

*TOMORROW starts here.*



Cisco *live!*

# IPv6 Deployment Best Practices for the Cable Access Network

Session ID BRKSPG-2607

Jeff Riddel

# Why we need IPv6...



# Agenda

- **IPv6 motivation and challenges**
- Key aspects of IPv6
- IPv6 in cable
- IPv6 for cable modem management
- IPv6 for CPEs
- IPv6 for CPE routers
- Other topics





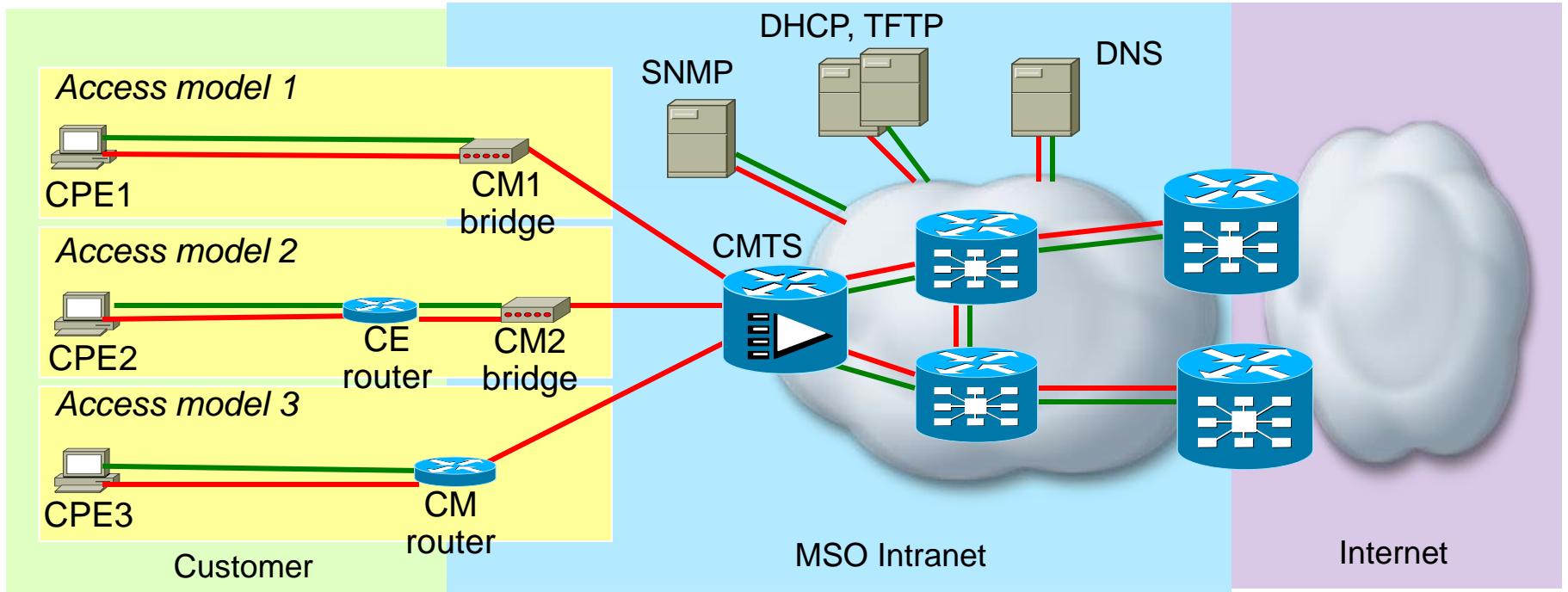
## IPv6 motivation & challenges

# Cable's IPv6 motivators

- Main motivator – **IPv4 address depletion**
- From end user's perspective – marginal incentive to move to IPv6
- Other motivators?



# The transition to IPv6



← IPv4 →

← IPv6 →

# Product requirements



For Your  
Reference

- For the CMTS
  - PRE-4/5 processors (uBR10012); NPE-G2 (uBR72xxVXR)
  - MDF capable line cards (20x20V, 3Gx60V, wideband SPA, wideband 3G SPA, 8x8V)
  - Generally recommend latest IOS releases – 12.2(33)SCG4/SCG5, 12.2(33)SCH
- DOCSIS 3.0 or DOCSIS 2.0+ cable modems
- Generally recommended to use latest releases of BAC/CNR. Minimum recommended release for BAC/CNR are BAC 4.2.1.1 and CNR 7.2.2. BAC now called Cisco Prime Cable Provisioning (initial version 5.0). As of release 8.0 CNR rebranded as Cisco Prime Network Registrar

# Agenda

- IPv6 motivation and challenges
- **Key aspects of IPv6**
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## Key aspects of IPv6

# Important IPv6 RFCs



For Your  
Reference

RFC Number	Description
<b>3315</b>	Dynamic Host Configuration Protocol for IPv6 (DHCPv6)
<b>3633</b>	IPv6 Prefix Options for DHCPv6
<b>4861</b>	Neighbor Discovery for IP Version 6 (IPv6)
<b>4862</b>	IPv6 Stateless Address Autoconfiguration
<b>5942</b>	IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes
<b>6204</b>	Basic Requirements for IPv6 Customer Edge Routers

# IPv6 neighbor discovery

- IPv6 neighbor discovery (RFC 4861) is vital to understanding 1<sup>st</sup> hop connectivity
- IPv6 ND works over ICMPv6 (RFC 4443) and is often multicast based



# IPv6 neighbor discovery

## Router discovery

- Router Advertisement (RA) sent periodically by router or on request upon receipt of Router Solicitation (RS)



RA packet definitions:

ICMP Type = 134

Src = Router Link-local Address

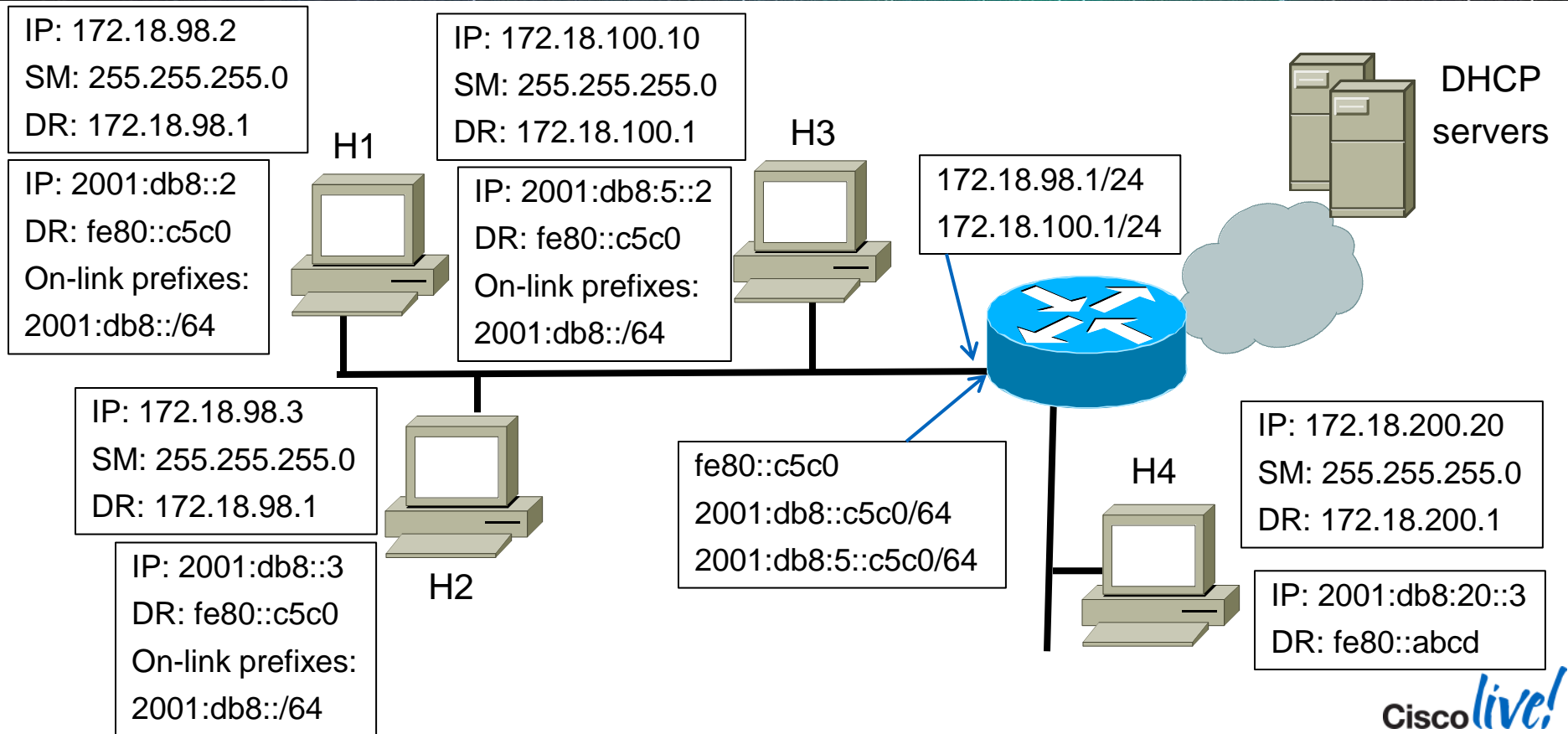
Dst = All-nodes multicast address (FF02::1)

Data= options, prefix, lifetime, autoconfig flag

- Note:** for a cable access network the CMTS will be the only valid sender of Router Advertisement messages

# IPv6 neighbor discovery

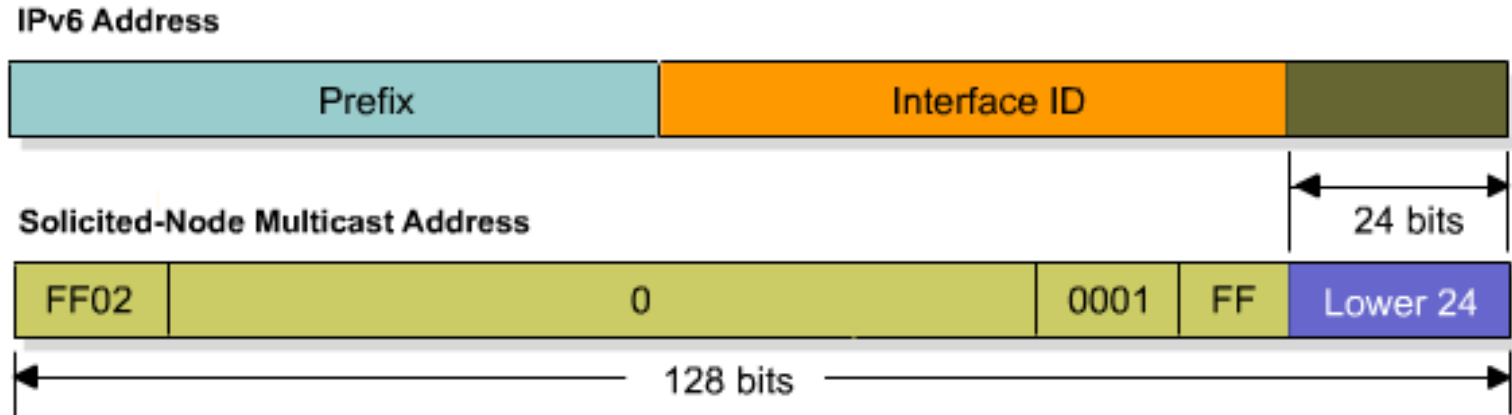
On-link vs. off-link prefix (next hop determination)



# IPv6 neighbor discovery

## L2 address resolution in IPv6

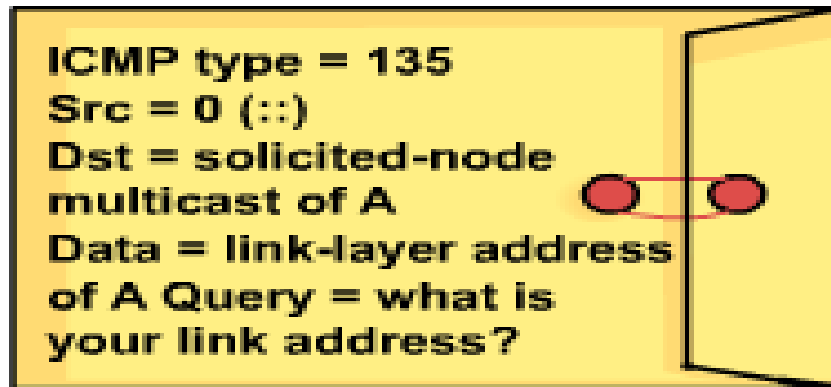
- Address resolution achieved via Neighbor Solicitation (NS) message destined to the solicited-node multicast address of the target



# IPv6 neighbor discovery

## Duplicate Address Detection (DAD)

- Neighbor Solicitation Duplicate Address Detection (DAD) checks that an address is unique on the link



# IPv6 neighbor discovery

## Neighbor cache and Neighbor Unreachability Detection

- Reachability state of neighbors tracked using the Neighbor Unreachability Detection (NUD) mechanism

**INCOMPLETE** – initial NS sent but no NA received

**REACHABLE** – recently (tens of second ago) reachable by NS/NA or via confirmation from upper layer protocol e.g. TCP ACK

**STALE** - no longer known to be reachable but until traffic is sent to the neighbor, no attempt should be made to verify its reachability

**DELAY** – no longer known to be reachable and traffic has recently been sent to the neighbor, before sending NS wait for potential upper layer protocol confirmation

**PROBE** – no longer known to be reachable so (unicast) NS is sent

# IPv6 address acquisition

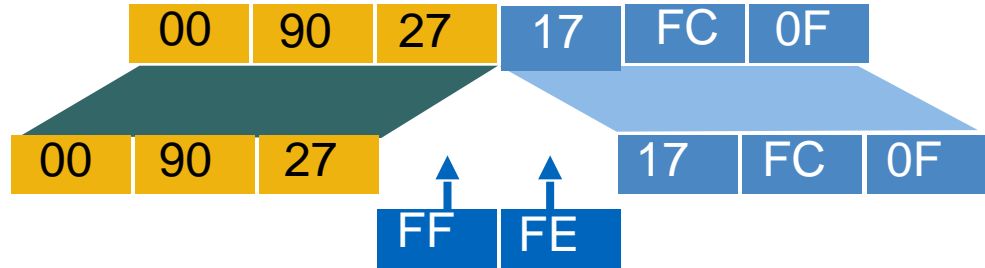
## Router Advertisement

Type (134)	Code (0)						Checksum			
Hop Limit	M	○	H	Pr	P	RR	Router Lifetime			
Reachable Time										
Retransmit Timer										
Source LL(1)	Length (1)					Link-layer Address				
Link-layer Address (continued)										
MTU(5)	Length (1)					Reserved				
MTU										
PIO(3)	Length(4)				Prefix Len		L	A	R	Resv
Valid Lifetime										
Preferred Lifetime										
Reserved (all zeroes)										
Prefix										

# IPv6 address acquisition

EUI-64

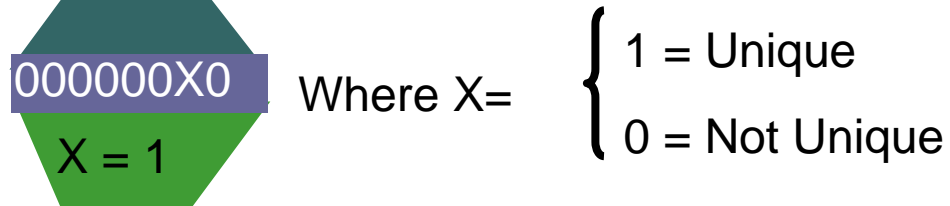
Ethernet MAC Address  
(48 bits)



64-bit Version



Uniqueness of the MAC



EUI-64 Address



# IPv6 address acquisition

StateLess Address AutoConfiguration (SLAAC) – RFC 4862



For Your  
Reference

- Autoconfiguration defined for link-local and global addresses.
- Stateless means based on locally available information (e.g. MAC address) and information advertised by routers.
  - EUI-64 procedure for generating 64-bit long interface identifier
  - Prefix in RA with A-bit set and corresponding preferred lifetime
- Link local
  - FE80::/64 concatenated with interface identifier (EUI-64)
- Link global
  - Prefix from RA concatenated with interface identifier (EUI-64)
  - Prefix must be 64-bit long

# IPv6 address acquisition

## DHCPv6 message types

- DHCPv6 (RFC 3315) defines a number of message types
  - SOLICIT(1), ADVERTISE (2), REQUEST(3), REPLY (7)
  - CONFIRM(4), RENEW(5), REBIND (6)
  - RELEASE (8), DECLINE (9)
  - RECONFIGURE (10)
  - INFORMATION-REQUEST (11)
  - RELAY-FORW (12), RELAY-REPL (13)
- DHCPv6 Leasequery (RFC 5007) adds
  - LEASEQUERY(14), LEASEQUERY-REPLY(15)



# IPv6 address acquisition

## DHCPv6 options

- RFC 3315 defined base options that are extended by other RFCs
  - <http://www.iana.org/assignments/dhcpv6-parameters/dhcpv6-parameters.xml>
- Clients request DHCP options via Option Request Option (ORO – option 6)

OPTION-ORO	Option-len
Requested-option-code-1	Requested-option-code-2
.....	

- Client may also send options in SOLICIT with the values that are interpreted as hints

# IPv6 address acquisition

## DHCP Unique Identifier (DUID)

- Each client and server has a DHCP Unique Identifier (DUID) which is carried as an option and **must be unique and stable over time.**
- Three formats or types defined by RFC 3315
  - Link-layer address plus time – DUID-LLT (1)
  - Vendor-assigned unique ID based on enterprise number – DUID-EN (2)
  - Link-layer Address – DUID-LL (3)

DUID-LLT (1)	hardware type
time	
link-layer address (variable length)	

# IPv6 address acquisition

Client & Server identifier options

**DUID-LL (3)**

**hardware type**

**link-layer address  
(variable length)**

**option RELAY-MSG(9), len 214**

**type ADVERTISE(2), xid 4304265**

**option CLIENTID(1), len 10**

**0003000138C85CB2540A**

**option SERVERID(2), len 14**

**00010001134AAEE5005056B53D27**

# IPv6 address acquisition

## Address option

option IA-NA(3), len 40

IAID 0x5CB2540A, T1 302400, T2 483840

Identity Association ID  
references a single client  
interface

option IAADDR(5), len 24

IPv6 address 2001:DB8:FFFF:0:3AC8:5CFF:FEB2:540A

preferred 604800, valid 604800

Full 128-bit  
address returned;  
could be multiple

# IPv6 address acquisition

## Prefix option

- The Prefix Delegation option (IA-PD option 25) as defined by RFC 3633 has a similar structure to the IA-NA option and is **associated with one or more interfaces from the requesting router**
- The IA-PD includes the IAPREFIX option

<code>OPTION-IAPREFIX (26)</code>	<code>option-len</code>
<code>preferred-lifetime</code>	
<code>valid-lifetime</code>	
<code>prefix-length</code>	<code>IPv6 prefix</code>
<code>.....</code>	
<code>IAprefix options</code>	

# IPv6 address acquisition

## Rapid commit

- Client willing to complete DHCPv6 in two steps (SOLICIT-REPLY) includes Rapid Commit option (option 14) in SOLICIT. If accepted by the server, REPLY must contain Rapid Commit option as well.

OPTION_RAPID_COMMIT (14)	0
--------------------------	---

- When Rapid Commit is used the server commits the address assignment without any knowledge on if the client actually uses it or not; should only be used with multiple servers if they are deployed such that only one server will respond to a Solicit message**

# IPv6 address acquisition

## Vendor extensions

- Vendor Class Option is used by a client to identify the vendor that manufactured the hardware on which the client is running as well as some

<code>OPTION_VENDOR_CLASS (16)</code>	<code>option-len</code>
<code>Enterprise-number</code>	
<code>Vendor-class-data</code>	
.....	

- Vendor-specific Information is used to exchange vendor specific information that must follow code/length/value format (the same as option)

<code>OPTION_VENDOR_OPTS (17)</code>	<code>option-len</code>
<code>Enterprise-number</code>	
<code>option-data</code>	
.....	

# Agenda

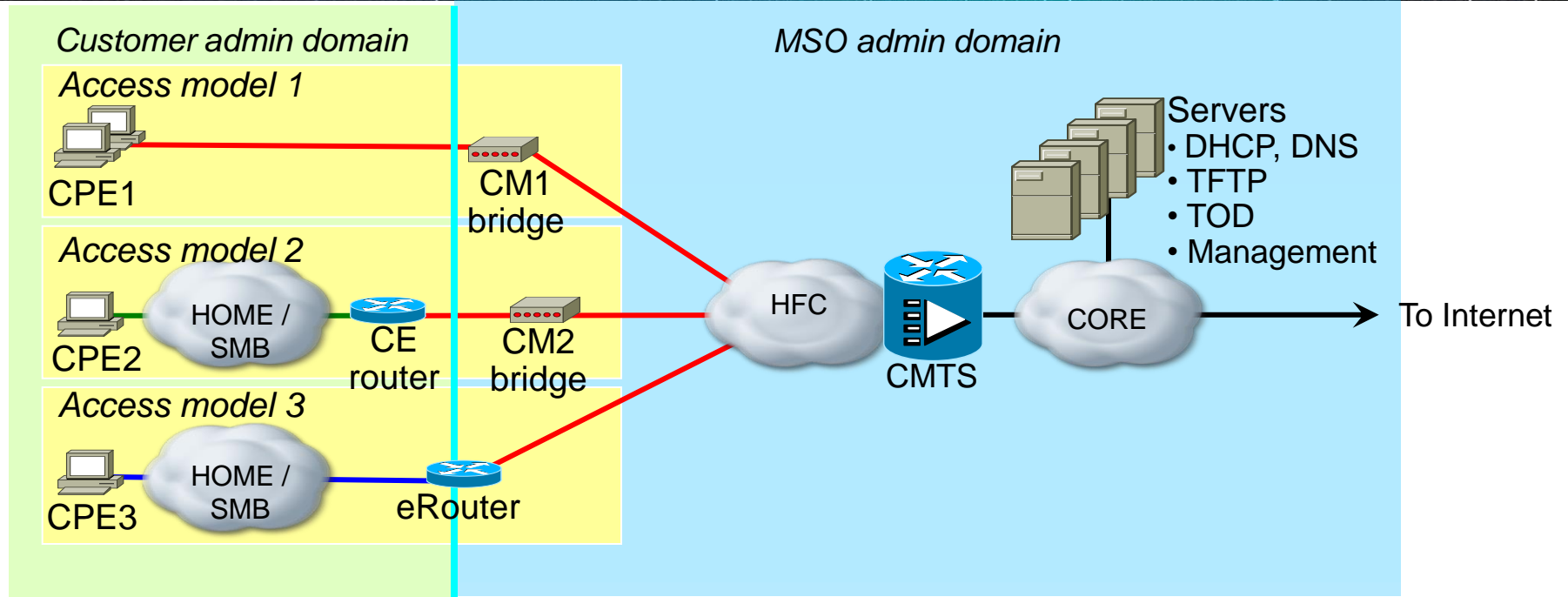
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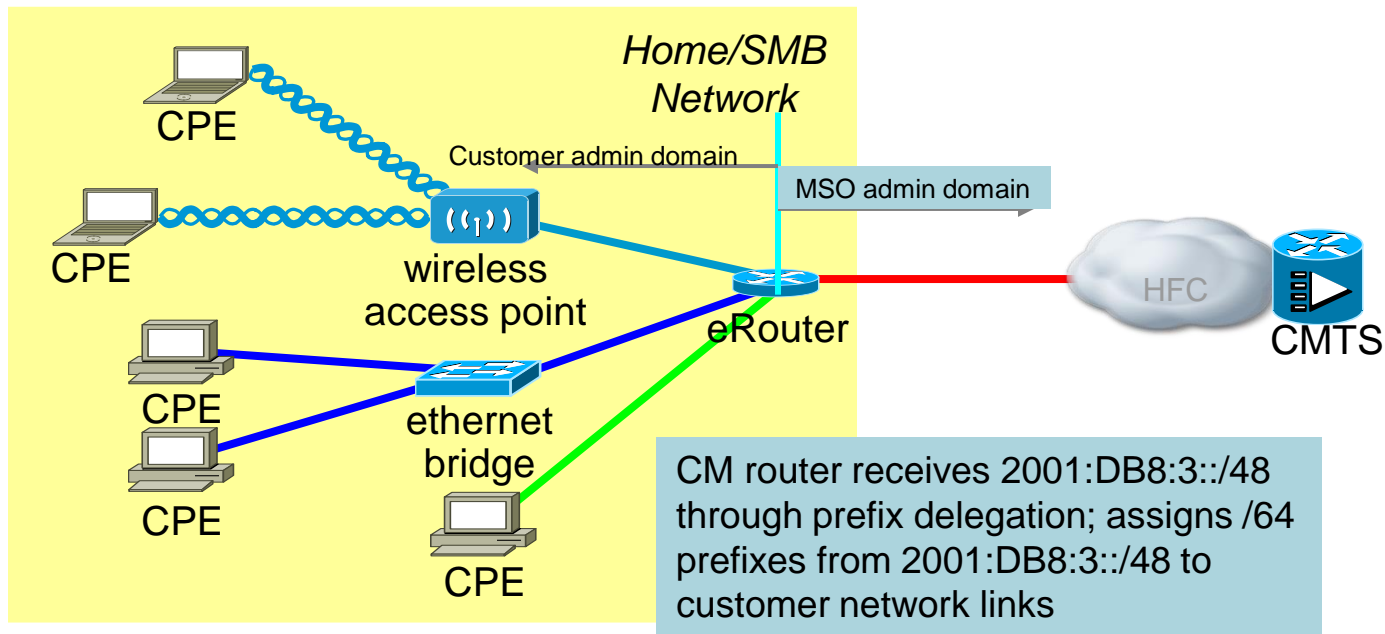
IPv6 in cable





# DOCSIS 3.0 IPv6 reference architecture



# DOCSIS 3.0 IPv6 reference architecture

## Customer premises network



-  HFC link; assigned 2001:DB8:FFFF:0::/64 (mgmt) and 2001:DB8:FFFE:0::/64 (service)
-  Customer network link 1; assigned 2001:DB8:3:0::/64
-  Customer network link 2; assigned 2001:DB8:3:1::/64
-  Customer network link 3; assigned 2001:DB8:3:2::/64

# IPv6 relevant CableLabs<sup>®</sup> specifications



For Your  
Reference

- DOCSIS 3.0 MAC and Upper Layers Protocol Interface (CM-SP-MULPv3.0)
- DOCSIS 3.0 Operations Support System Interface (CM-SP-OSSv3.0)
- DOCSIS 2.0 + IPv6 Cable Modem (CM-SP-DOCSIS2.0-IPv6)
- eDOCSIS (CM-SP-eDOCSIS)
- IPv4 and IPv6 eRouter (CM-SP-eRouter)
- PacketCable Multimedia (PKT-SP-MM)
- PacketCable 2.0 E-UE Provisioning Framework (PKT-SP-EUE-PROV)
- PacketCable 2.0 Dual-Stack IPv6 Architecture (PKT-TR-DS-IP6)
- OpenCable Host Device 2.1 Core Functional Requirements (OC-SP-HOST2.1-CFR)
- CableLabs' DHCP Options Registry (CL-SP-CANN-DHCP-Reg)

# Embedded devices



For Your  
Reference

- Embedded router (eRouter) is one type of embedded Service/Application Functional Entity (eSAFE) device
- eRouter is a Customer Edge (CE) router embedded with a cable modem
- RFC 6204 defines basic requirements for a CE router
- Other types of eSAFE devices include:
  - eMTA (Multimedia Terminal Adapter)
  - eDVA (Digital Voice Adapter)
  - eSTB (Set-Top Box)
- eSAFE devices undergo their own provisioning process which can be IPv4, IPv6, or dual-stack

# Multicast DSID Forwarding (MDF)

## DOCSIS 3.0 Multicast Model

DSIDs communicated 3-ways

1. Pre-registration DSID (MDD)
2. Static DSID(s) (REG-RSP)
3. Dynamic DSID(s) (DBC-REQ)

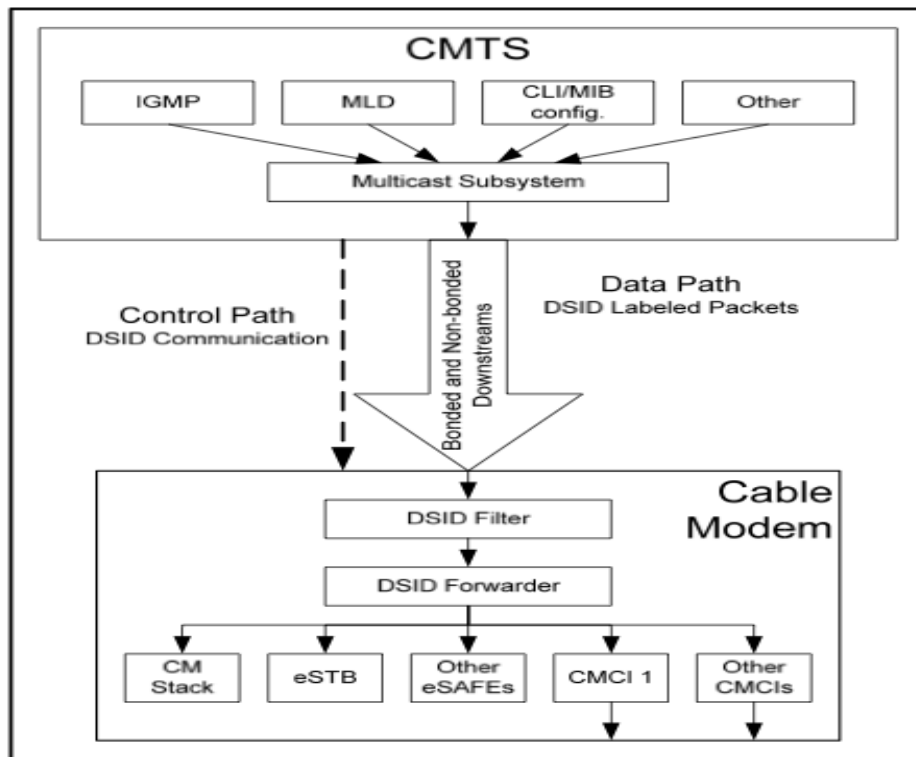


Figure 9-2 - Multicast Model

# Example DSID labeled DOCSIS packet

## DOCSIS

```
00.. .... = FCType: Packet PDU (0x00)
..00 000. = FCParm: 0
.... ...1 = EHDRON: Extended Header Present
Extended Header Length (bytes): 4
Length after HCS (bytes): 94
  ▾ Extended Header
    1000 .... = Type: Reserved (8)
    .... 0011 = Length: 3
    Value: 09f018
    Header check sequence: 0x1c0d
```

```
#show cable multicast dsid Modular-Cable 5/1/0:4 static
```

Dsid	Stat	Index	Type
0x9F014	64956		IGMPv1/v2
0x9F015	64957		IGMPv3
0x9F016	64958		MLDv1
0x9F017	64959		MLDv2
<b>0x9F018</b>	<b>64960</b>		<b>PreReg</b>

```
> Ethernet II, Src: Cisco_1a:0b:3f (00:12:00:1a:0b:3f), Dst: IPv6mcast_00:00:00:01 (33:33:00:00:00:01)
> Internet Protocol Version 6, Src: fe80::212:ff:fe1a:b3f (fe80::212:ff:fe1a:b3f), Dst: ff02::1 (ff02::1)
> Internet Control Message Protocol v6
  Type: Router Advertisement (134)
  Code: 0
  Checksum: 0xccb2 [correct]
  Cur hop limit: 64
  ▸ Flags: 0xc8
  Router lifetime (s): 9000
  Reachable time (ms): 600000
  Retrans timer (ms): 0
  ▸ ICMPv6 Option (Source link-layer address : 00:12:00:1a:0b:3f)
  ▸ ICMPv6 Option (MTU : 1500)
```

# DOCSIS 2.0 + IPv6

- IPv6 unsupported in DOCSIS prior to version 3.0
- DOCSIS 2.0 still widely deployed
- D2.0 + IPv6 specification introduced to provide aspects of D3.0 required to support IPv6 for D2.0 modems
- **Can operate in either MDF incapable (0) or MDF GMAC explicit (1) modes**



# MDF disabled/incapable mode (MDF = 0)

- Used by some DOCSIS 2.0+ modems; can also be set by the CMTS
- Modem does NOT make forwarding decisions based on DSIDs
- Processes well-known IPv6 multicast addresses
- Solicited node multicast MAC corresponding to all unicast IPv6 addresses assigned for CM host stack and eSAFE host stacks
- **Does not know solicited node multicast MAC addresses of connected CPEs; unless learned via snooping**
- **Mechanism for multicast forwarding of CPE IPv6 traffic is vendor proprietary**

# MDF 0 example

```
CMTS#show cable modem 0015.cf0b.d0c2 verbose
```

```
MAC Address           : 0015.cf0b.d0c2
IP Address            : ---
IPv6 Address         : 2001:DB8:FFFF:0:215:CFFF:FE0B:D0C2
Dual IP              : N
Wideband Capable     : N
MAC Version         : DOC2.0
Modem Status         : {Modem= online(pt), Security=assign(tek)}
Number of Multicast DSIDs Support : 0
MDF Capability Mode : 0
IGMP/MLD Version     : IGMPv2
FCType10 Forwarding Support : N
CFG Max IPv6 CPE Prefix : 16 (-1 used)
```

# MDF GMAC explicit mode (MDF = 1)

- Used by some DOCSIS 2.0+ modems
- Forwards DSID labeled packets according to forwarding rules associated with the DSID
- However, modem is unable to filter unknown DSIDs in hardware and requires the GMACs
- **CMTS includes the GMAC (Group MAC) encoding when signaling a DSID to a CM**
- **MDF explicit CM forwards downstream multicast packets with a known DSID AND a known GMAC**

# MDF 1 example

```
CMTS#show cable modem 000f.2173.2356 verbose
```

```
MAC Address           : 000f.2173.2356
IP Address            : ---
IPv6 Address         : 2001:DB8:FFFF:0:20F:21FF:FE73:2356
Dual IP              : N
Wideband Capable     : N
MAC Version         : DOC2.0
Modem Status         : {Modem= online(pt), Security=assign(tek)}
Number of Multicast DSIDs Support : 16
MDF Capability Mode : 1
IGMP/MLD Version     : MLDv2
FCType10 Forwarding Support : N
CFG Max IPv6 CPE Prefix : 16 (-1 used)
```

# MDF GMAC promiscuous mode (MDF = 2)

- Used by DOCSIS 3.0 modems
- Forwards and filters all GMAC addresses with known DSIDs
- Multicast packets without a DSID label are discarded
- Multicast packets with an unknown DSID label are discarded

# MDF 2 example

```
CMTS#show cable modem 38c8.5cb2.540a verbose
```

```
MAC Address           : 38c8.5cb2.540a
IP Address            : ---
IPv6 Address         : 2001:DB8:FFFF:0:3AC8:5CFF:FEB2:540A
Dual IP              : N
Wideband Capable     : Y
MAC Version         : DOC3.0
Modem Status         : {Modem= w-online(pt), Security=assign(tek)}
Number of Multicast DSIDs Support : 16
MDF Capability Mode : 2
IGMP/MLD Version     : MLDv2
FCType10 Forwarding Support : Y
CFG Max IPv6 CPE Prefix : 16 (-1 used)
```

# Agenda

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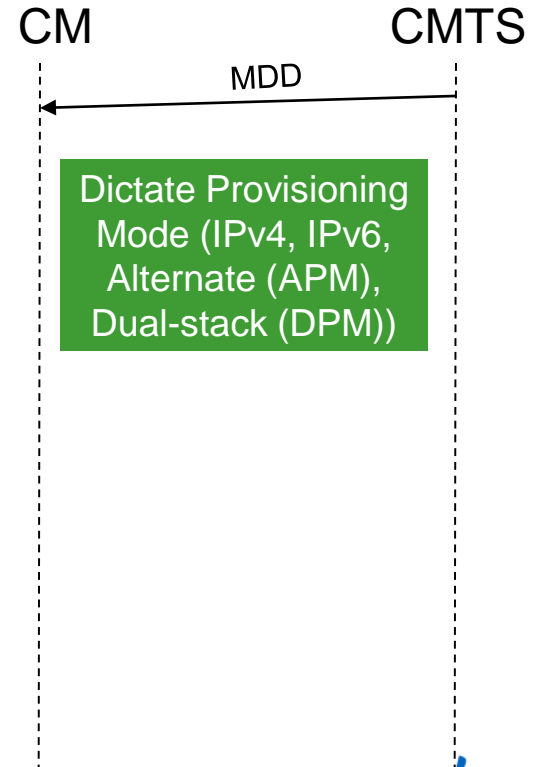




## IPv6 for cable modem management

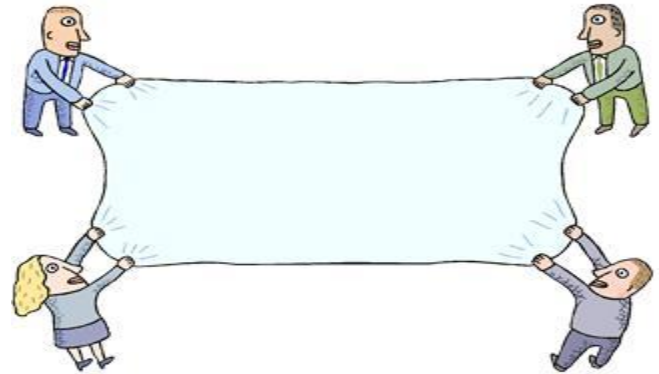
# DOCSIS cable modem provisioning

- CMTS periodically sends MDD messages which dictate CM IP establishment procedure
- Controlled by **cable ip-init** <> configuration under the cable interface
- If the CM does not receive any MDD messages from the CMTS it operates in DOCSIS 2.0 mode



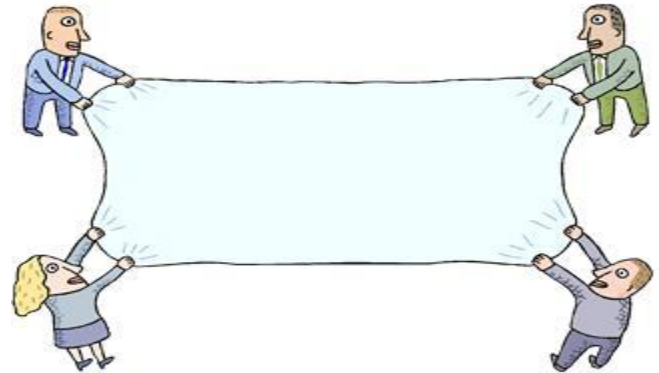
# Dual-stack Provisioning Mode (DPM)

- CM first uses DHCPv6 to acquire an IPv6 address and then uses DHCPv4 to acquire an IPv4 addresses
- If able to acquire an IPv6 address it continues the provisioning process using IPv6; otherwise it continues the provisioning process using IPv4
- Useful during the transition period until confidence is gained in IPv6 management infrastructure; will NOT result in freeing up IPv4 addresses
- DPM support is optional for D2.0+ cable modems



# Alternate Provisioning Mode (APM)

- CM first attempts to provision using IPv6 and if that fails reverts to provisioning using IPv4
- If able to provision using IPv6 no IPv4 address is acquired
- Useful during the transition period until confidence is gained in IPv6 management infrastructure and unlike DPM will most likely result in the savings of IPv4 address space
- APM support is optional for D2.0+ cable modems



# MDD message example

```
MDD MESSAGE
<snip>
dcid - 8
MDD TLV, Total TLV size - 379
MDD TLV
  Downstream Active Channel List
  Channel ID: 1
  Frequency: 687000000Hz
  Modulation Order/Annex: 256 QAM/Annex B
  Primary Capable: Primary-Capable
<snip>
  Downstream Active Channel List
  Channel ID: 8
  Frequency: 729000000Hz
  Modulation Order/Annex: 256 QAM/Annex B
  Primary Capable: Primary-Capable
  CM-STATUS Event Bitmask: 0x36
  MDD Timeout
  QAM FEC failure
  MDD Recovery
  QAM FEC recovery
  MAC Domain Downstream Service Group
  MD-DS-SG ID: 1
  Channel IDs: 1
               2
               3
               4
               5
               6
               7
               8|
<snip>
  IP Initialization Parameters
  IP Provisioning Mode: IPv6
  Pre-Registration DSID: 585767
<snip>
```

IP Provisioning Mode set to IPv6  
Pre-Registration DSID included

# MDD override

- The IP provisioning mode in the MDD message will affect all DOCSIS 3.0 and DOCSIS 2.0+ modems in the MAC domain
- Can have tighter control via SNMP setting in cable modem configuration file or SNMP Set (DOCS-IF3-MIB::docsIf3CmMdCfgIpProvMode)

*Table O-44 - CmMdCfg Object*

Attribute Name	Type	Access	Type Constraints	Units	Default
ifIndex	InterfaceIndex	key	InterfaceIndex of MAC Domain interface	N/A	N/A
IpProvMode	Enum	read-write	ipv4Only(0) ipv6Only(1) honorMdd(4)	N/A	honorMdd
IpProvModeResetOnChange	TruthValue	read-write	true(1) false(2)	N/A	false
IpProvModeResetOnChangeHoldOffTimer	Unsigned32	read-write	0...300	seconds	0
IpProvModeStorageType	StorageType	read-write	volatile(2) nonVolatile(3)	N/A	nonVolatile

# CM provisioning

## Acquiring IPv6 connectivity

**MSOs are providing a managed service and thus need full control of IP address assignments**

### **Appendix VII Notes on Address Configuration in DOCSIS 3.0<sup>704</sup>**

DOCSIS 3.0 specifies DHCPv6 as the method of choice to provision IPv6 addresses for CM and bridged devices. RFC 4862 defines an alternate mechanism known as stateless address autoconfiguration, where devices build their own IPv6 address by concatenating a prefix learn through IPv6 Router Advertisements (RAs) and an interface ID derived from the MAC address. Such addresses are usually not registered within the Cable Operator, so their usage is not recommended in DOCSIS 3.0. **The simplest way to prevent CM and bridged devices to use stateless address autoconfiguration is to configure router advertisement to not include any prefixes at all.**

A CMTS can provide support for enforcing a deployment in which devices attached to the HFC use only DHCPv6 addresses by filtering IPv6 traffic and dropping any IPv6 datagrams whose source address has not been assigned through DHCPv6. Note that this filtering will catch manually assigned address as well as unauthorized SLAAC addresses.

# DHCPv6 solicit

```
CMTS DHCPV6: Incoming DHCPv6 SOLICIT from 38c8.5cb2.540a (sid 51 prim_sid 51) in Cable6/0/0.  
IPv6 DHCP: detailed packet contents  
  src FE80::3AC8:5CFF:FEB2:540A (Bundle99)  
  dst FF02::1:2  
  type SOLICIT(1), xid 5531996  
  option RAPID-COMMIT(14), len 0  
  option RECONF-ACCEPT(20), len 0  
  option VENDOR-CLASS(16), len 15  
  option ORO(6), len 2  
    VENDOR-OPTS  
  option VENDOR-OPTS(17), len 284  
  option CLIENTID(1), len 10  
    0003000138C85CB2540A  
  option IA-NA(3), len 12  
    IAID 0x5CB2540A, T1 0, T2 0  
  option ELAPSED-TIME(8), len 2  
    elapsed-time 0  
CMTS DHCPV6: Adding CMTS relay agent options DOCSIS version 3.0 and CM MAC 38c8.5cb2.540a
```

Lists requested CableLabs options

# Example DHCPv6 relay-forward

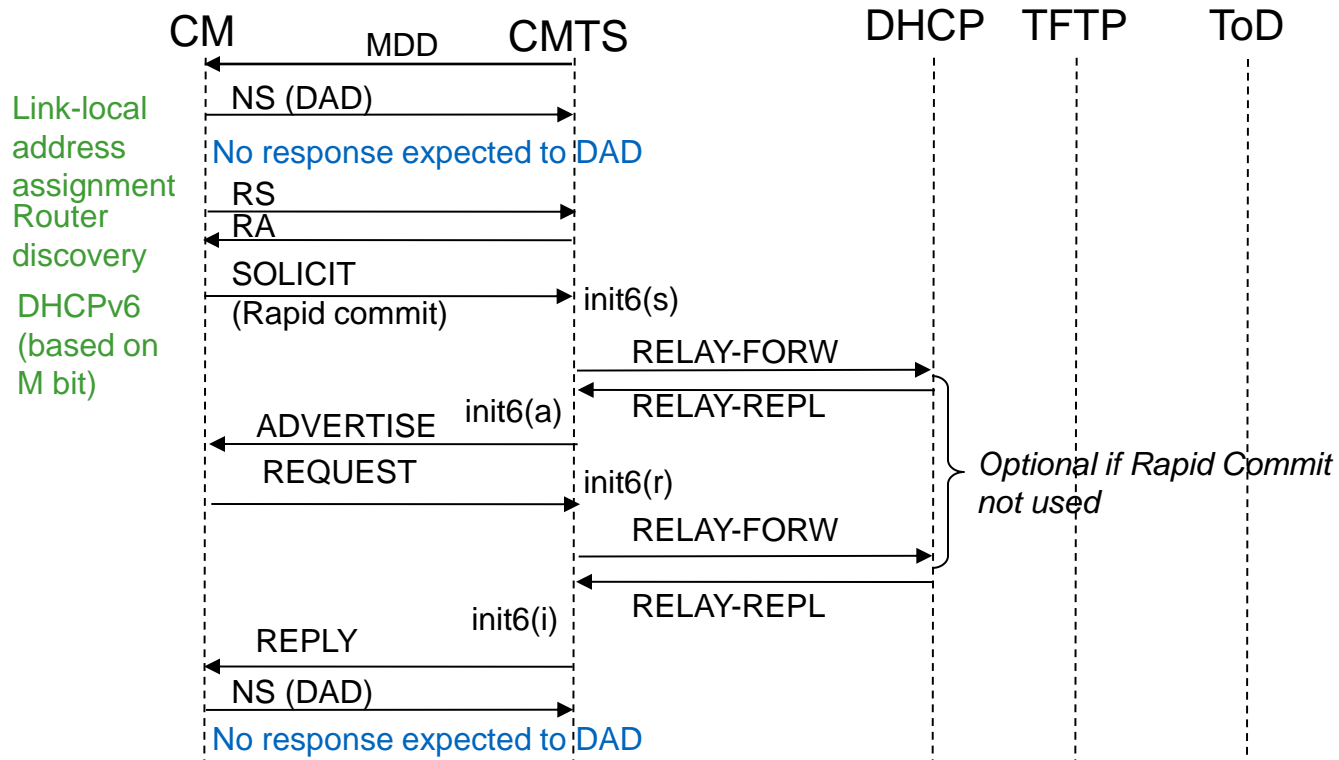
## DHCPv6 solicit forwarded

Relay Agent options 1025 and 1026 included by the CMTS identifying the CMTS as DOCSIS 3.0 capable and the cable modem sourcing the message

```
DHCPv6
  Message type: Relay-forw (12)
  Hopcount: 0
  Link address: 2001:db8:fffe::1 (2001:db8:fffe::1)
  Peer address: fe80::3ac8:5cff:feb2:540a (fe80::3ac8:5cff:feb2:540a)
  ▾ Relay Message
    Option: Relay Message (9)
    Length: 361
    Value: 01cc492a000e0000001400000010000f0000118b0009646f...
    ▾ DHCPv6
      Message type: Solicit (1)
      Transaction ID: 0xcc492a
      ▸ Rapid Commit
      ▸ Reconfigure Accept
      ▸ Vendor Class
      ▸ Option Request
      ▸ Vendor-specific Information
      ▸ Client Identifier: 0003000138c85cb2540a
      ▸ Identity Association for Non-temporary Address
      ▸ Elapsed time
      ▸ Interface-Id
      ▾ Vendor-specific Information
        Option: Vendor-specific Information (17)
        Length: 22
        Value: 0000118b04010004010203000402000638c85cb2540a
        Enterprise ID: Cable Television Laboratories, Inc. (4491)
        ▾ Suboption 1025: CMTS Capabilities Option :
          DOCSIS Version Number 3.0
          Suboption 1026: CM MAC Address Option = 38:c8:5c:b2:54:0a
```

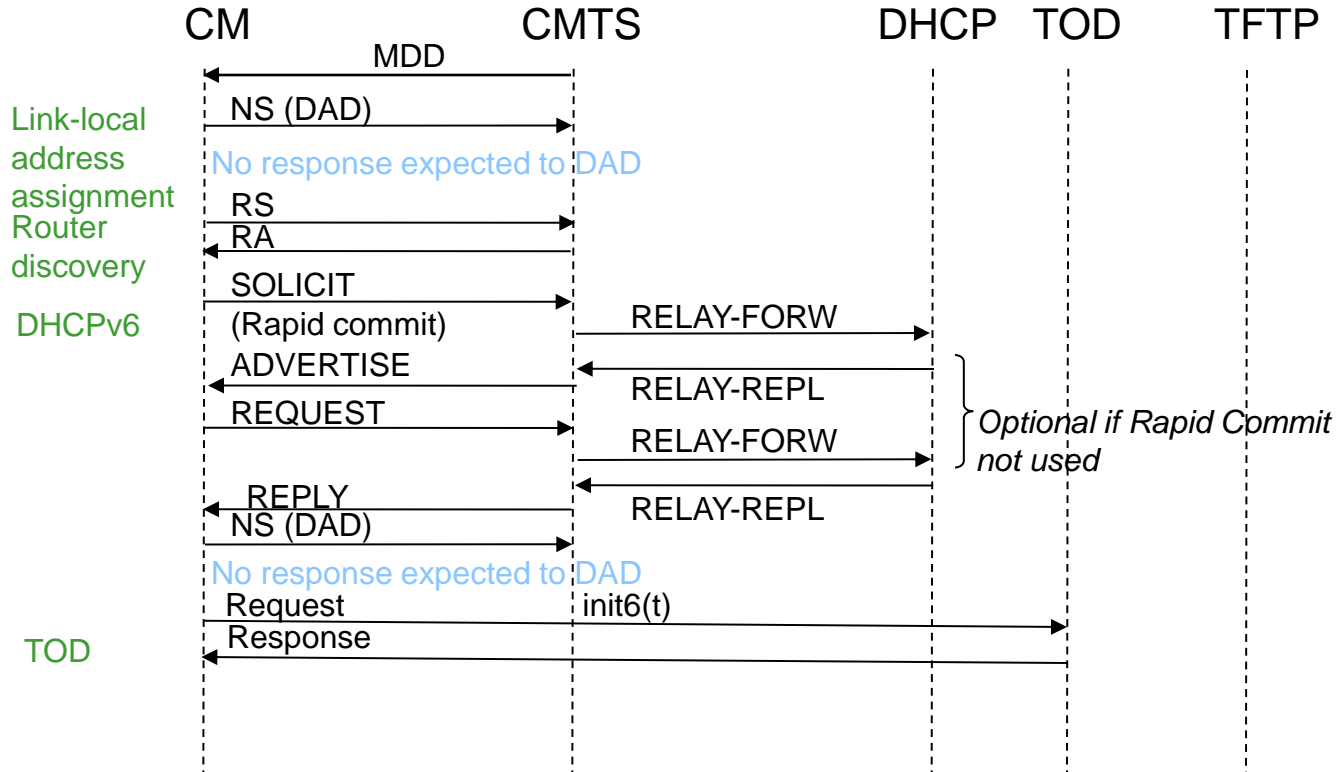
# CM provisioning:

Acquire IPv6 connectivity



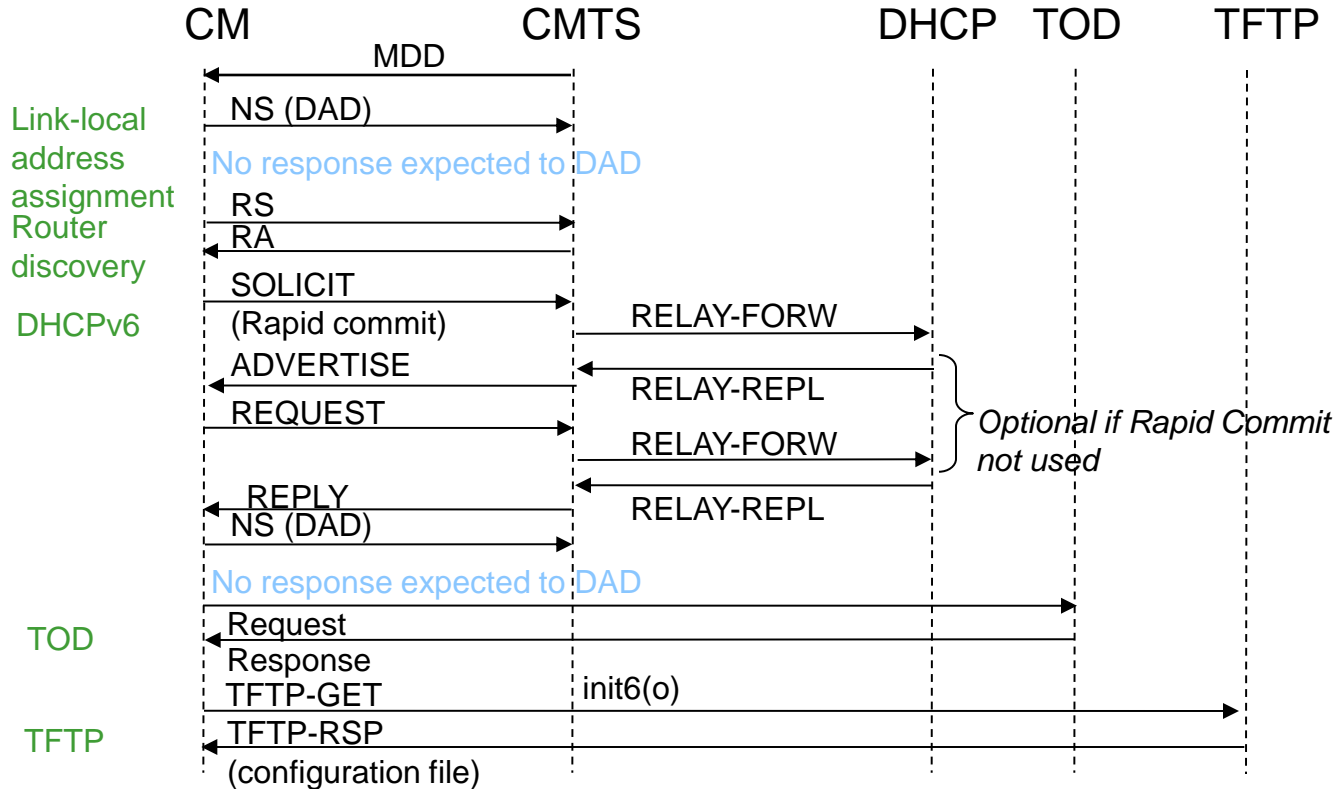
# CM provisioning:

Obtain TOD



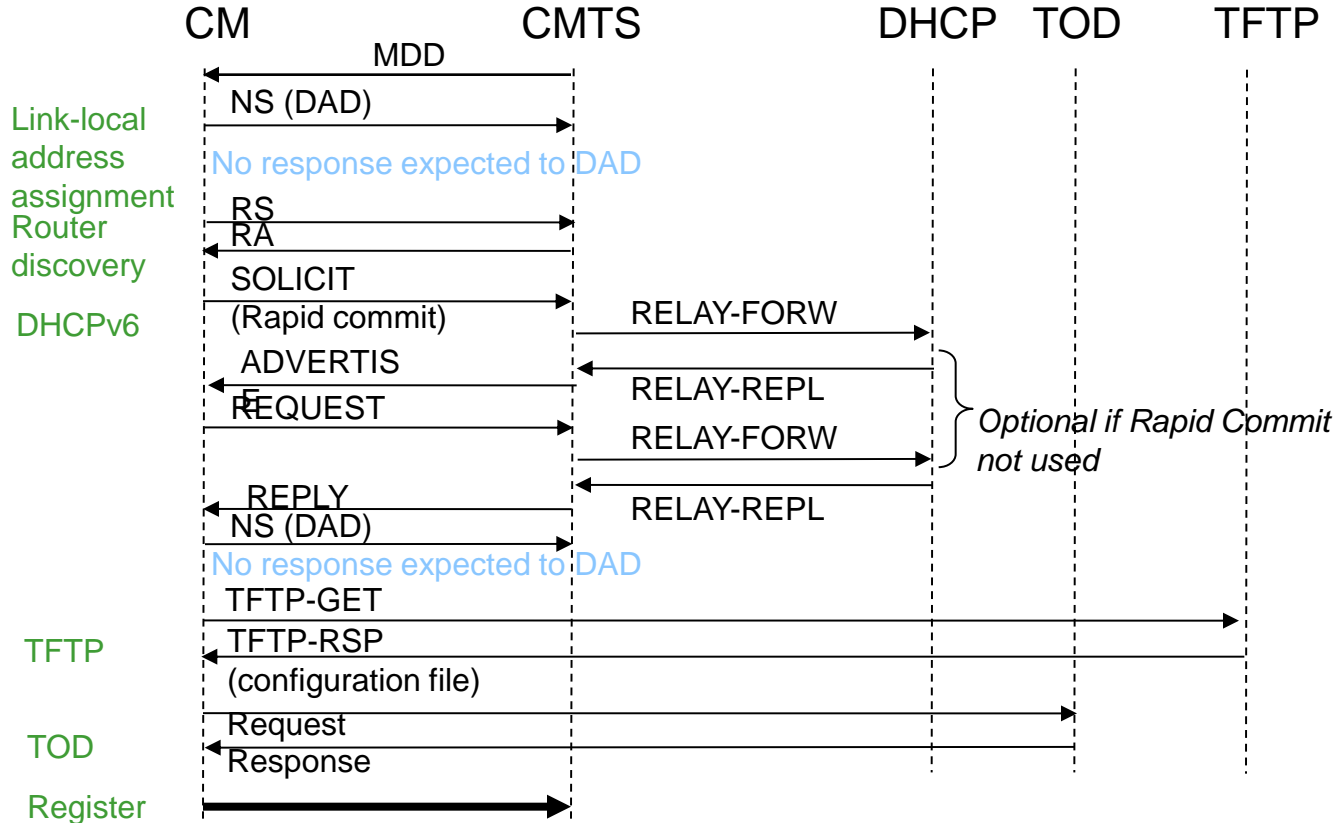
# CM provisioning:

## Obtain Configuration File



# CM provisioning:

## Complete registration



# CNR example: DHCPv6 link

## Edit DHCP v6 Link *TEST\_LINK*

Expand All Collapse All Default View Show A-Z View

Attribute	Value	Data Type	Default	Unset?
name*	TEST_LINK	string		
vpn-id		VPN	0	
description		string		<input type="checkbox"/>
policy	[none]	Policy	default	<input type="checkbox"/>
owner	[none]	CCMOwner		<input type="checkbox"/>
region	[none]	CCMRegion		<input type="checkbox"/>
free-address-config	[none]	AddrTrapConfig		<input type="checkbox"/>

Prefix Stability

Reserved

Embedded Policy

Create New Embedded Policy

CMTS has a prefix for CMM, CPE addressing, and CPE prefix delegation

Prefixes Currently Associated with this Link

Name	Address	Range	DHCP Type	Allocation Group
TEST_PD_PREFIX	2001:db8::/48	2001:db8::/49	prefix-delegation	
TEST_CPE_PREFIX	2001:db8:ffe::/64	2001:db8:ffe::/65	[dhcp]	
TEST_CMM_PREFIX	2001:db8:fff::/64		[dhcp]	

# CNR example: DHCPv6 prefix for CMM addressing

Edit DHCP v6 Prefix **TEST\_CMM\_PREFIX, 2001:db8:ffff::/64**

Expand All Collapse All Default View Show A-Z View

Universal Settings

Attribute	Value	Data Type	Default	Unset?
name*	TEST_CMM_PREFIX	string		
vpn-id		string	0	<input type="checkbox"/>
description		string		<input type="checkbox"/>
dhcp-type	[dhcp]	32-bit enum	dhcp	<input type="checkbox"/>
address*	2001:db8:ffff::/64	IPv6 prefix/prefix length		<input type="checkbox"/>
owner	[none]	CCMOwner		<input type="checkbox"/>
region	[none]	CCMRegion		<input type="checkbox"/>
reverse-zone-prefix-length		bounded integer (0 - 124)		<input type="checkbox"/>

Non-Parent Settings

Attribute	Value	Data Type	Default	Unset?
range		IPv6 prefix/prefix length		<input type="checkbox"/>
link	TEST_LINK	Link		<input type="checkbox"/>
policy	CM_IPv6_Policy	Policy		<input type="checkbox"/>
Selection Tags (selection-tags)	Tag Value tagCompanyY Add Selection Tag	string list		<input type="checkbox"/>
allocation-algorithms	<input type="checkbox"/> client-request <input checked="" type="checkbox"/> reservation <input type="checkbox"/> extension <input checked="" type="checkbox"/> interface-identifier <input type="checkbox"/> random <input type="checkbox"/> best-fit <input type="checkbox"/> [none]	flags	reservation, extension, random, best-fit	<input type="checkbox"/>
restrict-to-reservations	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
max-leases		bounded integer (0 - 2000000)	65536	<input type="checkbox"/>
ignore-declines	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
expiration-time		date		<input type="checkbox"/>
free-address-config	[none]	AddrTrapConfig		<input type="checkbox"/>
deactivated	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>

Allocation Group

**A /64 is recommended for simplicity and should be more than enough addresses**

**The EUI-64 interface ID format allows server redundancy w/o fear of overlap**

# CNR example: IPv6 policy for CMM

## Edit DHCP Policy *CM\_IPv6\_Policy*

Attribute	Value	Data Type	Default	Unset?
Name *	CM_IPv6_Policy			
Offer Timeout	2m	unsigned time	24h	<input type="checkbox"/>
Grace Period	5m	unsigned time		<input type="checkbox"/>
<input type="checkbox"/> DHCPv4 Options <input type="checkbox"/> DHCPv6 Options <input type="checkbox"/> DHCPv4 Vendor Options				
	APc1200			
<input type="checkbox"/> DHCPv6 Vendor Options				
	dhcp6-cablelabs-config			
<input type="button" value="Expand All"/> <input type="button" value="Collapse All"/> <input type="button" value="Default View"/> <input type="button" value="Show A-Z View"/>				
unavailable-timeout		unsigned time	24h	<input type="checkbox"/>
inhibit-all-renews	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
inhibit-renews-at-reboot	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
permanent-leases	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
renewal-pct		percentage	50%	<input type="checkbox"/>
rebind-pct		percentage	80%	<input type="checkbox"/>
lease-retention-limit	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
<input type="checkbox"/> DHCPv4 Settings <input type="checkbox"/> DNS Update Settings <input type="checkbox"/> DHCPv6 Settings				
allow-non-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean	true	<input type="checkbox"/>
allow-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean	true	<input type="checkbox"/>
allow-rapid-commit	<input type="radio"/> true <input checked="" type="radio"/> false	boolean	false	<input type="checkbox"/>
allow-client-hints	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
min-preferred-lifetime		unsigned time		<input type="checkbox"/>
preferred-lifetime		unsigned time	1w	<input type="checkbox"/>
min-valid-lifetime		unsigned time		<input type="checkbox"/>
valid-lifetime		unsigned time	2w	<input type="checkbox"/>
affinity-period		unsigned time		<input type="checkbox"/>
v6-reply-options	server-identifier,preference,domain-list,dns-	dhcpv6 option id list		<input type="checkbox"/>
default-prefix-length		bounded integer (0 - 128)	64	<input type="checkbox"/>
longest-prefix-length		bounded integer (0 - 128)		<input type="checkbox"/>
shortest-prefix-length		bounded integer (0 - 128)		<input type="checkbox"/>
excluded-prefix		IPv6 prefix/prefix length		<input type="checkbox"/>
reconfigure	[allow]	32-bit enum	allow	<input type="checkbox"/>
reconfigure-via-relay	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>

CableLabs DHCP options such as time offset, syslog server, etc. defined here

If multiple DHCP servers Rapid Commit needs to be disabled

May opt to use longer lifetimes

# Basic CMTS IPv6 configuration example

- Enable IPv6 globally

```
ipv6 unicast-routing  
no ipv6 source-route  
ipv6 cef
```

- Configure IPv6 on WAN and Loopback interfaces

```
interface TenGigabitEthernet1/0/0  
  ipv6 address FC00:1111:1111:111D::2/64  
  ipv6 nd ra suppress  
  ipv6 ospf network point-to-point  
  ipv6 ospf 1 area 1  
  no ipv6 redirects  
  no ipv6 unreachable  
  
interface Loopback0  
  ipv6 address FC00:1111:1111:FFFF::4/128
```

Could use GUA or ULA addressing (or both) for infrastructure links

Recommended to use a separate address block for infrastructure and customers

Infrastructure links typically configured with /64 prefixes; some prefer to use /126 or /127 instead

Allocate one /64 for loopbacks

# Basic CMTS Bundle interface configuration example

```
interface Bundle99
  no cable nd
  cable ipv6 source-verify dhcp
  cable ipv6 source-verify leasequery-filter upstream 3 5
  ipv6 address 2001:DB8:FFFE::1/64
  ipv6 address 2001:DB8:FFFF::1/64
  ipv6 traffic-filter security in
  ipv6 nd reachable-time 600000
  ipv6 nd dad attempts 0
  ipv6 nd prefix default no-advertise
  ipv6 nd managed-config-flag
  ipv6 nd other-config-flag
  ipv6 nd router-preference High
  ipv6 nd ra interval 20
  ipv6 nd ra lifetime 9000
  no ipv6 redirects
  no ipv6 unreachable
  ipv6 verify unicast reverse-path
  ipv6 dhcp relay destination FC00:1111:1111:1111:20C:29FF:FEB8:68DF
  ipv6 dhcp relay destination FC00:1111:1111:1111:250:56FF:FEB5:3D27
```

IPv6 ND configured on bundle interface

RA will not advertise any prefix since that is the only way to signal off-link to IPv6 hosts. BEST METHOD to prevent SLAAC

# Basic CMTS Cable interface configuration example

- Configure Cable interfaces

Interface Cable6/0/0  
**cable ip-init ipv6**

**cable ip-init** mac-domain configuration is for CM management stack only.

This configuration NOT needed if only doing IPv6 for CPE

Interface Cable5/0/0  
**cable ip-init apm**

May opt to use APM so modems can get online in IPv4 mode in the event of a failure with the DHCPv6 provisioning process

# Basic IPv6 configuration

## IPv6 parameters of bundle interface

```
CMTS#show ipv6 interface bundle 99
```

```
Bundle99 is up, line protocol is up
```

```
IPv6 is enabled, link-local address is FE80::212:FF:FE1A:B3F
```

```
No Virtual link-local address(es):
```

```
Global unicast address(es):
```

```
2001:DB8:FFFE::1, subnet is 2001:DB8:FFFE::/64
```

```
2001:DB8:FFFF::1, subnet is 2001:DB8:FFFF::/64
```

```
Joined group address(es):
```

```
FF02::1
```

```
FF02::2
```

```
FF02::1:2
```

```
FF02::1:FF00:1
```

```
FF02::1:FF1A:B3F
```

```
MTU is 1500 bytes
```

```
ICMP error messages limited to one every 100 milliseconds
```

```
ICMP redirects are disabled
```

```
ICMP unreachable are disabled
```

```
.....
```

Link local address is auto generated from MAC address of bundle interface:

```
Bundle99 is up, line protocol is up
```

```
Hardware [...] address is 0012.001a.0b3f
```

CMTS is joining several IPv6 multicast groups

FF02::1 – link scoped all-nodes

FF02::2 – all routers on the local network

FF02::1:2 - all DHCPv6 agents

FF02::1:FF00:1 - solicited-node multicast for link global address

FF02::1:FF1A:B3F – solicited-node multicast for link local address

# Basic IPv6 configuration

## IPv6 parameters of bundle interface continued

.....

Input features: Verify Unicast Reverse-Path, Access List

IPv6 verify source reachable-via rx, allow default

0 verification drop(s) (process), 42414 (CEF)

0 suppressed verification drop(s) (process), 0 (CEF)

Inbound access list security

**ND DAD is disabled**

**ND reachable time is 600000 milliseconds**

**ND advertised reachable time is 600000 milliseconds**

ND advertised retransmit interval is 0 milliseconds

ND router advertisements are sent every 20 seconds

ND router advertisements live for 9000 seconds

ND advertised default router preference is High

**Hosts use DHCP to obtain routable addresses.**

**Hosts use DHCP to obtain other configuration.**

**ipv6 nd dad attempts 0** - ND DAD is disabled

**ipv6 nd reachable-time 600000** – 10 minutes

**ipv6 nd ra interval 20** – RA is sent every 20 seconds

**ipv6 nd ra lifetime 9000** – RA's lifetime is 9000 secs (2 ½ hrs)

Hosts must use DHCPv6

**ipv6 nd managed-config-flag**

**ipv6 nd other-config-flag**

# Basic IPv6 configuration

## IPv6 parameters of bundle interface continued

```
CMTS#show ipv6 interface bundle 99 prefix
```

```
IPv6 Prefix Advertisements Bundle99
```

```
Codes: A - Address, P - Prefix-Advertisement, O - Pool
```

```
U - Per-user prefix, D - Default
```

```
N - Not advertised, C - Calendar
```

```
PN default [LA] Valid lifetime 2592000, preferred lifetime 604800
```

```
AD 2001:DB8:FFFE::/64 [LA] Valid lifetime 2592000, preferred lifetime 604800
```

```
AD 2001:DB8:FFFF::/64 [LA] Valid lifetime 2592000, preferred lifetime 604800
```

Prefixes not advertised as they follow default of  
**ipv6 nd prefix default no-advertise**

# How to determine if CM is IPv6 enabled?

```
CMTS#show cable modem cab 6/0/0
```

MAC Address	IP Address	I/F	MAC State	Prim Sid	RxPwr (dBmV)	Timing Offset	Num CPE	D I
7cb2.1b2d.dac0	---	C6/0/0/U1	w-online (pt)	49	0.00	1580	2	N
7cb2.1b0a.b464	---	C6/0/0/U1	w-online (pt)	50	-0.50	1499	0	N
001e.6bfb.0872	---	C6/0/0/U1	w-online (pt)	52	0.00	1732	0	N
0025.2e12.4b04	13.35.0.9	C6/0/0/U1	w-online (pt)	53	0.00	1490	1	N
38c8.5cb2.540a	---	C6/0/0/U1	w-online (pt)	63	-0.50	1475	1	N

```
CMTS#show cable modem cab 6/0/0 ipv6
```

```
Device Type: B - CM Bridge, R - CM Router
```

```
IP Assignment Method: D - DHCP
```

MAC Address	Type	Interface	Mac State	D/IP	IP Address
7cb2.1b2d.dac0	B/D	C6/0/0/U1	w-online (pt)	N	2001:DB8:FFFF:0:7EB2:1BFF:FE2D:DAC0
7cb2.1b0a.b464	B/D	C6/0/0/U1	w-online (pt)	N	2001:DB8:FFFF:0:7EB2:1BFF:FE0A:B464
38c8.5cb2.540a	B/D	C6/0/0/U1	w-online (pt)	N	2001:DB8:FFFF:0:3AC8:5CFF:FEB2:540A
001e.6bfb.0872	B/D	C6/0/0/U1	w-online (pt)	N	2001:DB8:FFFF:0:21E:6BFF:FEFB:872
0025.2e12.4b04	B/D	C6/0/0/U1	w-online (pt)	N	---

# Maintaining host & network database

## IPv6 ND cache

```
CMTS#show ipv6 neighbors
```

IPv6 Address	Age	Link-layer Addr	State	Interface
FE80::7EB2:1BFF:FE2D:DAC0	-	7cb2.1b2d.dac0	REACH	Bu99
FE80::21E:6BFF:FEFB:872	-	001e.6bfb.0872	REACH	Bu99
2001:DB8:FFFF:0:7EB2:1BFF:FE0A:B464	-	7cb2.1b0a.b464	REACH	Bu99
FE80::3AC8:5CFF:FEB2:540A	-	38c8.5cb2.540a	REACH	Bu99
2001:DB8:FFFF:0:7EB2:1BFF:FE2D:DAC0	-	7cb2.1b2d.dac0	REACH	Bu99
FE80::7EB2:1BFF:FE0A:B464	-	7cb2.1b0a.b464	REACH	Bu99
2001:DB8:FFFF:0:3AC8:5CFF:FEB2:540A	-	38c8.5cb2.540a	REACH	Bu99
2001:DB8:FFFF:0:21E:6BFF:FEFB:872	-	001e.6bfb.0872	REACH	Bu99

**show ipv6 neighbors** displays the ND cache and state follows the NUD algorithm

Starting with the SCG1 release NUD is no longer used to maintain neighbors for cable modems; the entries are static and remain as long as the modem is online; can only remove by a **clear cable modem <> delete** or by being “offline” for the SID inactivity period (default 24 hours)

# Cable modem configuration file

- If using SNMPv2c to manage IPv6 cable modems; need to enable SNMP coexistence (TLV 53)

```
SNMPv1v2c Coexistence Configuration
SNMPv1v2c Community Name:changeme
SNMPv1v2c Transport Address Access
  SNMPv1v2c Transport Address:0:0:0:0:0:0:0:0/0
  SNMPv1v2c Transport Address Mask:0:0:0:0:0:0:0:0/0
SNMPv1v2c Access View Type:read-write
SNMPv1v2c Access View Name:docsisManagerView
```

- To support cable modem firmware upgrades over IPv6 identify the TFTP server (TLV 58)

```
Software Upgrade IPv6 TFTP Server:0:0:0:0:0:0:0:0
```

# Agenda

- IPv6 motivation and challenges
- Key aspects of IPv6
- IPv6 in cable
- IPv6 for cable modem management
- **IPv6 for CPEs**
- IPv6 for CPE routers
- Other topics





## IPv6 for CPEs

# IPv6 CPE provisioning

- CPEs will typically have at least two IPv6 address
  - Link local IPv6 address
  - Link global IPv6 address(es) learned via DHCPv6 or SLAAC.
- The link local may or may not use the EUI-64 format for the interface identifier (disabled by default in many common CPE OS's)
- **For security reasons the MSO may opt not to use the EUI-64 format for the interface-identifier portion of the global IPv6 address**



# Trace of CPE provisioning

Source	Destination	Protocol	Info
::	ff02::16	ICMPv6	Multicast Listener Report Message v2
::	ff02::16	ICMPv6	Multicast Listener Report Message v2
::	ff02::16	ICMPv6	Multicast Listener Report Message v2
::	ff02::1:ff49:25c1	ICMPv6	Neighbor Solicitation for fe80::426c:8fff:fe49:25c1
fe80::426c:8fff:fe49:25c1	ff02::1	ICMPv6	Neighbor Advertisement fe80::426c:8fff:fe49:25c1 (ovr) is at 40:6c:8f:49:25:c1
fe80::426c:8fff:fe49:25c1	ff02::2	ICMPv6	Router Solicitation from 40:6c:8f:49:25:c1
fe80::212:ff:fe1a:b3f	ff02::1	ICMPv6	Router Advertisement from 00:12:00:1a:0b:3f
fe80::426c:8fff:fe49:25c1	ff02::1:2	DHCPv6	Solicit XID: 0xbc989d CID: 000100011811aac2406c8f4925c1
fe80::212:ff:fe1a:b3f	fe80::426c:8fff:fe49:25c1	DHCPv6	Advertise XID: 0xbc989d CID: 000100011811aac2406c8f4925c1 IAA: 2001:db8:fffe:0:f060:7945:20b2:188
fe80::212:ff:fe1a:b3f	fe80::426c:8fff:fe49:25c1	DHCPv6	Advertise XID: 0xbc989d CID: 000100011811aac2406c8f4925c1 IAA: 2001:db8:fffe:0:f060:7945:20b2:188
fe80::426c:8fff:fe49:25c1	ff02::1:2	DHCPv6	Request XID: 0x6ba2c7 CID: 000100011811aac2406c8f4925c1 IAA: 2001:db8:fffe:0:f060:7945:20b2:188
fe80::212:ff:fe1a:b3f	fe80::426c:8fff:fe49:25c1	DHCPv6	Reply XID: 0x6ba2c7 CID: 000100011811aac2406c8f4925c1 IAA: 2001:db8:fffe:0:f060:7945:20b2:188
::	ff02::1:ffb2:188	ICMPv6	Neighbor Solicitation for 2001:db8:fffe:0:f060:7945:20b2:188
fe80::426c:8fff:fe49:25c1	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::426c:8fff:fe49:25c1	ff02::1	ICMPv6	Neighbor Advertisement 2001:db8:fffe:0:f060:7945:20b2:188 (ovr) is at 40:6c:8f:49:25:c1
fe80::426c:8fff:fe49:25c1	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::426c:8fff:fe49:25c1	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::426c:8fff:fe49:25c1	fe80::212:ff:fe1a:b3f	ICMPv6	Neighbor Solicitation for fe80::212:ff:fe1a:b3f from 40:6c:8f:49:25:c1
fe80::212:ff:fe1a:b3f	fe80::426c:8fff:fe49:25c1	ICMPv6	Neighbor Advertisement fe80::212:ff:fe1a:b3f (rtr, sol)
fe80::212:ff:fe1a:b3f	2001:db8:fffe:0:f060:7945:20b2:188	ICMPv6	Neighbor Solicitation for 2001:db8:fffe:0:f060:7945:20b2:188 from 00:12:00:1a:0b:3f
fe80::426c:8fff:fe49:25c1	fe80::212:ff:fe1a:b3f	ICMPv6	Neighbor Advertisement 2001:db8:fffe:0:f060:7945:20b2:188 (sol)
fe80::212:ff:fe1a:b3f	ff02::1	ICMPv6	Router Advertisement from 00:12:00:1a:0b:3f

# CNR example: DHCPv6 prefix for CPE addresses

Edit DHCP v6 Prefix *TEST\_CPE\_PREFIX, 2001:db8:ffe::/64*

Expand All Collapse All Default View Show A-Z View

Universal Settings

Attribute	Value	Data Type	Default	Unset?
name*	TEST_CPE_PREFIX	string		
vpn-id		VPN	0	
description		string		<input type="checkbox"/>
dhcp-type	[dhcp]	32-bit enum	dhcp	<input type="checkbox"/>
address*	2001:db8:ffe::/64	IPv6 prefix/prefix length		
owner	[none]	CCMOwner		<input type="checkbox"/>
region	[none]	CCMRegion		<input type="checkbox"/>
reverse-zone-prefix-length		bounded integer		<input type="checkbox"/>

Non-Parent Settings

Attribute	Value	Data Type	Default	Unset?
range	2001:db8:ffe:: 65			<input type="checkbox"/>
link	TEST_LINK			<input type="checkbox"/>
policy	CPE_IPv6_Policy	Policy		<input type="checkbox"/>
Selection Tags (selection-tags)	Tag Value unprovisioned-computer Add Selection Tag	string list		<input type="checkbox"/>
allocation-algorithms	<input type="checkbox"/> client-request <input checked="" type="checkbox"/> reservation <input type="checkbox"/> extension <input type="checkbox"/> interface-identifier <input checked="" type="checkbox"/> random <input type="checkbox"/> best-fit <input type="checkbox"/> [none]	flags	reservation, extension, random, best-fit	<input type="checkbox"/>
restrict-to-reservations	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
max-leases		bounded integer (0 - 2000000)	65536	<input type="checkbox"/>
ignore-declines	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
expiration-time		date		<input type="checkbox"/>
free-address-config	[none]	AddrTrapConfig		<input type="checkbox"/>
deactivated	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>

A /64 is recommended for simplicity and should be more than enough addresses

Allocate half the address range on this server; other half on the other server

Using randomly generated interface IDs provides security by not exposing the CPE manufacturer

# CNR example: IPv6 policy for CPEs

## Edit DHCP Policy *CPE\_IPv6\_Policy*

Attribute	Value	Unset?
Name *	CPE_IPv6_Policy	<input type="checkbox"/>
Offer Timeout	2m	<input type="checkbox"/>
Grace Period	5m	<input type="checkbox"/>
DHCPv4 Options		
DHCPv6 Options		
Configured Options		
[24] (dhcp6-config) domain-list (DNS name)		
[23] (dhcp6-config) dns-servers (IPv6 address)		
[7] (dhcp6-config) preference (unsigned 8-bit)		
Add Option		
company-v6.cisco.com. fc00:1111:1111:1111:250:56ff:feb5:5318,fc00:1111:1111:1111:250:56ff:feb5:5310 255		
DHCPv4 Vendor Options		
DHCPv6 Vendor Options		
APc1200 Select		
dhcp6-cablelabs-config Select		

Set preference option to maximum value to influence CPEs to use addresses from this server

Expand All Collapse All Default View Show A-Z View				
Attribute	Value	Data Type	Default	Unset?
unavailable-timeout	<input type="text"/>	unsigned time	24h	<input type="checkbox"/>
inhibit-all-renews	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
inhibit-renews-at-reboot	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
permanent-leases	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
renewal-pct	<input type="text"/>	percentage	50%	<input type="checkbox"/>
rebind-pct	<input type="text"/>	percentage	80%	<input type="checkbox"/>
lease-retention-limit	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
DHCPv4 Settings				
DNS Update Settings				
DHCPv6 Settings				
Attribute	Value	Data Type	Default	Unset?
allow-non-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean	true	<input type="checkbox"/>
allow-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean	true	<input type="checkbox"/>
allow-rapid-commit	<input type="radio"/> true <input checked="" type="radio"/> false	boolean	false	<input type="checkbox"/>
allow-client-hints	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
min-preferred-lifetime	<input type="text"/>	unsigned time		<input type="checkbox"/>
preferred-lifetime	<input type="text"/>	unsigned time	1w	<input type="checkbox"/>
min-valid-lifetime	<input type="text"/>	unsigned time		<input type="checkbox"/>
valid-lifetime	<input type="text"/>	unsigned time	2w	<input type="checkbox"/>
affinity-period	<input type="text"/>	unsigned time		<input type="checkbox"/>
v6-reply-options	server-identifier,preference,domain-list,dns-	dhcpv6 option id list		<input type="checkbox"/>
default-prefix-length	<input type="text"/>	bounded integer (0 - 128)	64	<input type="checkbox"/>
longest-prefix-length	<input type="text"/>	bounded integer (0 - 128)		<input type="checkbox"/>
shortest-prefix-length	<input type="text"/>	bounded integer (0 - 128)		<input type="checkbox"/>
excluded-prefix	<input type="text"/>	IPv6 prefix/prefix length		<input type="checkbox"/>
reconfigure	[allow] <input type="text"/>	32-bit enum	allow	<input type="checkbox"/>
reconfigure-via-relay	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>

If multiple DHCP servers Rapid Commit needs to be disabled

May opt to use longer lifetimes

# Maintaining host & network database

## IPv6 CPE show commands

```
CMTS#show interface cab 6/0/0 modem ipv6
```

SID	Type	State	IPv6 Address	M MAC address
49	CM	w-online (pt)	2001:DB8:FFFF:0:7EB2:1BFF:FE2D:DAC0	D 7cb2.1b2d.dac0
49	CPE	unknown	2001:DB8:FFFE:0:95F6:33FA:6D0F:CBCE	D 0015.587e.9d30
50	CM	w-online (pt)	2001:DB8:FFFF:0:7EB2:1BFF:FE0A:B464	D 7cb2.1b0a.b464
50	CPE	unknown	2001:DB8:FFFE:0:F060:7945:20B2:188	D 406c.8f49.25c1
51	CM	w-online (pt)	2001:DB8:FFFF:0:3AC8:5CFF:FEB2:540A	D 38c8.5cb2.540a
51	CPE	unknown	2001:DB8:FFFE:0:3084:9310:46C9:3B20	D 001c.2512.a794

```
CMTS#show cable modem 7cb2.1b0a.b464 cpe
```

IP address	MAC address	Dual IP	Device Class
24.35.0.238	406c.8f49.25c1	<b>Y</b>	Host

```
CMTS#show cable modem 7cb2.1b0a.b464 ipv6 cpe
```

MAC Address	IP Address
406c.8f49.25c1	2001:DB8:FFFE:0:F060:7945:20B2:188

# Maintaining host & network database

## IPv6 CPE show commands

```
CMTS#show ipv6 neighbors
```

IPv6 Address	Age	Link-layer Addr	State	Interface
FE80::426C:8FFF:FE49:25C1	35	406c.8f49.25c1	REACH	Bu99
2001:DB8:FFFE:0:95F6:33FA:6D0F:CBCE	14	0015.587e.9d30	REACH	Bu99
2001:DB8:FFFE:0:F060:7945:20B2:188	34	406c.8f49.25c1	REACH	Bu99
FE80::144C:B972:3F42:4971	142	001c.2512.a794	STALE	Bu99
FE80::215:58FF:FE7E:9D30	135	0015.587e.9d30	STALE	Bu99
2001:DB8:FFFE:0:3084:9310:46C9:3B20	21	001c.2512.a794	REACH	Bu99

```
CMTS#show ipv6 neighbors statistics
```

```
IPv6 ND Statistics
```

```
Entries 40, High-water 42, Gleaned 12, Scavenged 13, Static 38
```

```
Entry States
```

```
INCMP 0 REACH 40 STALE 0 GLEAN 0 DELAY 0 PROBE 0
```

```
Resolutions
```

```
Requested 4, timeouts 3, resolved 2, failed 1
```

```
In-progress 0, High-water 1, Throttled 0, Data discards 1
```

```
NUD
```

```
Requested 7966, timeouts 20, resolved 7968, failed 4
```

```
in-progress 1, high-water 3, throttled 0, current queue 0, queue high-water 0
```

# Maintaining host & network database

## IPv6 ND Gleaning

- ND cache entry is initially created when device is provisioned
- ND cache entry can be lost (e.g. CLI command, CM reload) and packet forwarding in DS can't resolve L2 address
- ND gleaning allows CMTS to recover lost information without the need to reload the CPE
- ND gleaning is enabled by default and controlled with the “[no] cable nd” command under bundle interface

# IPv6 address acquisition

## Static IPv6 and SAV

- Static IPv6 addressing may be required
- The CMTS learns about a static IPv6 CPE when the static IPv6 CPE sends any data (including an NS(DAD)) to the CMTS.
- CMTS checks the IPv6 source address using the Source Address Verification (SAV) feature
  - (1) CM configuration file includes a TLV (43.7.1) that identifies the SAV Prefix group name that the CM belongs to. The prefixes in the group are configured on the CMTS.
  - (2) CM configuration file includes a TLV (43.7.2) that provides the actual prefix
- Enabled with global CLI: **cable source-verify enable-sav-static**

# Controlling the amount of CPE IPv6 traffic

- **Once the CMTS is configured for IPv6 and starts sending Router Advertisements any CPE behind an IPv6 capable cable modem is able to attempt to obtain IPv6 network connectivity**
- Most client devices are enabled for IPv6 by default and are just waiting for the RAs



# Controlling the amount of CPE IPv6 traffic

- Can set the DOCSIS DEVICE-MIB objects [docsDevFilterLLCUnmatchedAction](#) and [docsDevFilterLLCTable](#) in the CM configuration file to explicitly block IPv6 to/from the modem's Ethernet port.
- Below is an example where IPv4 (Ethertype 0x0800 – 2048 in decimal) and ARP (Ethertype 0x0806 – 2054 in decimal) are allowed and any unspecified Ethertype (such as IPv6) are denied

```
11 (SNMP MIB Object) = docsDevFilterLLCUnmatchedAction.0 (Integer) = 1
11 (SNMP MIB Object) = docsDevFilterLLCStatus.1 (Integer) = 5
11 (SNMP MIB Object) = docsDevFilterLLCIfIndex.1 (Integer) = 0
11 (SNMP MIB Object) = docsDevFilterLLCProtocolType.1 (Integer) = 1
11 (SNMP MIB Object) = docsDevFilterLLCProtocol.1 (Integer) = 2048
11 (SNMP MIB Object) = docsDevFilterLLCStatus.1 (Integer) = 1
11 (SNMP MIB Object) = docsDevFilterLLCStatus.2 (Integer) = 5
11 (SNMP MIB Object) = docsDevFilterLLCIfIndex.2 (Integer) = 0
11 (SNMP MIB Object) = docsDevFilterLLCProtocolType.2 (Integer) = 1
11 (SNMP MIB Object) = docsDevFilterLLCProtocol.2 (Integer) = 2054
11 (SNMP MIB Object) = docsDevFilterLLCStatus.2 (Integer) = 1
```

# Controlling the amount of CPE IPv6 traffic

- Another option is to use Subscriber Management Filter Groups (TLV 37) to block IPv6 traffic on a per device basis

```
***** Add an index to the CPE upstream Filter Group to drop all IPv6 *****  
cable filter group 2 index 18 ip-version IPv6  
cable filter group 2 index 18 match-action drop
```

```
***** Either explicitly assign this FG in the CM configuration file or use the default FG *****  
cable submgmt default filter-group cpe upstream 2  
cable submgmt default active
```

- Yet another option would be to use Upstream Drop Classifiers (TLVs 60 and 62) in the modem configuration file to drop the IPv6 traffic

# Agenda

- IPv6 motivation and challenges
- Key aspects of IPv6
- IPv6 in cable
- IPv6 for cable modem management
- IPv6 for CPEs
- **IPv6 for CPE routers**
- Other topics

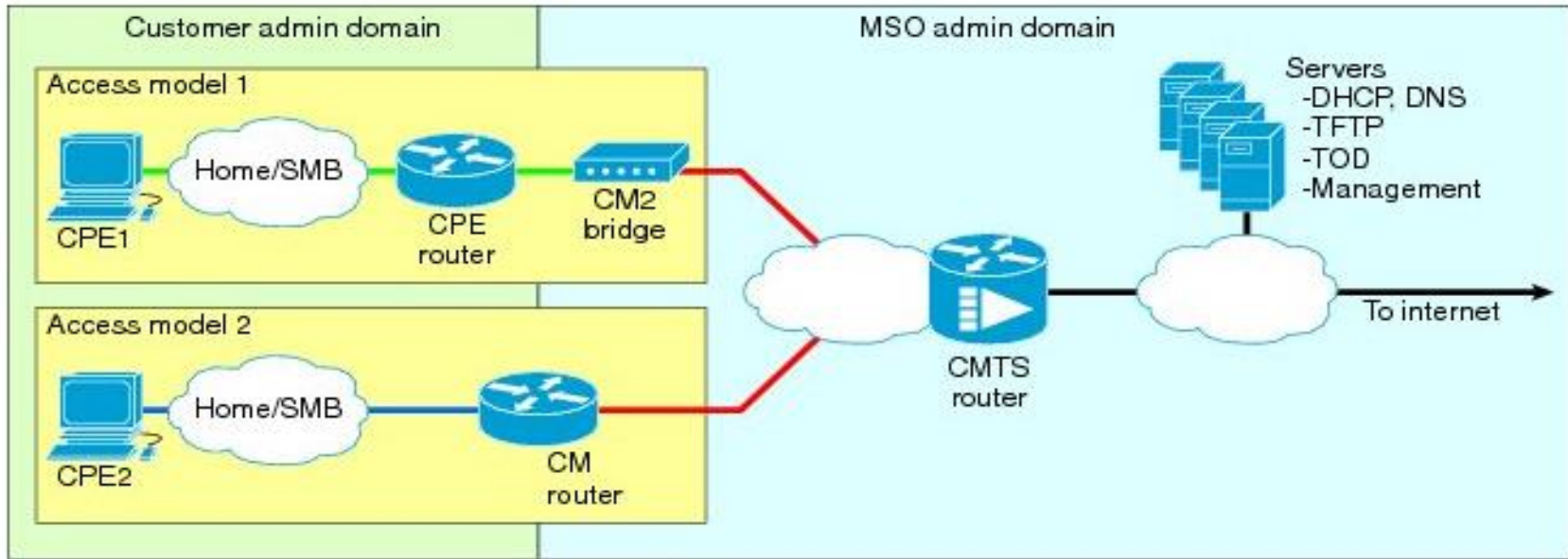




## IPv6 for CPE routers

# IPv6 address acquisition

## IPv6 CPE router architecture



246187

- HFC link; assigned 2001:DB8:FFFF:0::/64 (mgmt)
- Customer 1 premises link; assigned 2001:DB8:2:1::/64
- Customer 2 premises link; assigned 2001:DB8:3:1::/64

- Management prefix: 2001:DB8:FFFF:0::/64 (mgmt)
- Customer 1 prefix: 2001:DB8:2::/48
- Customer 2 prefix: 2001:DB8:3::/48

Routers span customer and MSO administrative domains

# IPv6 in eRouter

## eRouter mode of provisioning

eDOCSIS specification defines a TLV for each eSAFE entity to be included in the corresponding cable modem's configuration file. TLV 202 is used for eRouter and sub-type "1" dictates the eRouter initialization mode

Mode	IPv4 Behavior	IPv6 Behavior
<b>Disabled (0)</b>	CM bridges all traffic	CM bridges all traffic
<b>IPv4 Protocol Enabled (1)</b>	IPv4 traffic forwarded via NAPT	IPv6 traffic not forwarded
<b>IPv6 Protocol Enabled (2)</b>	IPv4 traffic not forwarded	IPv6 traffic forwarded
<b>Dual IP Protocol Enabled (3)</b>	IPv4 traffic forwarded via NAPT	IPv6 traffic forwarded

Ex: GenericTLV TlvCode 202 TlvLength 3 TlvValue 0x0101**03**;` /\* dual IP \*/

# IPv6 in eRouter

## IPv6 provisioning of operator facing interface

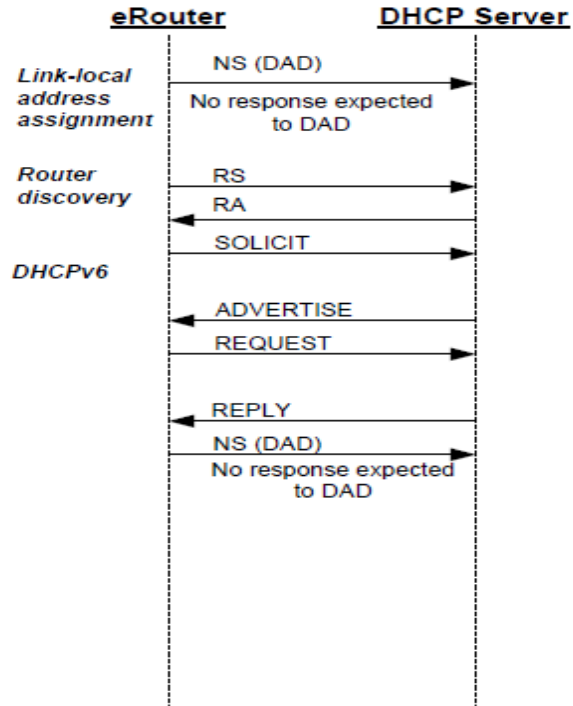


Figure 8-1 - IPv6 Provisioning Message Flow

Link local = FE80:: + EUI-64

DAD to confirm uniqueness (NS/NA)

Router discovery (RS/RA)

DHCPv6 includes PD option and Rapid Commit (MUSTs in Solicit, PD MUST in Advertise/Reply)

DAD to confirm uniqueness of DHCP address

# Example eRouter DHCPv6 debugs

```
+ Start of RELAY-FORW (12) message (345 bytes)
| hop-count 0,
| link-address 2001:db8:fffe::1,
| peer-address fe80::3ac8:5cff:feb2:540e
| relay-message (9) option (256 bytes)
+ Start of SOLICIT (1) message (256 bytes)
| transaction-id 13356830
| rapid-commit (14) option (0 bytes)
| reconfigure-accept (20) option (0 bytes)
| oro (6) option (8 bytes)
| 17,23,24,25
| vendor-class (16) option (16 bytes)
| (enterprise-id 4491,
| ((00:0a:65:52:6f:75:74:65:72:31:2e:30)))
| vendor-opts (17) option (127 bytes)
| (enterprise-id 4491,
| ((device-type 2 EROUTER),
| (embedded-components-list 3 ECM:EROUTER),
| (device-serial-number 4 231638530),
| (hardware-version-number 5 1.0),
| (software-version-number 6 D3925-P15-5-v302r12555
| (boot-rom-version 7 2.3.0_R1),
```

```
| (vendor-oui 8 0011E6),
| (model-number 9 DPC3925),
| (vendor-name 10 Cisco)))
| client-identifier (1) option (10 bytes)
| 00:03:00:01:38:c8:5c:b2:54:0e
| ia-pd (25) option (41 bytes)
| (iaid 1555190799, t1 0, t2 0)
| iaprefix (26) option (25 bytes)
| (preferred-lifetime 0,
| valid-lifetime 0,
| prefix-length 56,
| prefix ::)
| ia-na (3) option (12 bytes)
| (iaid 1555190798, t1 0, t2 0)
| elapsed-time (8) option (2 bytes)
| 0
+ End of SOLICIT message
| interface-id (18) option (21 bytes)
| 42:75:39:39:26:43:61:36:2f:30:2f:30:00:38:c8:5c:b2:54:0e:00:00
| vendor-opts (17) option (22 bytes)
| (enterprise-id 4491,
| ((cmts-capabilities 1025 01:02:03:00),
| (cm-mac-address 1026 38:c8:5c:b2:54:0a)))
+ End of RELAY-FORW message
```

Hint, indicating  
desired delegated  
prefix length

# Example eRouter DHCPv6 debugs

```
+-- Start of ADVERTISE (2) message (232 bytes)
  transaction-id 13356830
  client-identifier (1) option (10 bytes)
    00:03:00:01:38:c8:5c:b2:54:0e
  server-identifier (2) option (14 bytes)
    00:01:00:01:13:4a:ae:e5:00:50:56:b5:3d:27
  ia-na (3) option (40 bytes)
    (iaid 1555190798,
     t1 2d6h14m,
     t2 3d14h46m24s)
  iaaddr (5) option (24 bytes)
    (address 2001:db8:fffe:0:e5a1:df2b:5099:2f8e,
     preferred-lifetime 4d12h28m1s,
     valid-lifetime 1w4d12h28m1s)
  ia-pd (25) option (41 bytes)
    (iaid 1555190799, t1 29m4s, t2 46m31s)
  iaprefix (26) option (25 bytes)
    (preferred-lifetime 58m9s,
     valid-lifetime 58m9s,
     prefix-length 60,
     prefix 2001:db8:0:8000::)
  reconfigure-accept (20) option (0 bytes)
  preference (7) option (1 bytes)
    0
  vendor-opts (17) option (32 bytes)
    (enterprise-id 4491,
     ((time-offset 38 -5h),
     (syslog-servers 34 fc00:1111:1111:1111:203:baff:fe67:e489)))
  dns-servers (23) option (32 bytes)
    fc00:1111:1111:1111:250:56ff:feb5:5318,fc00:1111:1111:1111:250:56ff:feb5:5310
  domain-list (24) option (22 bytes)
    company-v6.cisco.com.
+-- End of ADVERTISE message
```

IA\_PD & IA\_NA returned

A /60 prefix delegated in this example

# IPv6 prefix delegation

- In its role as a DHCPv6 relay agent the CMTS is aware of all IPv6 address assignments AND delegated prefixes
- Gleaned addresses populate the IPv6 neighbor cache and cable modem host database
- Gleaned prefix delegations automatically inserted into the IPv6 routing table as static routes and also included in the cable modem host database
- These static routes then need to be redistributed into the routing protocol to provide global connectivity (will likely want to aggregate as well)
- The CLI **cable ipv6 pd-route <PD Prefix> <Bundle Interface>** will create a static route as well assist with DHCPv6 lease query (covered later)



# CNR Example: DHCPv6 prefix for prefix delegation

Edit DHCP v6 Prefix **TEST\_PD\_PREFIX, 2001:db8::/48**

Expand All Collapse All Default View Show A-Z View

Universal Settings

Attribute	Value	Data Type	Default	Unset?
name*	TEST_PD_PREFIX	string		
vpn-id		VPN	0	
description		string		<input type="checkbox"/>
dhcp-type	prefix-delegation	32-bit enum	dhcp	<input type="checkbox"/>
address*	2001:db8::/48	IPv6 prefix/prefix length		
owner	[none]	CCMOwner		<input type="checkbox"/>
region	[none]	CCMRegion		<input type="checkbox"/>
reverse-zone-prefix-length		bounded integer (0 - 124)		<input type="checkbox"/>

Non-Parent Settings

Attribute	Value	Data Type	Default	Unset?
range	2001:db8:: 49			<input type="checkbox"/>
link	TEST_LINK			<input type="checkbox"/>
policy	CM_IPv6_PD			<input type="checkbox"/>
Selection Tags (selection-tags)	Tag Value unprovisioned-computer Add Selection Tag	string list		<input type="checkbox"/>
allocation-algorithms	<input type="checkbox"/> client-request <input checked="" type="checkbox"/> reservation <input type="checkbox"/> extension <input type="checkbox"/> interface-identifier <input type="checkbox"/> random <input checked="" type="checkbox"/> best-fit <input type="checkbox"/> [none]	flags	reservation, extension, random, best-fit	<input type="checkbox"/>
restrict-to-reservations	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>
max-leases		bounded integer (0 - 2000000)	65536	<input type="checkbox"/>
ignore-declines	<input type="radio"/> true <input type="radio"/> false	boolean	false	<input type="checkbox"/>
expiration-time		date		<input type="checkbox"/>
free-address-config	[none]	AddrTrapConfig		<input type="checkbox"/>
deactivated	<input type="radio"/> enabled <input type="radio"/> disabled	boolean	disabled	<input type="checkbox"/>

Choose a prefix length which should be more than enough for the foreseeable future

Allocate half the address range on this server; other half on the other server

The "best-fit" algorithm is used to determine the right sized prefix to delegate based upon what was requested

# CNR Example: IPv6 policy for CPE PD

## Edit DHCP Policy *CM\_IPv6\_PD*

Attribute	Value	Unset?
Name *	CM_IPv6_PD	
Offer Timeout	2m	<input type="checkbox"/>
Grace Period	5m	<input type="checkbox"/>
DHCPv4 Options		
DHCPv6 Options		
DHCPv4 Vendor Options	APc1200	Select
DHCPv6 Vendor Options	dhcp6-cablelabs-config	Select
Expand All Collapse All Default View Show A-Z View		
Attribute	Value	Data Type Default Unset?
unavailable-timeout		unsigned time 24h <input type="checkbox"/>
inhibit-all-renews	<input type="radio"/> true <input type="radio"/> false	boolean false <input type="checkbox"/>
inhibit-renews-at-reboot	<input type="radio"/> true <input type="radio"/> false	boolean false <input type="checkbox"/>
permanent-leases	<input type="radio"/> enabled <input type="radio"/> disabled	boolean disabled <input type="checkbox"/>
renewal-pct		percentage 50% <input type="checkbox"/>
rebind-pct		percentage 80% <input type="checkbox"/>
lease-retention-limit	<input type="radio"/> enabled <input type="radio"/> disabled	boolean disabled <input type="checkbox"/>
DHCPv4 Settings		
DNS Update Settings		
DHCPv6 Settings		
Attribute	Value	Data Type Default Unset?
allow-non-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean true <input type="checkbox"/>
allow-temporary-addresses	<input type="radio"/> true <input type="radio"/> false	boolean true <input type="checkbox"/>
allow-rapid-commit	<input type="radio"/> true <input checked="" type="radio"/> false	boolean false <input type="checkbox"/>
allow-client-hints	<input type="radio"/> true <input type="radio"/> false	boolean false <input type="checkbox"/>
min-preferred-lifetime		unsigned time <input type="checkbox"/>
preferred-lifetime		unsigned time 1w <input type="checkbox"/>
min-valid-lifetime		unsigned time <input type="checkbox"/>
valid-lifetime		unsigned time <input type="checkbox"/>
affinity-period		unsigned time <input type="checkbox"/>
v6-reply-options	server-identifier,preference,domain-list,dns-	<input type="checkbox"/>
default-prefix-length	60	<input type="checkbox"/>
longest-prefix-length	60	<input type="checkbox"/>
shortest-prefix-length	60	<input type="checkbox"/>
excluded-prefix		<input type="checkbox"/>
reconfigure	[allow]	32-bit enum allow <input type="checkbox"/>
reconfigure-via-relay	<input type="radio"/> true <input type="radio"/> false	boolean false <input type="checkbox"/>

If multiple DHCP servers Rapid Commit needs to be disabled

Can define the allowable range of delegated prefix size as well as a default size

# Maintaining host & network database

## IPv6 DHCPv6 IA\_PD gleaning and IPv6 RIB

```
CMTS#show ipv6 route static
```

```
IPv6 Routing Table - default - 18 entries
```

```
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
```

```
      B - BGP, R - RIP, I1 - ISIS L1, I2 - ISIS L2
```

```
      IA - ISIS interarea, IS - ISIS summary, D - EIGRP, EX - EIGRP external
```

```
      O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
```

```
      ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
```

```
S 2001:DB8::/48 [1/0]
```

```
    via Bundle99, directly connected
```

```
S 2001:DB8::/60 [1/0]
```

```
    via FE80::3AC8:5CFF:FEB2:727A, Bundle99
```

```
S 2001:DB8:0:10::/60 [1/0]
```

```
    via FE80::3AC8:5CFF:FEB2:540E, Bundle99
```

```
CMTS#show cable modem ipv6 prefix
```

```
Device Type: B - CM Bridge, R - CM Router
```

```
IP Assignment Method: D - DHCP
```

```
MAC Address      Type IPv6 prefix
```

```
38c8.5cb2.727a R/D 2001:DB8::/60
```

```
38c8.5cb2.540e R/D 2001:DB8:0:10::/60
```

# Maintaining host & network database

## IPv6 DHCPv6 IA\_PD gleaning and IPv6 RIB

```
CMTS#show cable modem 38c8.5cb2.540a ipv6 prefix
```

```
Device Type: B - CM Bridge, R - CM Router
```

```
IP Assignment Method: D - DHCP
```

```
MAC Address      Type IPv6 prefix  
38c8.5cb2.540e R/D  2001:DB8:0:10::/60
```

```
CMTS#show ipv6 route summary
```

```
IPv6 routing table name is default(0) global scope - 18 entries
```

```
IPv6 routing table default maximum-paths is 16
```

Route Source	Networks	Overhead	Memory (bytes)
connected	3	288	384
local	5	480	640
ospf 1	7	672	896
Intra-area: 4  Inter-area: 1  External-1: 0  External-2: 0			
NSSA External 1: 0  NSSA External 2: 2			
static	3	288	384
Static: 3  Per-user static: 0			
Total	18	1728	2304

```
Number of prefixes:
```

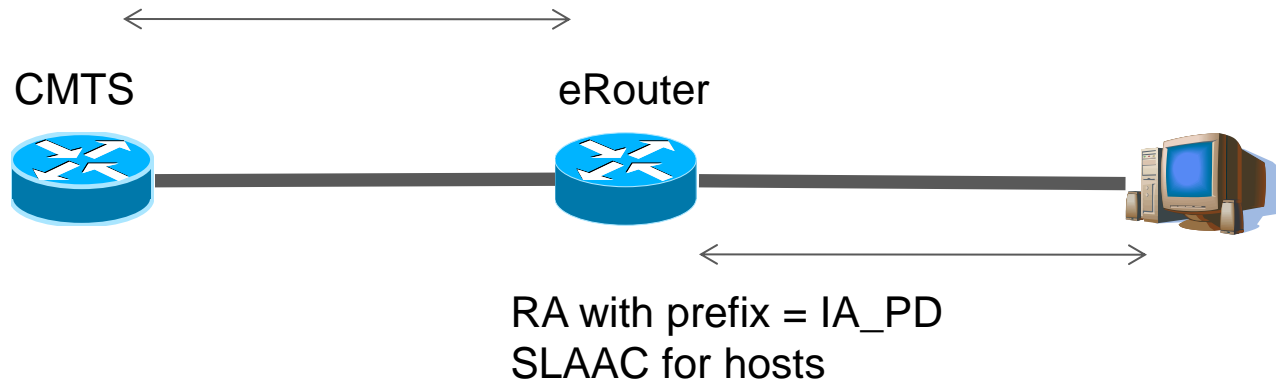
```
/0: 1, /8: 1, /48: 1, /60: 2, /62: 2, /64: 7, /128: 4
```

# IPv6 in a CPE Router

## Local interfaces and CPEs

- eRouter generates RA (M=0, O=1, prefix = IA\_PD with **A=1**, L=1)
- **CPE will use SLAAC to get IP address**

DHCPv6 for IA\_NA and IA\_PD



# Trace of CPE provisioning

Source	Destination	Protocol	Info
::	ff02::1:ff42:4971	ICMPv6	Neighbor Solicitation for fe80::144c:b972:3f42:4971
fe80::144c:b972:3f42:4971	ff02::2	ICMPv6	Router Solicitation from 00:1c:25:12:a7:94
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::144c:b972:3f42:4971	ff02::2	ICMPv6	Router Solicitation from 00:1c:25:12:a7:94
fe80::144c:b972:3f42:4971	ff02::1	ICMPv6	Router Advertisement from 38:c8:5c:b2:54:0d
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2
fe80::144c:b972:3f42:4971	ff02::1:2	DHCPv6	Information-request XID: 0xa98dd2 CID: 000100011278426e001c2512a794
fe80::3ac8:5cff:feb2:540d	fe80::144c:b972:3f42:4971	DHCPv6	Reply XID: 0xa98dd2 CID: 000100011278426e001c2512a794
fe80::144c:b972:3f42:4971	ff02::1:ffb2:540d	ICMPv6	Neighbor Solicitation for fe80::3ac8:5cff:feb2:540d from 00:1c:25:12:a7:94
fe80::3ac8:5cff:feb2:540d	fe80::144c:b972:3f42:4971	ICMPv6	Neighbor Advertisement fe80::3ac8:5cff:feb2:540d (rtr, sol, ovr) is at 38:c8:5c:b2:54:0d
::	ff02::1:ff42:4971	ICMPv6	Neighbor Solicitation for 2001:db8:0:8001:144c:b972:3f42:4971
::	ff02::1:ffb10:74e9	ICMPv6	Neighbor Solicitation for 2001:db8:0:8001:d437:bc24:a910:74e9
fe80::144c:b972:3f42:4971	ff02::16	ICMPv6	Multicast Listener Report Message v2

Internet Protocol Version 6, Src: fe80::3ac8:5cff:feb2:540d (fe80::3ac8:5cff:feb2:540d), Dst: ff02::1 (ff02::1)

Internet Control Message Protocol v6

Type: Router Advertisement (134)

Code: 0

Checksum: 0x5956 [correct]

Cur hop limit: 64

Flags: 0x40

0... .. = Managed address configuration: Not set  
 .1... .. = Other configuration: Set  
 ..0... .. = Home Agent: Not set  
 ...0 0... = Prf (Default Router Preference): Medium (0)  
 .... .0... = Proxy: Not set  
 .... ..0. = Reserved: 0

Router lifetime (s): 9000

Reachable time (ms): 0

Retrans timer (ms): 0

ICMPv6 Option (Source link-layer address : 38:c8:5c:b2:54:0d)

ICMPv6 Option (Prefix information : 2001:db8:0:8001::/64)

Type: Prefix information (3)

Length: 4 (32 bytes)

Prefix Length: 64

Flag: 0xc0

Valid Lifetime: 3600

Preferred Lifetime: 3600

Reserved

Prefix: 2001:db8:0:8001:: (2001:db8:0:8001::)

ICMPv6 Option (Route Information : Medium 2001:db8:0:8001::/64)

ICMPv6 Option (Recursive DNS Server fc00:1111:1111:1111:250:56ff:feb5:5318 fc00:1111:1111:1111:250:56ff:feb5:5310)

ICMPv6 Option (DNS Search List Option company.v6.cisco.com)

BRKSPG-2607

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M-bit not set in RA but O-bit is set

PIO included in the RA with /64 prefix from the delegated prefix L-bit and A-bit set as well

# IPv6 prefix stability

- Typically a range of IPv6 prefixes available for delegation are allocated to a particular CMTS
- **Thus if a CPE router is moved from CMTS “A” to CMTS “B” due to a node-split by the MSO it’s delegated prefix changes**
- Node-splits are where a MSO alters the RF plant resulting in a portion of the customer moving to a new MAC domain in order to alleviate congestion
- This behavior could be problematic for some end customers; such as a business customer that requires it’s addressing to remain constant



# CM and CPE router online on CMTS-1



WAN Router



PD route IGP update



Provisioning System

CMTS-1



CMTS-2

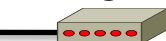


PD gleaned during DHCPv6 and static route created

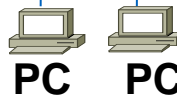
Since no local CM with that PD; PD route added to routing table

CPE router provisions via DHCPv6 requesting PD

CM

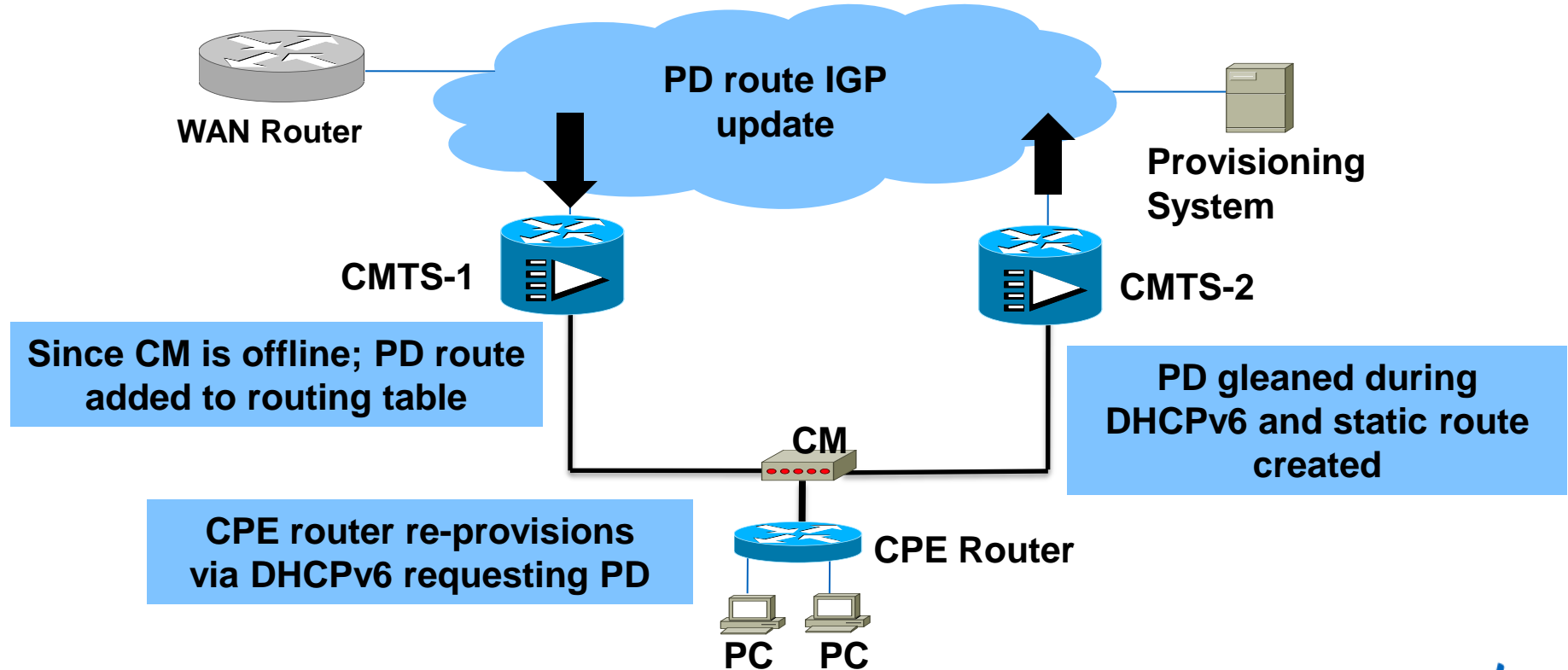


CPE Router



PC PC

# CM and CPE router move to CMTS-2



# D3.0 MULPI solution












For Your  
Reference

- In the provisioning system a range of IPv6 prefixes available for delegation are now allocated to a group of CMTS's
- A routing protocol such as IS-IS or OSPFv3 runs between CMTSs at a site and delegated prefixes are redistributed into this routing protocol such that all CMTSs in the site learn the route
- When a CMTS receives a routing update for a prefix that is associated to a locally connected cable modem it checks the status of the cable modem
- If the CM is currently online the routing update is ignored (route next hop continues to point to this CM's CPE)
- If the CM is offline the prefix routing entry is updated (now points to new CMTS instead of this CM's CPE)
- **After CM move, this solution assumes the CPE router will reset and thus the new CMTS gleans the PD and sends a routing update to the old CMTS to purge the PD.**

# Prefix stability configuration

## List/Add DHCP v6 Links

 Add Link			
 Name	Link Type	Link Group	
 ASCABLE-PREFIX-STABLE	location-independent	ASCABLE	
 F241-38-00-uBR10K-1	topological	ASCABLE	
 F241-38-01-UBR10K-1	topological	ASCABLE	
 F241-38-02-UBR10K-1	topological	ASCABLE	
 F241-38-04-UBR10K-1	topological	ASCABLE	
 F241-38-05-UBR10K-1	topological	ASCABLE	
 F241-38-06-UBR10K-1	topological	ASCABLE	

# Agenda

- IPv6 motivation and challenges
- Key aspects of IPv6
- IPv6 in cable
- IPv6 for cable modem management
- IPv6 for CPEs
- IPv6 for CPE routers
- **Other topics**





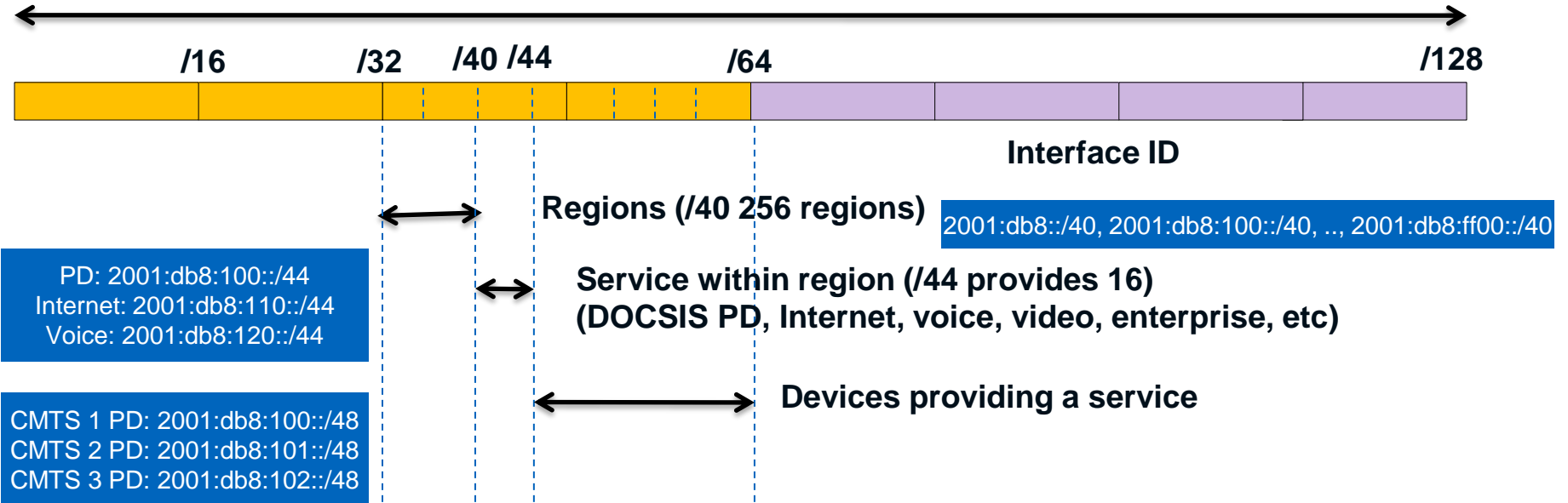
Other topics

# IPv6 address planning

Sub-netting example (assuming - /32 for customer)

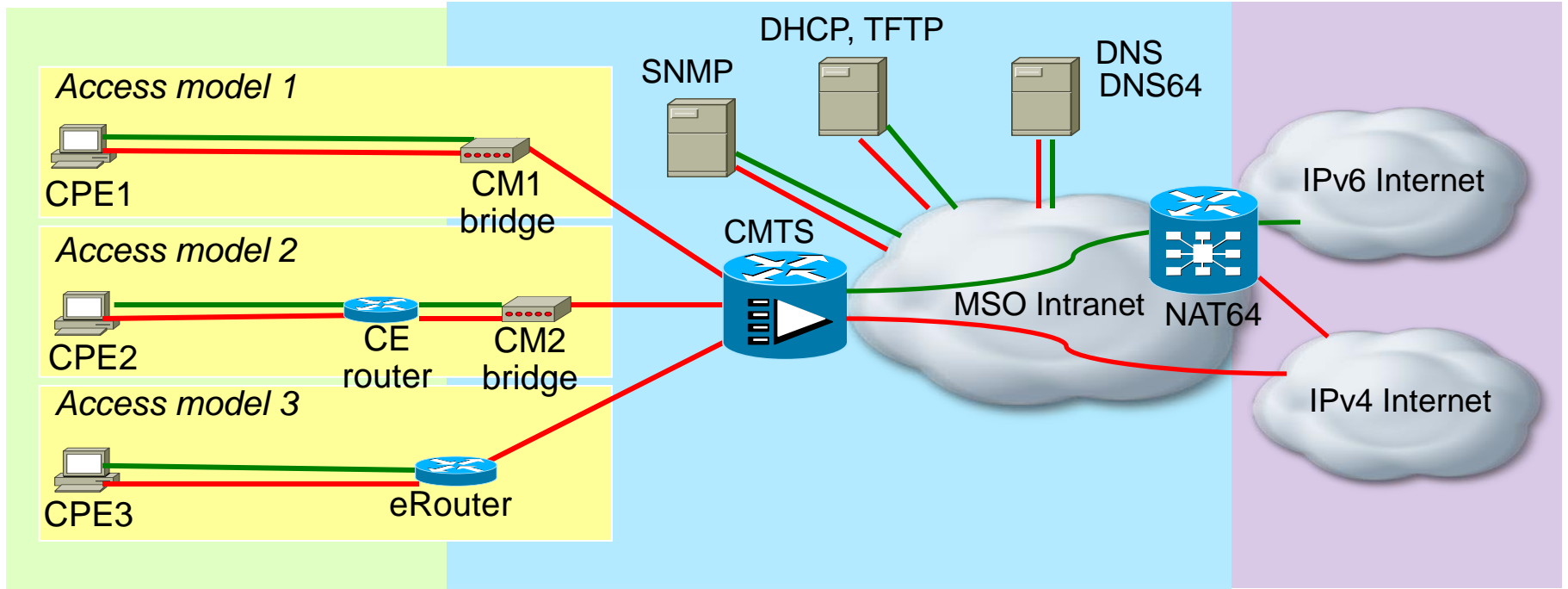
2001:db8::/32

128 Bits



[http://www.cisco.com/en/US/docs/solutions/SBA/February2013/Cisco\\_SBA\\_BN\\_IPv6AddressingGuide-Feb2013.pdf](http://www.cisco.com/en/US/docs/solutions/SBA/February2013/Cisco_SBA_BN_IPv6AddressingGuide-Feb2013.pdf)

# Transition Strategy – MSO “X”



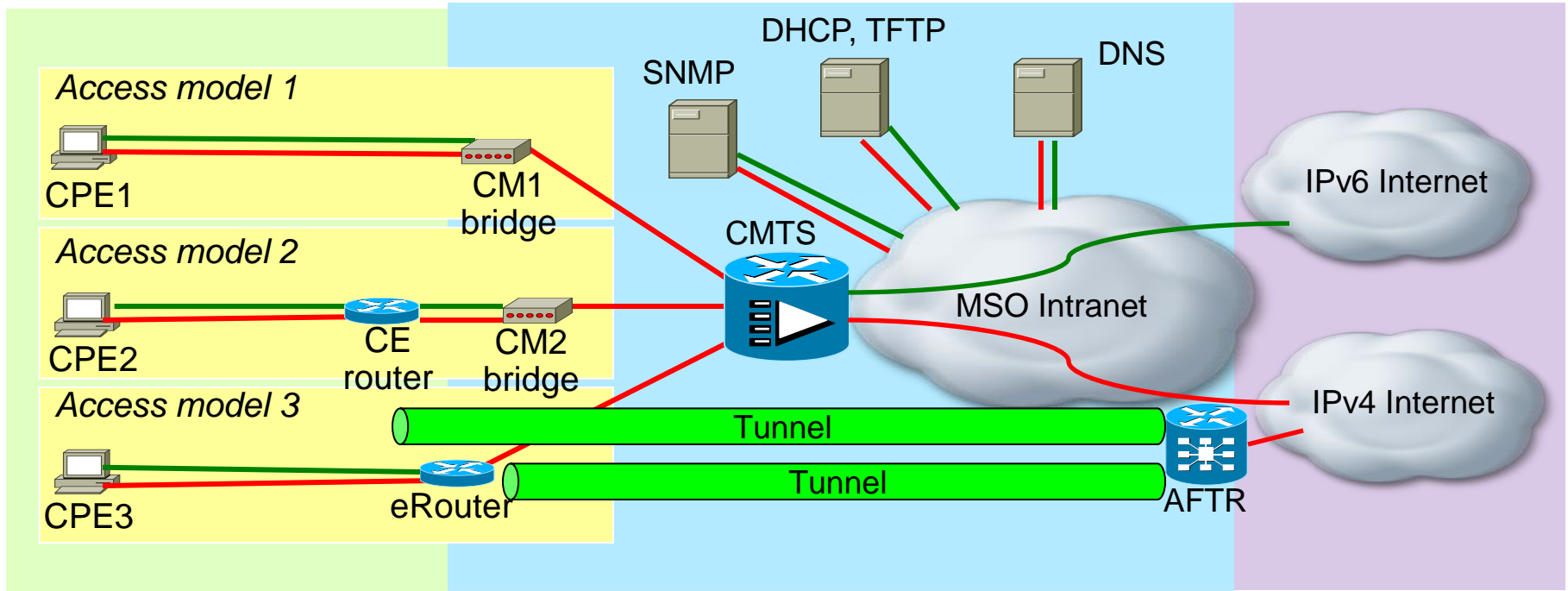
← IPv4 →

← IPv6 →

Private IPv4 space used for CMM freed

Public IPv4 space used for CPE reclaimed

# Transition Strategy – MSO “Y”



← IPv4 →

← IPv6 →

Public IPv4 space used for CMM reclaimed

Public IPv4 space used for CPE reclaimed

# Maintaining host & network database Security

- Like ARP, IPv6 neighbor discovery is inherently insecure
- Neighbor discovery relies on information from untrusted clients
- **Malicious clients could attempt to steal addresses and/or bombard the CMTS with bogus ND messages consuming memory and CPU resources**
- The service provider's provisioning system is in full control of all address assignments and is a trusted entity; thus a better source for populating host databases



# IPv6 forwarding

## IPv6 source verify

- Source verify validates the source IP to MAC and modem SID binding for packets received upstream on a cable interface; if it does not match the packet is dropped
- If the DHCP option is included the CMTS will send a DHCPv6 Lease Query (LQ) to the DHCP server whenever an unknown address is seen
- When DHCPv6 LQ is enabled it is **STRONGLY RECOMMENDED** to disable Neighbor Discovery (**no cable nd**); similar to disabling ARP (**no cable arp**) when implementing DHCPv4 LQ



# IPv6 forwarding

## CMTS downstream and PD recovery

- Unknown IPv6 addresses for directly connected CPEs can be determined based upon the prefixes configured on the Bundle interface
- However, this is not the case with prefix delegation
  - If the static route learned during DHCPv6 gleaning is lost traffic for this prefix would most likely end up following the default route
- Prevented by using the **cable ipv6 pd-route** CLI mentioned earlier
- Rate limiting SHOULD also be configured for both the upstream and downstream directions to prevent flooding the provisioning system with leasequeries

**cable ipv6 source-verify leasequery-filter downstream 3 5**

**interface Bundle <x>**

**cable ipv6 source-verify leasequery-filter upstream 3 5**



# Example DHCPv6 leasequery replies

```

DHCPv6
  Message type: Leasequery-reply (15)
  Transaction ID: 0x9e99cb
  Server Identifier: 00010001134aaee5005056b53d27
  Client Identifier: 0001000a000300010012
  Leasequery Client Data
    Option: Leasequery Client Data (45)
    Length: 262
    Value: 0001000e0001000113e334de0015587e9d30002e00040000...
  Client Identifier: 0001000113e334de0015587e9d30
    Option: Client Identifier (1)
    Length: 14
    Value: 0001000113e334de0015587e9d30
    DUID type: link-layer address plus time (1)
    Hardware type: Ethernet (1)
    Time: Jul 28, 2010 14:35:10 EDT
    Link-layer address: 00:15:58:7e:9d:30
  Client Last Transaction Time
    Option: Client Last Transaction Time (46)
    Length: 4
    Value: 00000f67
    Clt time: 3943
  IA Address: 2001:db8:fffe:0:997b:ef71:5058:6b61
    Option: IA Address (5)
    Length: 24
    Value: 20010db8fffe0000997bef7150586b6100092b1900126599
    IPv6 address: 2001:db8:fffe:0:997b:ef71:5058:6b61
    Preferred lifetime: 600857
    Valid lifetime: 1205657
  Leasequery Relay Data
    Option: Leasequery Relay Data (47)
    Length: 101
    Value: 20010db8fffe00000000000000000000010c0020010db8fffe...
    Peer address: 2001:db8:fffe::1
    DHCPv6 relay message
  Preference
  Domain Search List
  DNS recursive name server
  Vendor-specific Information

```

```

DHCPv6
  Message type: Leasequery-reply (15)
  Transaction ID: 0x9e99cb
  Server Identifier: 00010001134aaef3000c29b868df
    Option: Server Identifier (2)
    Length: 14
    Value: 00010001134aaef3000c29b868df
    DUID type: link-layer address plus time (1)
    Hardware type: Ethernet (1)
    Time: Apr 3, 2010 21:59:15 EDT
    Link-layer address: 00:0c:29:b8:68:df
  Client Identifier: 0001000a000300010012
  Status code
    Option: Status code (13)
    Length: 26
    Value: 000949502061646472657373206e6f7420696e2073657276...
    Status Code: NotConfigured (9)
    Status Message: IP address not in server

```

One positive response and one negative response

# IPv6 access control lists

- IPv6 Access Control Lists (ACLs) are always named lists
- To apply to a Bundle interface **ipv6 traffic-filter <name> in|out**
- The following ACL match parameters are supported for IPv6 ACL
  - Source/destination IPv6 addresses
  - Protocol (IPv6, TCP, UDP, ICMP etc)
  - Source/destination TCP/UDP ports
  - TCP flags
  - Traffic class
  - Flow label
  - Routing header type
  - Fragment flag
  - time-range

# IPv6 access control lists

- An example of what IPv6 traffic to block into the CMTS:

```
ipv6 access-list security
remark Block all traffic DHCP server -> client
deny udp any eq 547 any eq 546
remark Block Router Advertisements
deny icmp any any router-advertisement
remark Block Type 0 Routing Headers
deny ipv6 any any routing-type 0
permit ipv6 any any
!
interface Bundle99
ipv6 traffic-filter security in
```

- Note: **no ipv6 source-route** is also recommended for the global configuration to prevent source routing (RH0) via the CMTS

# IPv6 access control lists

- Typical IPv6 ACL use case is to restrict telnet and/or SSH access into the box; for example to block all IPv6 access

```
ipv6 access-list no-v6-access
deny ipv6 any any
!
line vty 0 4
  ipv6 access-class no-v6-access in
```

- ACLs are also needed to restrict SNMP access to the CMTS; existing ACLs for IPv4 have no affect on IPv6 traffic thus an additional IPv6 ACL field is needed

```
snmp-server community changeme RO ipv6 no-v6-access 20
```

# Cable filter groups for IPv6

- Cable filter groups allow per device filters and can be applied via CMTS configuration, SNMP operation, or TLVs in the modem configuration file.
- Individual filter group entries (indices) apply to either IPv4 or IPv6; a single entry DOES NOT apply to both. IPv6 filter criterion include : source/destination addresses and prefix lengths, flow label, and IP version.
- **Note on the uBR10012 there is a restriction in the PXF forwarding functionality where either an interface ACL can be used to filter traffic or cable filter groups can be used. They cannot be used simultaneously.**

# Limiting IPv6 CPEs per modem

- Subscriber management mechanisms similar to IPv4 (DOCSIS TLVs 35 & 36); defined by DOCSIS 3.0 OSSI & MULPI (**DOCSIS TLV 63 – Max CPE IPv6 Addresses**)
- This maximum is the total number of CPE IPv6 delegated prefixes and CPE addresses (including link-local) that can be learned from a modem
- Permitted IPv6 prefixes and addresses can also be configured for a cable modem using DOCSIS TLVs 61 and 67 respectively
- Interaction with DOCSIS TLV 18 (Maximum Number of CPEs) which is number of CPE MACs granted access during a CM epoch

# Divert Rate Limiting (DRL)

- DRL protects the uBR10012 PRE from having to process large amounts of traffic draining CPU resources.
- Existing cable side configuration is on a per SID basis and covers all types of traffic (IPv4 and IPv6).
- The WAN side configuration is configured on a divert code basis and thus new ones are used for IPv6.

```
service divert-rate-limit ipv6 ipv6_rp_dest rate 4 limit 4
service divert-rate-limit ipv6 ipv6_rp_punt rate 4 limit 4
service divert-rate-limit ipv6 ipv6_rp_glean rate 1 limit 4
service divert-rate-limit trusted-site-ipv6 FC00:1111:1111::/48 traffic-class 0x0 mask 0x0
```

# IPv6 for PacketCable and PacketCable Multimedia

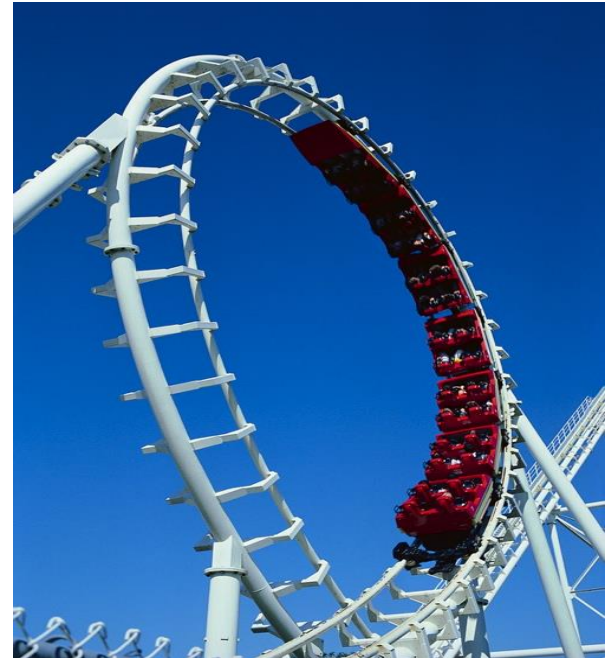
- Used to provide dynamic QoS
- With PacketCable the eDVA undergoes it's own provisioning process independent from the cable modem
- Just like the cable modem the eDVA can be IPv4 only, IPv6 only, or dual-stack
- The protocol used by the eDVA for management & signaling can be different than what is used for the payload
- For generic PCMM case may need to setup “gates” before or without knowledge of the protocol eventually used

# IPv6 multicast

- CMTS global configuration **ipv6 multicast-routing** is needed to support user joined (i.e. MLD) multicast traffic; not required to support IPv6 multicast as used for neighbor discovery or routing protocols
- Globally enabling **ipv6 multicast-routing** enables MLD and PIM on all interfaces
- How to handle multicast when receivers can be either IPv4 or IPv6?

# Summary

- IPv6 motivation and challenges
- Key aspects of IPv6
- IPv6 in cable
- IPv6 for cable modem management
- IPv6 for CPEs
- IPv6 for CPE routers
- Other topics



# General IPv6 considerations



- IPv6 addressing strategy
  - Global and/or unique local addressing for infrastructure or perhaps link-local only
  - If global addressing for infrastructure - separate address block from customer addressing?
  - Prefix size for p2p links - /64, /126, /127?
  - Block for loopbacks (loopbacks configured with /128)
  - Use /64s for CMM and CPEs
  - Preventing SLAAC
  - Need to support customers with Provider Independent (PI) addressing
- IPv6 routing
  - ISIS (single topology or multi-topology), OSPFv3, MP-BGP, static

# IPv6 for cable modem management



- Is public IPv4 addressing currently used?
- Will both DOCSIS 3.0 and DOCSIS 2.0+ modems be used?
- IPv6, DPM, or APM?
- Do the provisioning systems support IPv6?
- Same provisioning systems for IPv4 and IPv6?
- Redundant provisioning systems? How to handle DHCPv6 failover?
- Do the NMS applications support IPv6?
- Use of MDD Override to control which modems can provision IPv6?
- Enabling SNMP over IPv6 access on the modems

# IPv6 for CPEs



- IPv6 only or dual-stack? If IPv6 only methodology for translation?
- Will both DOCSIS 3.0 and DOCSIS 2.0+ modems be used?
- Do the provisioning systems support IPv6?
- Same provisioning systems for IPv4 and IPv6?
- Redundant provisioning systems? How to handle DHCPv6 failover?
- Mechanisms to control which modems can have IPv6 CPEs?
- Security considerations for interface identifier addressing
- Support for multiple GUAs?
- Support for static CPE addressing?

# IPv6 for prefix delegation



- eRouters and/or standalone CE routers?
- How to control which devices can be used?
- Redundant provisioning systems? How to handle DHCPv6 failover?
- Size of delegated prefixes? /64s only?
- Use of prefix stability?
- If prefix stability used size of prefix range for CMTS group?

# IPv6 security



- Use of cable source verify and DHCPv6 lease query
- Use of access control lists
- Use of cable filter groups
- Securing the CMTS (Telnet, SSH, SNMP)
- IPv6 neighbor tuning
  - Tweaking reachability time, router advertisement interval, etc
- Use of DRL (Divert Rate Limiting) to protect the CMTS CPU
- Use of DMIC
- Controlling the amount of addresses and prefixes per modem

# IPv6 related sessions

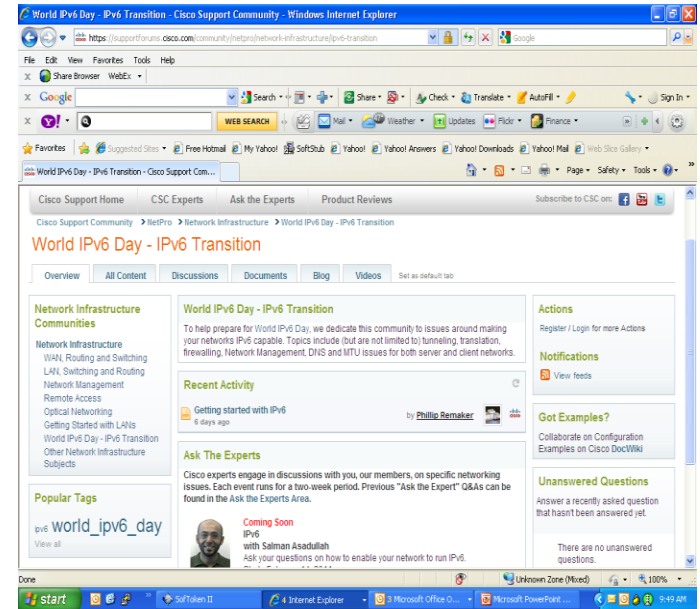
Session	Title
TECSPM-2001	IPv6 LTE/EPC Design and Deployment
BRKRST-2301	Enterprise IPv6 Deployment
BRKRST-2311	IPv6 Planning, Deployment and Operation Considerations
BRKSPG-2603	How to Securely Operate an IPv6 Network
BRKSEC-2003	IPv6 Security Threats and Mitigations
BRKSEC-3003	Advanced IPv6 Security: Securing Link Operations at First Hop
BRKRST-2044	Enterprise Multi-Homed Internet Edge Architectures
PNLCRS-2303	Experiences with Deploying IPv6
LTRRST-1301, LTRSEC-3033	IPv6 Hands-on Lab, IPv6 Network Threat Defense, Countermeasures and Controls
BRKSPG-2602	IPv4 Exhaustion: NAT and Transition to IPv6 for Service Providers
COCRST-2355	Inside Cisco IT: Making the Leap to IPv6
BRKCRT-9344	IPv6 for Cert Nuts
BRKEWN-2010	Design and Deployment of Enterprise WLANs
BRKRST-2304	Hitchhiker's Guide to Troubleshooting IPv6
BRKSPG-2606	MAP Technology - IPv6 Strategy for Solving IPv4 Address Exhaustion
BRKSPG-3300	Service Provider IPv6 Deployment

# Cable related sessions

Session	Title
BRKSPG-2501	Troubleshooting Cisco CMTS Based Services
BRKSPM-2001	Deploying Service Provider Wifi
BRKSPV-1126	Deploying IP Video over DOCSIS
BRKSPV-2016	Architectures for new services over Cable

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