traffic-share,…

- **Configure IS-IS for IPv6 specific attributes**

  IPv6 attributes are configured via the IPv6 address-family sub-mode of router-mode.

Cisco IOS IS-IS for IPv6 Specific Attributes

- **Entering address-family sub-mode**

  [no] address-family ipv6

- **IPv6 address-family sub-mode.**

  [no] adjacency-check

  Enables or disables adjacency IPv6 protocol-support checks. If checking is enabled (default condition when IS-IS IPv6 is configured) then the router will not form an adjacency with a neighbor not supporting IS-IS IPv6.

  [no] distance <1-254>

  Sets the administrative distance of IS-IS IPv6. Note that the administrative distance is applied to routes in the IPv6 routing table only.

  [no] maximum-paths <1-4>

  Sets the maximum number of paths allowed for a route learnt via IS-IS IPv6. Note that this applies to the IPv6 routing table only.

  [no] default-information originate [route-map <name>]

  Configures origination of the IPv6 default route (::) by IS-IS. Used in the same manner as the existing IPv4 "default-information" command.

Cisco IOS IS-IS for IPv6 Specific Attributes

[no] summary-prefix <prefix> [level-1|level-2|level-1-2]

Configures IPv6 summary prefixes. Command is used in same manner as the existing IPv4 "summary-prefix" command.

[no] redistribute <protocol> [metric <value>] [metric-type {internal|external}] [level-1|level-1-2|level-2] [route-map <name>]

Configures redistribution of routes learnt from other IPv6 sources into IS-IS. Command is used in same manner as existing IPv4 "redistribute" command.

[no] redistribute isis {level-1|level-2} into {level-1|level-2} distribute-list <prefix-list-name>

Configures IS-IS inter-area redistribution of IPv6 routes. Command is used in same manner as existing IPv4 "redistribute isis" command.

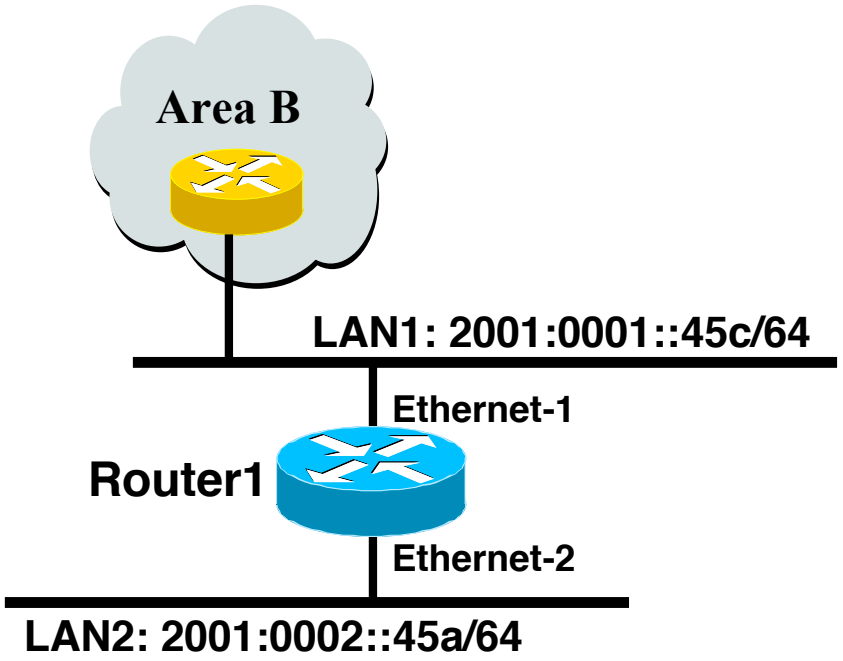
- **Leaving address-family sub-mode**

  exit-address-family

- **Showing the I/IS-ISv6 configuration**

  Show ipv6 protocols [summary]

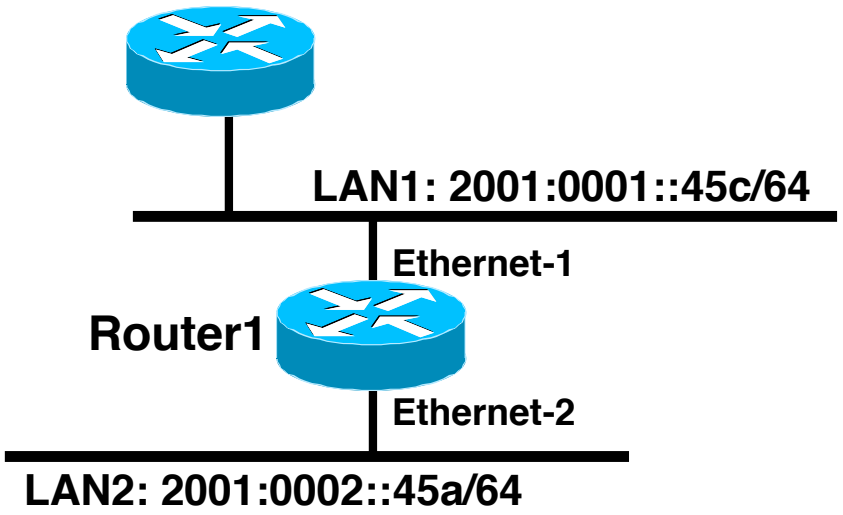
Cisco IOS IS-IS for IPv6-only configuration example



IPv6-only configuration.
Redistributing IPv6 static routes.

```
Router1#
 interface ethernet-1
     ipv6 address 2001:0001::45c/64
     ipv6 router isis
     isis circuit-type level-2-only

  interface ethernet-2
     ipv6 address 2001:0002::45a/64
     ipv6 router isis

  router isis
      address-family ipv6
      redistribute static
      exit-address-family
      net 42.0001.0000.0000.072c.00
```

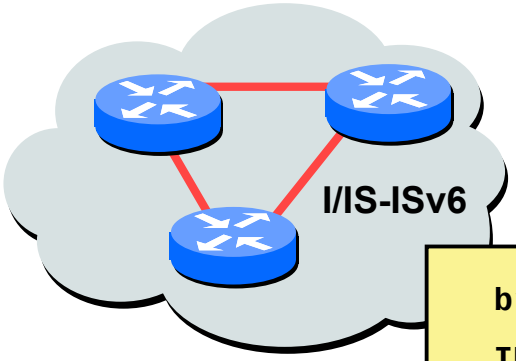
Cisco IOS IS-IS dual IP configuration




```
Router1#
 interface ethernet-1
     ip address 10.1.1.1 255.255.255.0
     ipv6 address 2001:0001::45c/64
     ip router isis
     ipv6 router isis

  interface ethernet-2
     ip address 10.2.1.1 255.255.255.0
     ipv6 address 2001:0002::45a/64
     ip router isis
     ipv6 router isis

  router isis
      address-family ipv6
      redistribute static
      exit-address-family
      net 42.0001.0000.0000.072c.00
      redistribute static
```

Dual IPv4/IPv6 configuration. Redistributing both IPv6 static routes and IPv4 static routes.

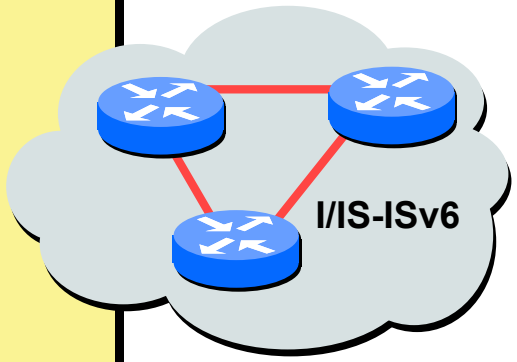
Cisco IOS IS-IS Display (1)

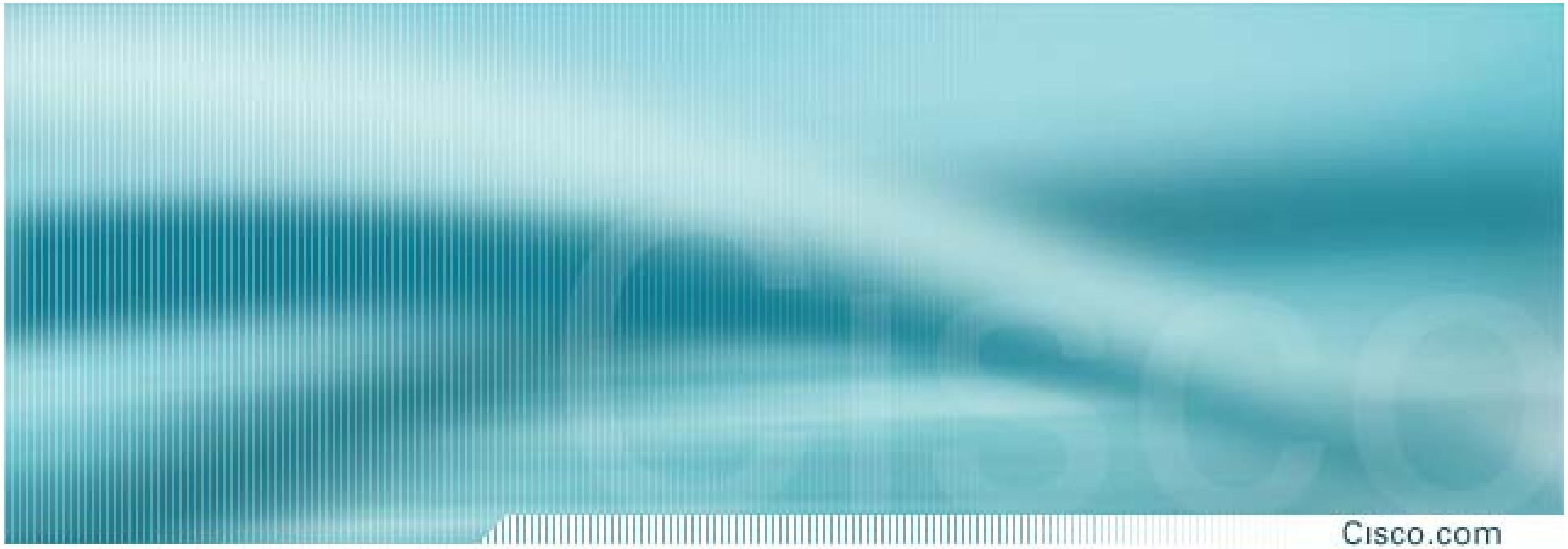



```
brum-45c#sho ipv6 rou is-is
IPv6 Routing Table - 14 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea
Timers: Uptime/Expires

I1  2001:45A:1000::/64 [115/20]
     via FE80::210:7BFF:FEC2:ACCC, Ethernet1, 00:10:12/never
I1  2001:72B:2000::/64 [115/10]
     via FE80::210:7BFF:FEC2:ACCC, Ethernet1, 00:05:19/never
I1  2002:49::/64 [115/10]
     via FE80::210:7BFF:FEC2:ACCC, Ethernet1, 00:05:19/never
```

Cisco IOS IS-IS Display (2)


```
brum-45c#sho clns is-neigh detail

System Id      Interface   State  Type Priority  Circuit Id         Format
brum-45a       Et1         Up     L1   64        brum-45c.01        Phase V
  Area Address(es): 47.0023.0001.0000.0001.0002.0001
  IPv6 Address(es): FE80::210:7BFF:FEC2:ACCC
  Uptime: 00:06:56

IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
brum-45c.00-00      * 0x00000003   0xA745        732               0/0/0
  Area Address: 47.0023.0001.0000.0001.0002.0001
  NLPID:        0x8E
  Hostname: brum-45c
  IPv6 Address: 3F02::45C
  IPv6 Address: 2001:45C:2000::45C
  Metric: 10         IPv6 2001:45C:1000::/64
  Metric: 10         IPv6 3F02::/64
  Metric: 10         IPv6 2001:45C:2000::/64
  Metric: 10         IS brum-45c.02
  Metric: 10         IS brum-45c.01
brum-45c.01-00      * 0x00000001   0x96DB        733               0/0/0
  Metric: 0          IS brum-45c.00
  Metric: 0          IS brum-45a.00
brum-45a.00-00        0x00000005   0xDDBA        1027              0/0/0
  Area Address: 47.0023.0001.0000.0001.0002.0001
  NLPID:        0x8E
  Hostname: brum-45a
  IPv6 Address: 2001:45A:1000::45A
  Metric: 10         IPv6 2001:45A:1000::/64
  Metric: 10         IS brum-45c.01
  Metric: 0          IPv6-Ext 2001:72B:2000::/64
  Metric: 0          IPv6-Ext 2002:49::/64
```





Multi-Topology IS-IS

Agenda

- Introduction
- The problem
- Multi-topologies architecture
- Implementation
- Applications
- Conclusion

Introduction

- Mechanism that allows IS-IS, used within a single domain, to maintain a set of independent IP topologies
- Multi-Topologies extension can be used to maintain separate topologies for:
  - IPv4
  - IPv6
  - Multicast
- Topologies need not to be congruent (of course)
- Multiple topologies for same address family is allowed
  - Think about QBR…
  - The multicast dimension …
- IETF draft: draft-ietf-isis-wg-multi-topology

Agenda

- Introduction
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- Conclusion

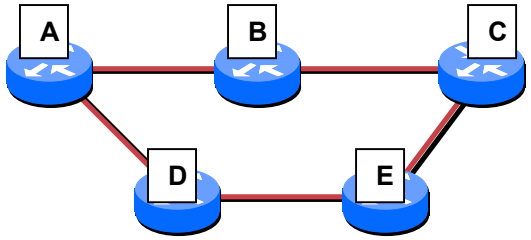
The problem

- IS-IS has the flexibility to carry routing information for different address families
  - Currently: clns, ipv4, ipv6, nlsp
- Other extensions are possible:
  - multicast

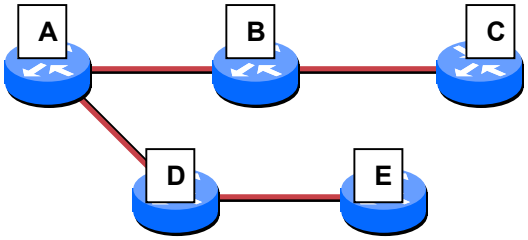
The problem

- Current IS-IS spec and implementation forces all protocols carried by IS-IS to agree on a common Shortest Path Tree
  - Single SPF run for all protocols
- Single SPT means congruent topologies
- Single SPT means all links need to understand all address families present in the domain

The problem



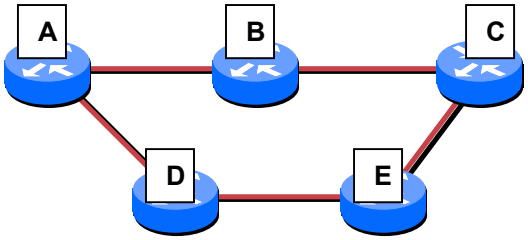
Physical Topology



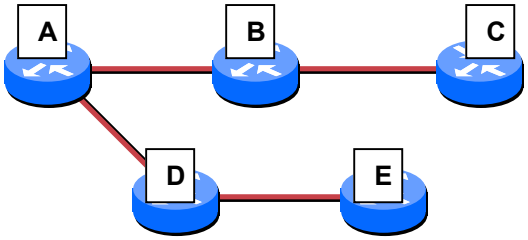
Shortest Path Tree

- From A perspective, C is only reachable through B
  - There is no path from E to C
- All protocols carried by IS-IS have to agree on the same SPT
  - No way to distribute traffic across the domain
  - All links need to understand all protocols

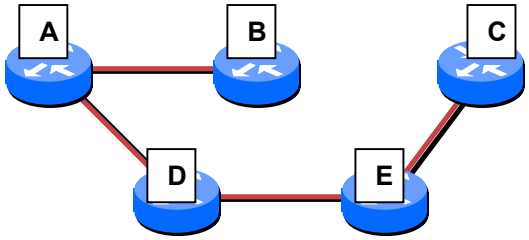
The need



Physical Topology



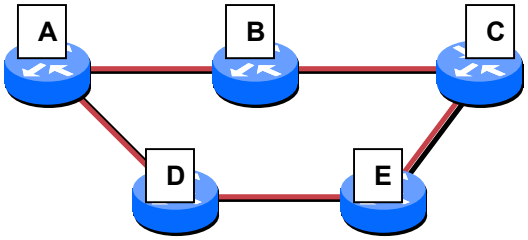
IPv4 Shortest Path Tree



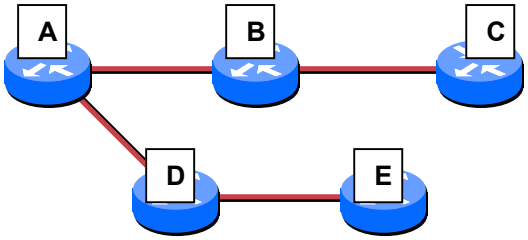
IPv6 Shortest Path Tree

- **Ability to distribute traffic across all links**
  - **Separate traffic per address families**

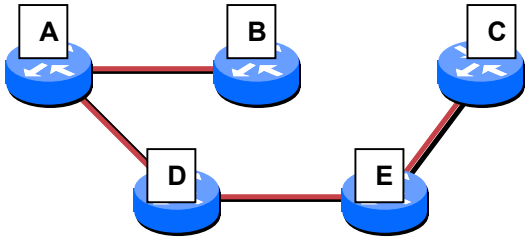
The need



Physical Topology



IPv4 Shortest Path Tree for QoS-1



IPv4 Shortest Path Tree for QoS-2

- **Ability to distribute traffic across all links independently from address families**

  The same AF may have different topologies (QBR, VPN, …)

Agenda

- Introduction
- The problem
- Multi-topologies architecture
- Implementation
- Applications
- Conclusion

IS-IS Multi-Topologies Architecture

- **Each router knows on which topologies he will establish adjacencies and build SPTs**
  - **Through configuration**
- **During adjacency establishment, peers need to agree on topologies**
  - **Topologies identifiers are exchanged in IIH packets**

IS-IS Multi-Topologies Architecture
New TLVs

- New TLVs used to advertise neighbors and IP prefixes
  - TLV-229: Multi-Topologies Identifier
  - TLV-222: Multi-Topologies intermediate system
  - TLV-235: Multi-Topologies Reachable IPv4 address
  - TLV-237: Multi-Topologies Reachable IPv6 address

IS-IS Multi-Topologies Architecture
MT Identifiers

- **Multi-Topologies Identifier describes the address family of the topology**
- **Reserved values are:**

MT ID #0: Equivalent to the “standard” topology.

MT ID #1: Reserved for in-band management purposes.

MT ID #2: Reserved for IPv6 routing topology.

MT ID #3: Reserved for IPv4 multicast routing topology.

MT ID #4: Reserved for IPv6 multicast routing topology.

MT ID #5-#3995: Reserved for IETF consensus.

MT ID #3996-#4095: Reserved for development, experimental and proprietary features.

IS-IS Multi-Topologies Architecture Adjacencies

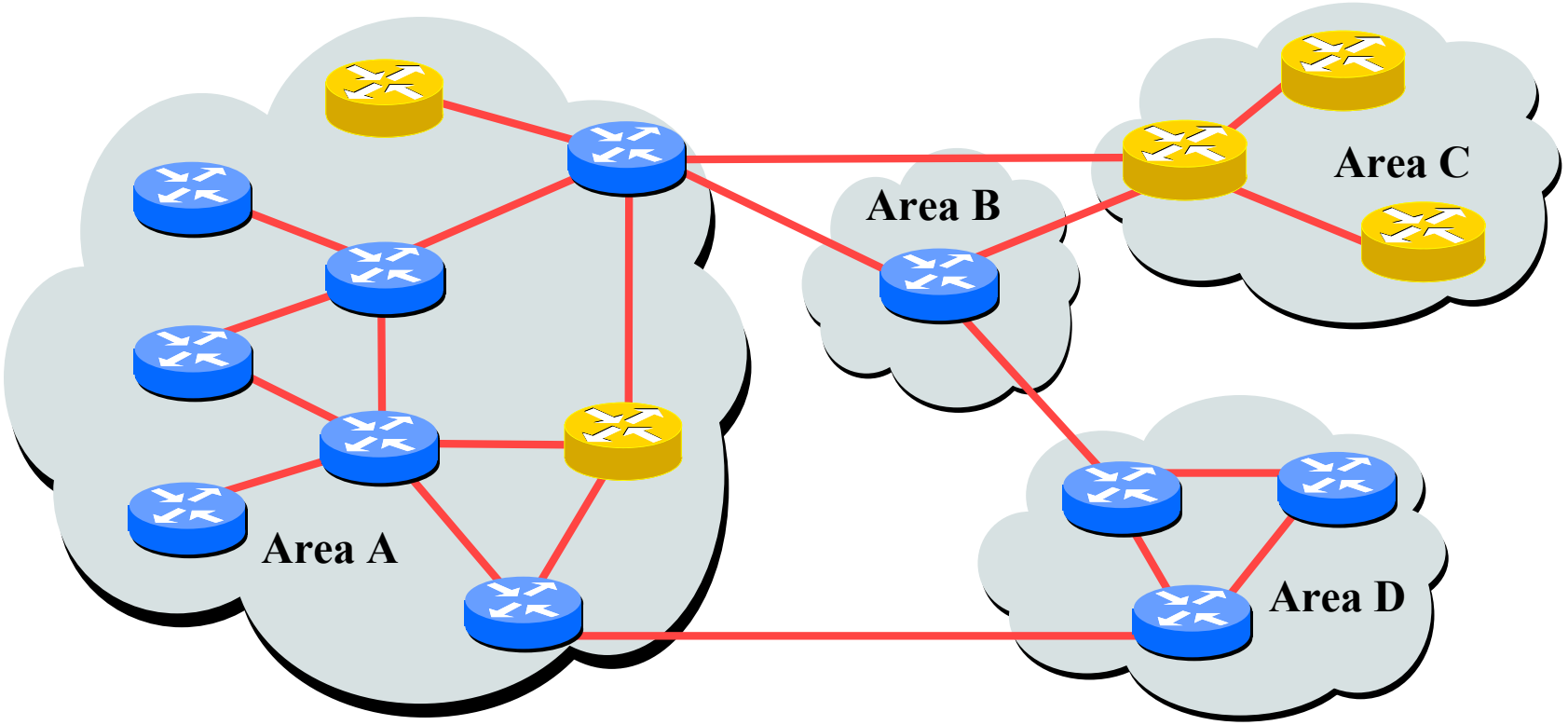
- **Maintaining MT Adjacencies**

  Each adjacency formed MUST be classified as belonging to a set of MTs on the interface.

  MT membership advertised in IIH packets

  Boundaries between levels will be the same for all MTs.

Multi-Topology IS-IS example

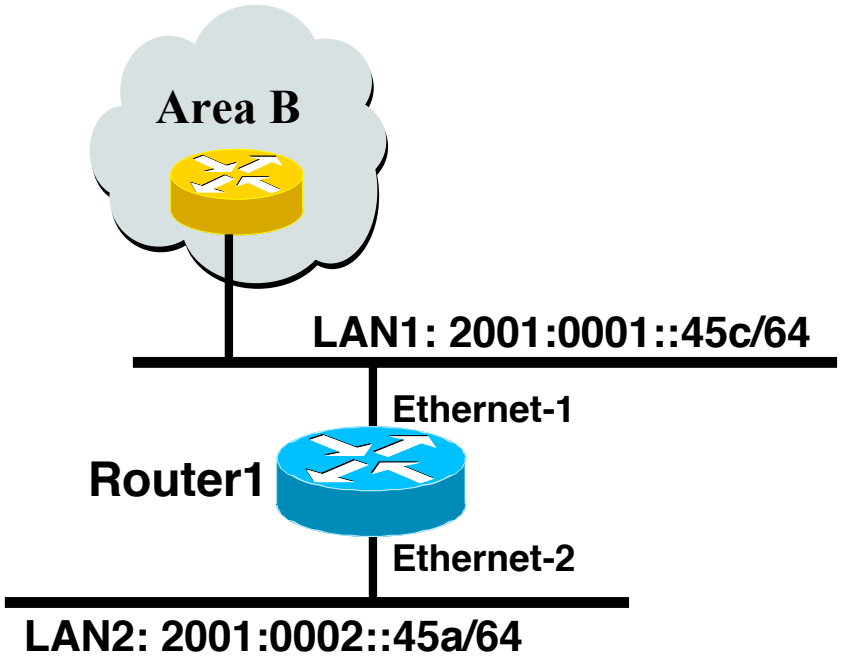


IPv4-IPv6 enable router

IPv4-only enable router

The Multi-Topology software will create two topologies inside Area
IPv4 and IPv6.
IPv4-only routers will be excluded from the IPv6 topology

Cisco IOS Multi-Topology IS-IS configuration example



- The optional keyword *transition* may be used for transitioning existing IS-IS IPv6 single SPF mode to MT IS-IS.
- Wide metric is mandated for Multi-Topology to work.

```
Router1#
 interface ethernet-1
    ip address 10.1.1.1 255.255.255.0
    ipv6 address 2001:0001::45c/64
    ip router isis
    ipv6 router isis
    isis ipv6 metric 20


  interface ethernet-2
    ip address 10.2.1.1 255.255.255.0
    ipv6 address 2001:0002::45a/64
    ip router isis
    ipv6 router isis
    isis ipv6 metric 20


router isis
net 49.0000.0100.0000.0000.0500
metric-style wide
!
address-family ipv6
multi-topology
exit-address-family
```

Cisco IOS Multi-Topology IS-IS Display


```
Router# show clns neighbors detail
System Id      Interface   SNPA            State  Holdtime  Type Protocol
2653           Se0/1       *HDLC*          Up     25        L1L2 M-ISIS
               Area Address(es): 49.0000.01
               IP Address(es): 192.168.0.6*
               IPv6 Address(es): FE80::204:C1FF:FEDB:2FA0
               Uptime: 00:01:22
               Topology: IPv4, IPv6

2652# show isis database detail
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP
Holdtime      ATT/P/OL
2651.00-00    0x0000000F   0x0161        1066      0/0/0
               Area Address: 49.0000.01
               Topology: IPv4 (0x0) IPv6 (0x2)
               NLPID: 0xCC 0x8E
               Hostname: 2651
               IP Address: 192.168.0.2
               IPv6 Address: 3FFF:FFFF:2::1
               Metric: 10 IS-Extended 2652.00
               Metric: 10 IS-Extended 2653.01
               Metric: 10 IS (MT-IPv6) 2653.01
               Metric: 10 IP 192.168.0.0/30
               Metric: 20 IP 192.168.0.4/30
               Metric: 10 IP 192.168.1.0/24
               Metric: 20 IPv6 (MT-IPv6) 3FFF:FFFF:1::/64
               Metric: 10 IPv6 (MT-IPv6) 3FFF:FFFF:2::/64
```