
University of Colorado Boulder

Network Management and Automation

Automatic IP Address Configuration and Dynamic Host Configuration Protocol (DHCP)

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Review

- **Lab**
- **Assignment**
  - Citation
- **SNMP**
- **IPv6**
  - EUI-64
  - SNMA
  - SLAAC

Dynamic Host Configuration Protocol (DHCP)

- **Every device needs an IP address**
  - Used to be manual on every machine
- **Dynamically assigns IP addresses**
  - IP address
  - Subnet mask
  - Default-gateway
  - Primary DNS server
  - Secondary DNS server
- **Server service**
  - Windows, Linux, Router
  - Where is this located?
- **UDP**
  - Ports 67 & 68

Scope

- **Administrative grouping of range of addresses server can hand out**

- **10.1.1.100 - 10.1.1.200**

- **Keep static servers out of scope**
  - Reservations
  - Exclude Range

- **Host (hardware)**

- **Options**
  - DNS, Gateway, TFTP server, etc.
    - ***VoIP & ZTP***

Lease

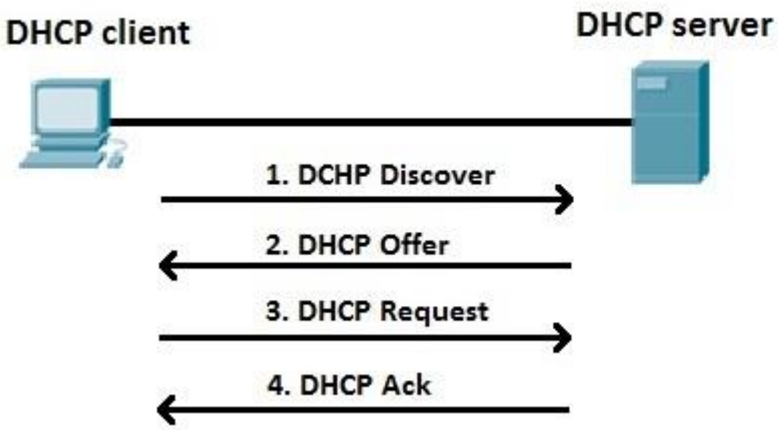
- **Limited number of addresses in the (pool/scope)**

- **1 day, 10 days, 100 days, etc.**
  - Coffee shop (1 day)
  - Large desktop enterprise (100 days)

- **50% of lease time; client requests to renew for another lease period**
  - Will re-try a random period of time (if can’t contact server)
    - ***CSMA/CD***

DHCP – (DORA)

- **Client**
  - Discover Request – (Broadcast)
- **Server**
  - Offer
- **Client**
  - Request
- **Server**
  - Acknowledgement



Security

- **Multiple DHCP servers**
  - First response

- **What else?**

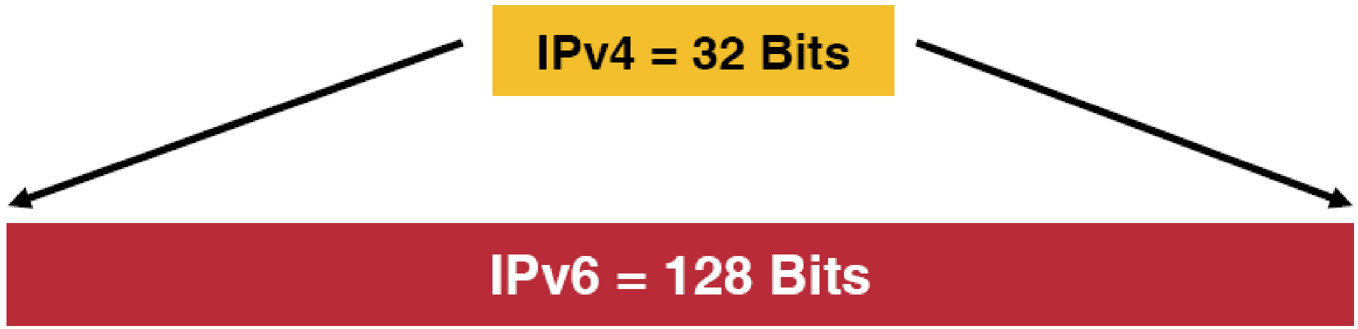
Notes

- **Misconfigure**
- **Multiple DHCP server**
- **Lease times**
- **Wireless Routers**
  - Rouge

IPv6 Advantages

- **Increased address space**
- **Streamlined IP header**
- **End-to-end connectivity**
- **Removal of IP broadcasts**
- **Mobile IPv6**

Addressing



•IPv4 - 32 bits, 2^{32}

=~ 4,200,000,000 possible addressable nodes

•IPv6 - 128 bits, 2^{128}

= 340,282,366,920,938,463,463,374,607,431,768,211,456 nodes

IPv6 Address Syntax

- IPv6 address in binary form
  - 0010000000000001000011011011100000000
    000000000000010111100111011
    0000001010101010000000001111111111111
    10001010001001110001011010
- Divided along 16-bit boundaries
  - 0010000000000001 0000110110111000
    0000000000000000 0010111100111011
    0000001010101010 0000000011111111
    1111111000101000 1001110001011010

IPv6 Address Syntax

- **Each 16-bit block is converted to hexadecimal and delimited with colons**
  - Each 16-bit block is called a hextet
  - 2001:0DB8:0000:2F3B:02AA:00FF:FE28:9C5A

- **Leading zeroes in any 16-bit hextet can be omitted (or reduced)**
  - 2001:0DB8:0000:2F3B:02AA:00FF:FE28:9C5A
  - 2001:DB8:0:2F3B:2AA:FF:FE28:9C5A

Addressing Tricks – Compressing Zeros

- **A single contiguous sequence of 16-bit blocks set to 0 can be compressed to "::" (double-colon)**
  - Example:
    - ***FE80:0:0:0:2AA:FF:FE9A:4CA2 becomes FE80::2AA:FF:FE9A:4CA2***
    - ***FF02:0:0:0:0:0:0:2 becomes FF02::2***
    - ***FF02:0:0:0:0:0:0:0 becomes FF02::***
  - Double-colon "::" can appear once in an address
  - Cannot use zero compression (double-colon) to include part of a 16-bit block
    - ***FF02:30:0:0:0:0:0:5 does not become FF02:3::5, but FF02:30::5***

Addressing Tricks – Compressing Zeros

- **A hextet with all zeros can be reduced to a single zero**
  - This is used when the double-colon has already been used
    - ***2001:DB8::12:0000:0000:FE becomes 2001:DB8::12:0:0:FE***

- **Typically, upper vs. lower case doesn't matter**

IPv6 Address Autoconfiguration

IPv6 Address Autoconfiguration Overview

- **IPv6 interfaces can automatically configure themselves**
  - Even without a stateful configuration protocol such as Dynamic Host Configuration Protocol for IPv6 (DHCPv6)
- **By default, link-local address for each interface**
- **By using router discovery (RS/RA), a host can determine**
  - Additional addresses
  - Router addresses (default-gateway)
  - Other configuration parameters (DNS)

Types of Autoconfiguration

1. **Stateless**
   – Receipt of Router Advertisement (RA) messages with one or more Prefix Information options

2. **Stateful**
   – Use of a stateful address configuration protocol such as DHCPv6

3. **Both / “Hybrid”**
   – Receipt of Router Advertisement messages and stateful configuration protocol

- **For all types, a link-local address is always configured**

IPv6 Address Autoconfiguration

- **Multiple interface addresses**

- **Enable IPv6 on interface (“ipv6 enable”)**
  - Automatically create a link-local address
    - ***Link-local***
      - FE80::/10
      - Only valid on local segment (“local link”)
      - Host ID is 64 bits
      - Network is typically FE80::/64
      - Note: Ping link-local - must specify interface
        - » Why?
          - Device has multiple interfaces in the FE80::/64 prefix
  - Note: “ipv6 unicast-routing” off by default on Cisco
    - ***Generates Router Advertisement (RA);***
      - if not; just an IPv6 node/host

EUI-64

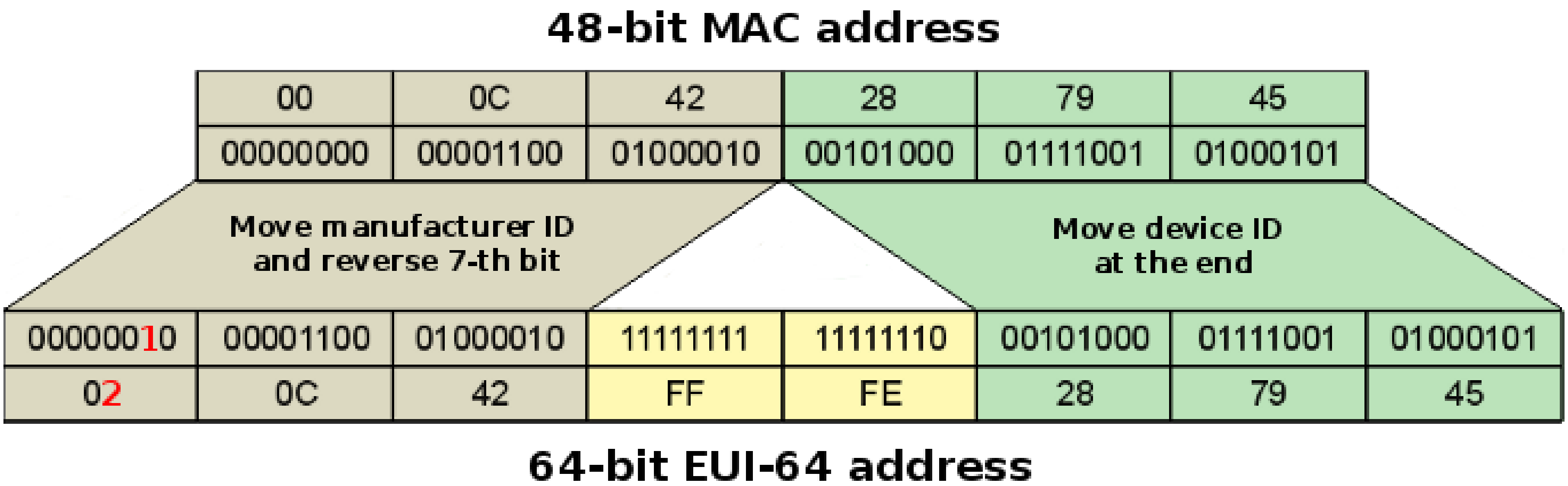
- **How does it create own unique host ID?**

- **What is a MAC address?**
  – 00:A0:C8:22:21:20
  – 48 bits
    - ***First 24 - Vendor specific***
    - ***Last 24 - Device specific***
  – Cisco uses - Burned In Address (BIA)
    - ***0001.4222.2120***

EUI-64

- **I'm going to take my unique MAC address and make a unique 64-bit <u>HOST</u> address (link-local)**
  - MAC is only 48 bits???!!!
    - ***Short 16 bits***
- **Take MAC and split in the middle**
  - mac-address 0000.1111.1111
  - 0000.11 (**split**) 11.1111
- **Injects "FFFE" in the middle**
  - mac-address 0000.1111.1111
  - 0000.11 (**split**) 11.1111
  - 0000.11FF.FE11.1111
- **Flip 7th most significant bit (invert)- (*if 0 change to 1; if 1 change to 0)***
  - 0000.11FF.FE11.1111
  - 0200.11FF.FE11.1111
- **Final EUI-64 address**
  - mac-address 0000.1111.1111
  - FE80::02:11FF:FE11:1111/64

Static EUI-64 Format



Unique Address (Link-local / EUI-64)

- **Create link-local (network prefix)**
  – FE80/10 (/64)

- **Use MAC to generate unique 64 host ID**
  – MAC + (FFFE) + “flip 7th most sig. bit”

- **FE80::”EUI-64”/64**

EUI-64 Tips

- **Can hard code MAC address**
  - Actual MAC = 00:A0:C8:22:21:20
  - Configured MAC = “mac-address 0000.1111.1111”
  - Results in Link Local with configured MAC = FE80::200:11FF:FE11:1111

- **Can hard code link-local (instead of EUI-64)**
  - “ipv6 address fe80::1 link-local”
    - ***Don’t need mask***

Neighbor Discovery (ND) - ICMPv6

- **Same segment only**
  - (does not traverse a router)

- **Replacement for ARP**

- **No broadcast (*kind of*)**

- **Send out multicast**
  - Asking for information
    - ***NS – Neighbor Solicitation***
    - ***Sent to SNMA – Solicited Node Multicast Address***
  - Supplying the information
    - ***NA – Neighbor Advertisement***
      - Provides L2 address (MAC) (Link-local)

ND - Multicast

- **Multicast starts with "FF"**
  - FF02 = MCAST with local link scope

- **Nodes will join multicast group/s**
  - FF02::1 (All nodes / every device)
    - ***Example –***
      - Router1 Pings FF02::1
      - Router1 will receive NS for all nodes on that network asking for L2 address
      - Router1 will reply with NA (providing L2 address)
    - ***Same affect as Broadcast***

  - FF02::2 (All routers)

- **Solicited Node Multicast Address (SNMA)**

Solicited Node Multicast Address (SNMA)

- **Why?**

- **How?**
- **Each host joins their own SNMA**
  - (*in addition to the ff02::1 multicast group*)

- **FF02::1:FFxx:xxxx**
  - xx:xxxx (last 24 host/MAC bits)
    - ***Match the client last 24 host bits (MAC)***
      - EUI-64 = FE80::2AA:FF:FE28:9C5A
      - SNMA = FF02::1:FF28:9C5A
        - » Or manually assigned link-local = FF02::1:FF:1

- **Key point – MCAST L2 addressing**
  - Switches with Multicast Listener Discovery (MLD)
    - ***Only forward to nodes that join that group***
  - Switches without MLD
    - ***Flood as unknown unicast***
  - Ethernet = 33:33:* (Last 32 bits of the mcast dest. IPv6 address (OR'ed))
    - ***Not all L2 technologies use MAC (PPP, ATM, etc.)***

- **Note: The SNMA is not the address we are trying to find, but a "tool" to address the NS to a limited subset of all hosts on the link**

SNMA – Summary Steps

- **From the known unicast IPv6 address**
  - Generate the SNMA (FF02::1FFXX:XXXX)
    - ***Put it into the destination address in the ICMPv6 ND NS message packet***
    - ***Encapsulate the IPv6 packet (with the NS inside) into frame on egress network (Ethernet)***
      - Create/map the L2 destination address based on the destination IPv6 address
        - » i.e. ff02::1:ffe8:658f = 33:33:e8:65:8f
      - Transmit on wire – switches will handle appropriately
        - » MLD – Groups
        - » Unknown Unicast

ARP Review

SNMA

- **Diagram**
- **Example 1 –**
  - R1 pings IPv6 address of PC1 (on same network)
    - ***Doesn't know layer 2 address***
  - Instead of ARP; R1 "converts" the ping/NS from the IPv6 address to the SNMA address; which is then converted again to the L2 MAC address
    - ***Then sends it as a multicast packet, because it can't send it to the L3 address!***
  - Switch1 floods frame (if no MLD); if MLD only send out single port
  - PC1 receives it and responds (including L2 address)
    - ***In this example, PC1 is the only node with that SNMA (thus only host on network that rx traffic)***
      - Reduces "bcast"
  - Now R1 has the L2 address and can send the ping as normal via IPv6 & L2 address
- **Example 2 -**
  - Router1 pings PC1 via SNMA
  - Switch1 floods frame (if no MLD)
  - PC!=1 Receive frame, but wouldn't process it, because they don't know that address (SNMA / MAC)

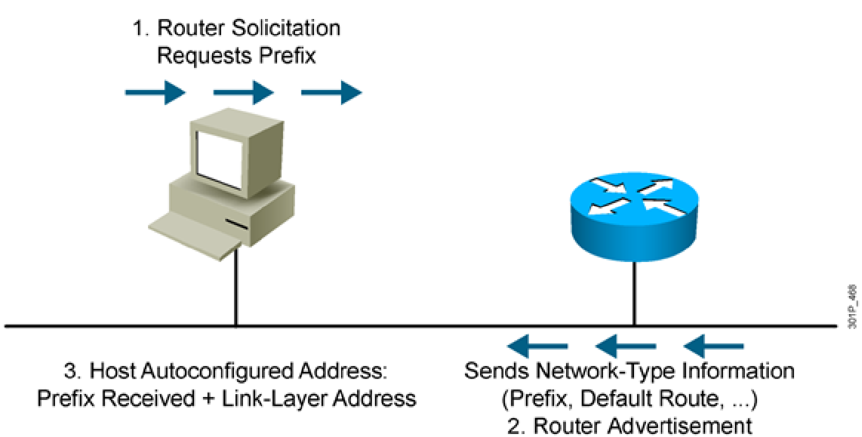
Duplicate Address Detection (DAD)

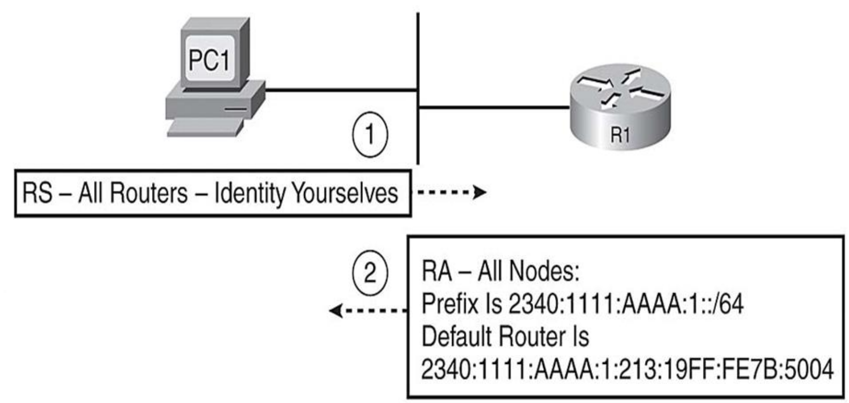
- **How do we know if anyone else is using that address (link-local / Global)?**

- **Process:**
  - Assign IPv6 address to interface – 2001:db8::a1/64
  - Before starting to use that address; Send out Neighbor Solicitation Solicited Node Request (to own/group SNMA) – ff02::1:ff:0:0:0:0:a1 “NS = does anyone have this address?”
  - Waits a period
  - If no duplicates
    - ***Updates all MLD (L2) of SNMA - ff02::1:ff:0:0:0:0:a1***
    - ***NA for new configured IPv6 address – 2001:db8::a1***
      - “Hey all nodes, I now have this address”
  - If duplicate
    - ***Owner sends NA to ff02::1 (because source is “::”)***

Stateless Address Autoconfiguration (SLAAC)

- **Built in IPv6 feature**
- **Use of NDP + EUI-64 FORMAT**
  - ONLY works with /64 prefix





Cisco Router Example

- **EUI-64**
  - ipv6 enable
  - Static MAC
  - Static link-local

Autoconfiguration Process - (SLAAC)

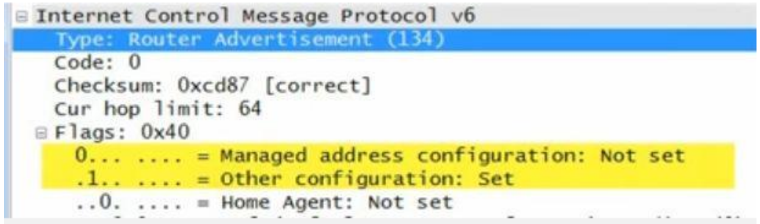
- **Router Solicitation (on boot)**
  - "I need to know network information"
  - FF02::2 (all routers)

- **Router Advertisement (200 seconds)**
  - FF02::1 (all nodes)
  - Prefix information
  - Default-gateway

- **Operating System**
  - Windows
    - ***Link-local (EUI-64)***
    - ***EUI-64 (Global)***
    - ***Global (random)***
      - Security profiling

SLAAC

- **Interface comes UP**
- **Configure link-local address - Perform duplicate address detection (DAD)**
- **Perform router discovery with Router Solicitation (RS)**
- **Receive Router Advertisement (RA)**



SLAAC

- **Inspect Router Advertisement (RA)**
  - If ‘**M**’ bit is set = 1
    - ***Use stateful DHCPv6 management to acquire an address (DAD & lifetimes/timers apply)***
  - If ‘**O**’ bit is set = 1
    - ***Use stateless DHCPv6 to acquire other configuration information (DNS and other server addresses, Domain name, etc.)***
      - “come back to me/router if you want any “other” information”
    - ***Normally used when SLAAC is the only method used to acquire addresses [M bit is not set].***
  - If a stateful exchange is performed to acquire an address (or prefix), the other configuration information is normally conveyed in that exchange so the stateless exchange is not necessary
- **Apply configuration and other parameters**

SLAAC

- **Continue inspecting Router Advertisement...**
  - If prefix information Option is received
    - ***If 'A' bit set, perform SLAAC to create an address on that prefix***
      - Combine advertised prefix with this Interface's ID
      - Perform DAD, if clear, apply address using supplied lifetimes
      - Prefix Delegations
    - ***If 'L' bit is set, add prefix to the Prefix Table (packets to this prefix may be reached locally, otherwise must go to default router)***
    - ***Note that A and L bit are entirely independent***
      - There can be an address with no on-link prefix
      - There can be an on-link prefix with no address
- **Note that multiple addresses may be configured with any combination of stateful and stateless autoconfig.**

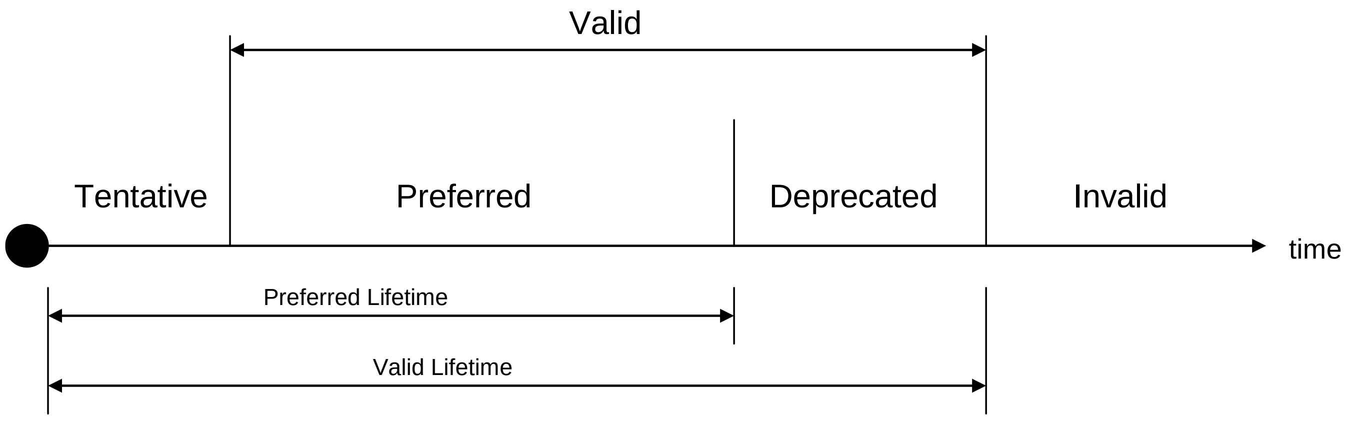
Router SLAAC Configuration

- **Enable “debug ipv6 nd”**
- **Enable v6 routing**

Autoconfigured Address States

- **Tentative**
  - The address is in the process of being verified as unique
- **Valid**
  - An address from which unicast traffic can be sent and received
- **Preferred state**
  - An address for which uniqueness has been verified, unrestricted use
- **Deprecated state**
  - An address that is still valid, but is discouraged for new communication
- **Invalid**
  - An address for which a node can no longer send or receive unicast traffic

Autoconfigured Address States



•While "preferred", use of the address for arbitrary communication is unrestricted.

•While “deprecated” its use is discouraged, but not strictly forbidden.

- •New communication should use a preferred address when possible
- •A deprecated address should be used only by applications that have been using it and would have difficulty switching to another address without a service disruption.

DHCPv6 (stateful & stateless)

- **Provides stateful address configuration or stateless configuration settings for IPv6 hosts**

  - Stateful information includes Addresses and Prefixes
    - ***Stateful exchange uses 4 messages***
      - (solicit/advertise/request/reply)
    - ***Rapid Commit option allows 2 messages (solicit/reply)***
    - ***Server maintains state on what was assigned where and for how long***

  - Stateless information includes server addresses (DNS, NTP, etc.) and domain settings, etc.
    - ***Stateless exchange uses 2 messages***
      - (information-request/reply)
    - ***Server does not maintain state, only hands out the information***

DHCPv6 - Stateless

- **Used in conjunction with SLAAC to acquire DNS and other parameters**

- **Inform host to use Stateless/Stateful DHCP configuration via Option Flags in the RA**
  - M-Managed Address Configuration flag
  - O-Other Stateful Configuration flag

DHCPv6 - Components

- **DHCPv6 clients**
- **DHCPv6 servers**
- **DHCPv6 relay agents**

DHCPv6 - Relay

- **What is DHCP relay, and why is it needed?**
- **Transparent to client**
- **Messages between client and server are encapsulated between the relay and server in the following messages**
- **Relay-Forward**
  - Sent by a relay agent to forward an encapsulated client message to a server
- **Relay-Reply**
  - Sent by a server to send an encapsulated server message to a client through a relay agent

DHCPv6 Messages

- **User Datagram Protocol (UDP) messages**
  - DHCPv6 clients listen on UDP port 546
  - DHCPv6 servers and relay agents listen on UDP port 547

DHCP Message Types (Comparison)

DHCPv6 Message Type	DHCPv4 Message Type
SOLICIT (1)	DHCPDISCOVER
ADVERTISE (2)	DHCPOFFER
REQUEST (3), RENEW (5), REBIND (6)	DHCPREQUEST
REPLY (7)	DHCPACK / DHCPNAK
RELEASE (8)	DHCPRELEASE
INFORMATION-REQUEST (11)	DHCPINFORM
DECLINE (9)	DHCPDECLINE
CONFIRM (4)	none
RECONFIGURE (10)	DHCPFORCERENEW
RELAY-FORW (12), RELAY-REPLY (13)	none

Stateful Message Exchange (SARR)

- **For address and/or prefix assignment**

1. <u>Solicit</u> message sent by the client to locate the servers.
2. <u>Advertise</u> message sent by a server to indicate that it can provide addresses and configuration settings.
3. <u>Request</u> message sent by the client to request addresses and configuration settings from a specific server.
4. <u>Reply</u> message sent by the requested server that contains addresses and configuration settings.

Stateless Message Exchange

- **For non-address/prefix information such as DNS servers, etc.**

1. Information-Request message sent by the client to request configuration settings from a server.

2. Reply message sent by a server that contains the requested configuration settings.

Prefix Delegation

Router IPv6 Address Provisioning – Prefix Delegation

- **Delegation done from ISP to customer**
- **Simple client end configurations**
- **Scalable way of delegating address blocks**

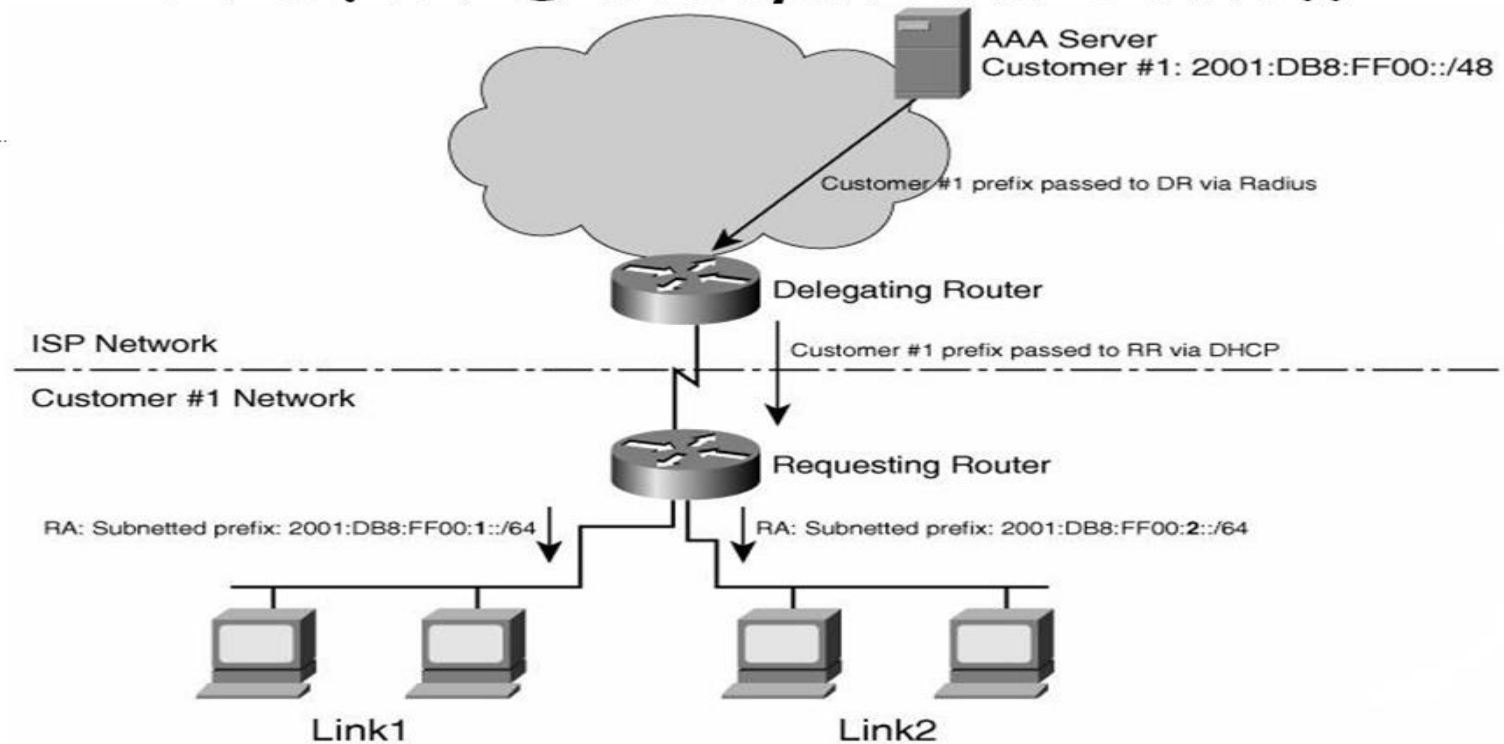
Prefix Delegation

- **Address assignment assigns a single address to a requesting interface**

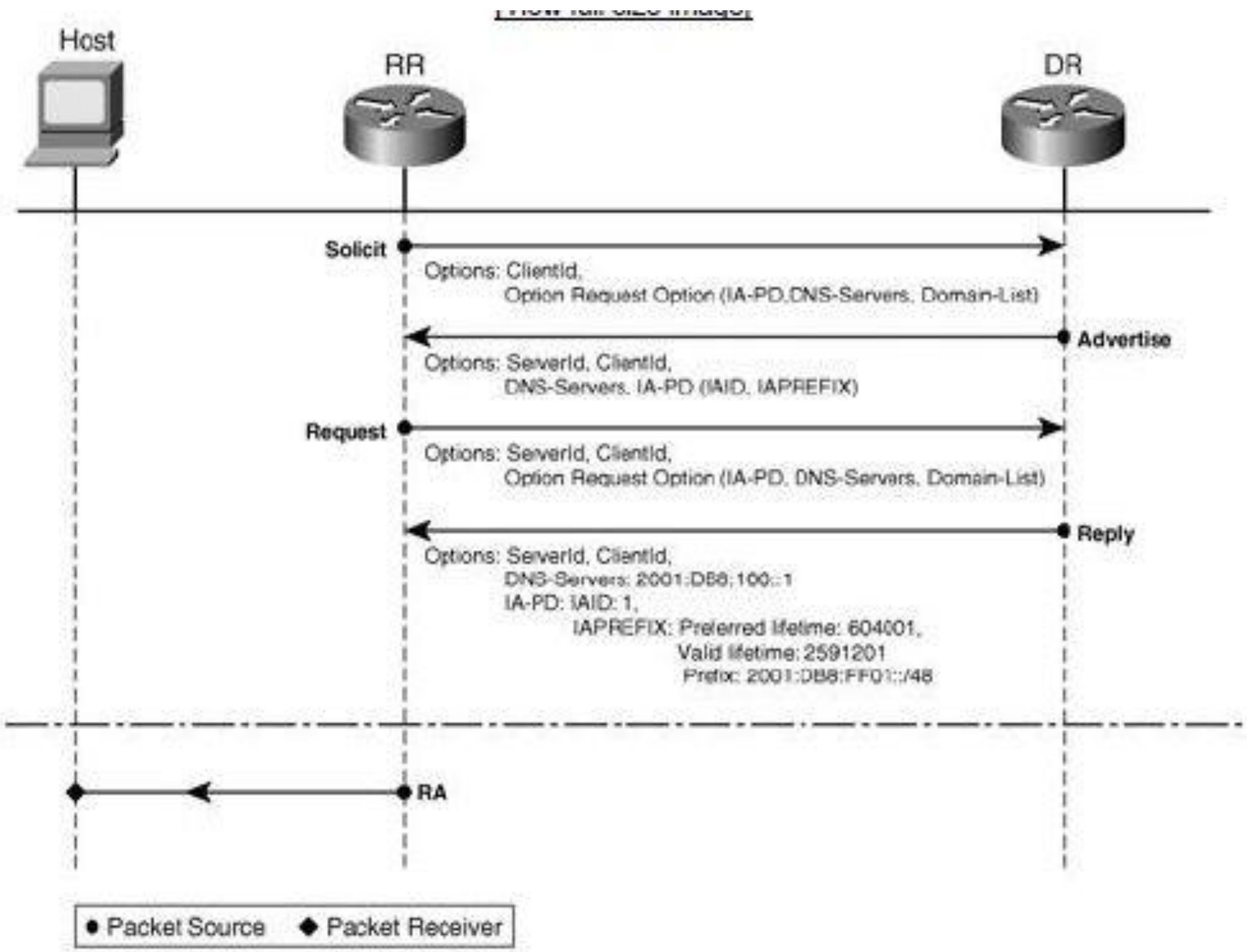
- **Prefix Delegation allows a server to assign an entire prefix to a router to be used as needed**

- **Two roles in prefix delegation**
  - Requesting Router (RR)
  - Delegating Router (DR)

Router IPv6 Address Provisioning: Prefix Delegation cont..



Using PD and Stateless Autoconfig



Prefix Delegation

- **When the DR assigns a prefix to the RR, the RR router stores the prefix to a variable, aka named or general prefix.**

- **Example RR config:**

```
interface Ethernet0/1
 ipv6 enable
 ipv6 dhcp client pd PREFIX1
 ipv6 nd ra suppress
end
```

- **The named prefix (PREFIX1) can then be used by other mechanisms on the router, such as applied to other interfaces or further delegated to other requestors.**

Prefix Delegation

- **The ipv6 address command allows the named prefix to be applied**
  - ipv6 address prefix-name sub-bits/prefix-length eui-64
- **Following is the RR's downstream interface config:**

```
interface ethernet 0/2
 description Link to Local Network
 ipv6 address PREFIX1 0:0:0:1::/64 eui-64

Resulting address is:
ipv6 address 2001:db8:100:1:0234:56ff:fe78:9a:bc/64
          named prefix
          interface sub-bits
          interface-id as host bits
```

Prefix Delegation

- **Ethernet 0/2 can now use RAs to advertise the prefix 2001:db8:100:1::/64 to its link with the A bit set.**
  - Attached hosts can use the SLAAC procedure and generate an address using this prefix.

- **The RR can use the same prefix subnetted locally to assign addresses to other interfaces.**

- **The local router-based DHCPv6 server can 'import' non-address/prefix information from the north facing DHCP client to allocate to local hosts.**

- **If the delegated prefix or other information needs to change, it can automatically propagate to the local network.**

Questions?