IPv6
Stateless Operations Explored

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Agenda

- Stateless Operation Goals
- Design of Node Discovery
- Auto Configuration

IPv6 Stateless Operation Goals

- Simple
  - Plug-and-play
  - Quick
  - No manual addressing of hosts
  - Generate routable address (es)
- Automate network address renumbering
- Self Healing / Maintenance-free
- IT SHOULD JUST WORK!

Can't I do this today with IPv4? IPv4 a victim of its own Success

- IPv4 addresses consumed at an alarming rate
- IPv4 System administration
  - Manual configuration of Addresses or use of Dynamic Host Configuration Protocol (DHCP)
  - Labor intensive and error prone
  - Not easy to setup and maintain
  - Not simple!
  - Usually requires NAT
- Security is optional; no single standard

IPv6 Addresses Explored

- Addresses assigned to interfaces (*)
- Interfaces typically have multiple addresses
- Subnets associated with single link (*)
- IPv6 addresses have scope and lifetime
- (*) No change from IPv4 model

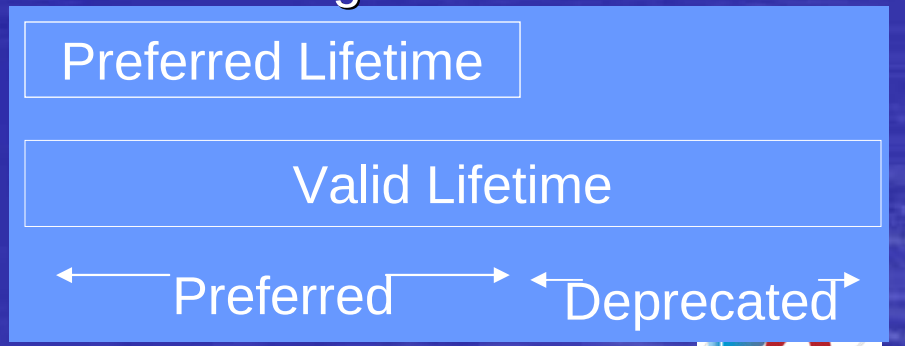
- Unicast: For a single I/F
- Multicast: For a set of I/F
  - A packet is delivered to ALL interfaces identified by this address
- Anycast: For a set of I/F
  - A packet is delivered to ONE of the interfaces identified by this address
- Unlike IPv4, IPv6 does not define a broadcast address
  - Use multicast

IPv6 Addresses Explored

- IPv6 supports notion of "scoped" addresses
- Scoped unicast addresses
  - Link scope, site scope

- Scoped multicast addresses
  - 16 scopes including node, link, site, organization, and global

- Addresses
  - Are leased to an interface
  - Have a Valid and Preferred lifetime
- Router advertises "preferred" and "valid" lifetimes
  - "Preferred" address - Unrestricted use
  - "Deprecated" address - Use is discouraged



IPv6 Automatic Connectivity

- Provides Network plug-and-play
  - Link Local Address Creation
    - No Router or Server required
  - Stateless mechanism
    - Router advertisements provide prefix
  - Stateful mechanism
    - Server provides address
- Simplified Network Administration
    - Lower network maintenance
- Easy Renumbering - Designed to happen!
    - Improved Competition and an end of ISP “lock in”!

IPv6 Neighbor Discovery

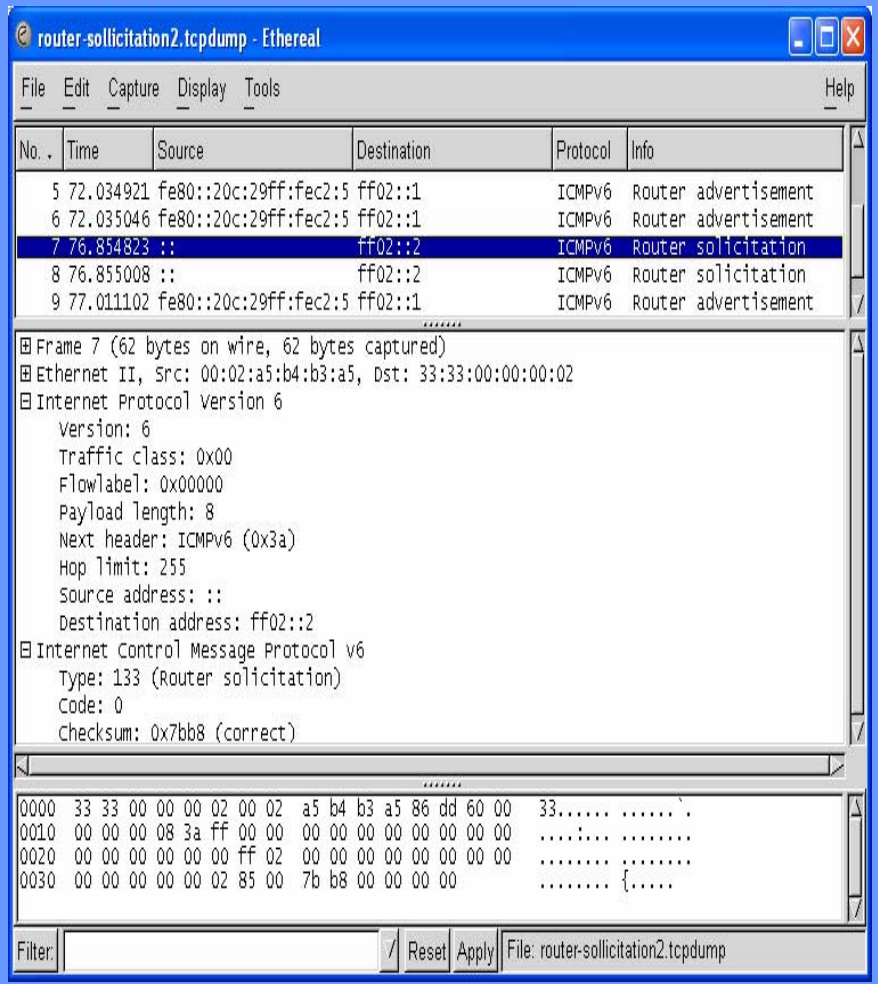
- Used to:
  - Discover presence of other nodes on the Link
  - Determine datalink-layer addresses for other nodes
  - Find routers
  - Maintain reachability information about the paths to active neighbors
  - Obtain link configuration parameters
- Integral part of IPv6
  - Must be implemented on every node

IPv6 Neighbor Discovery Comparison with IPv4

- Combines features
  IPv4 ARP + ICMP Router Discovery + ICMP Redirect
- Provides improvements over IPv4:
  - Router Discovery is part of the base protocol set
  - Neighbor Unreachability Detection
  - Address resolution at ICMP layer above the IP layer
    - Can use IPsec mechanisms
  - Router Advertisements Carry
    - link-layer addresses, prefixes for a link
    - advertise an MTU for hosts to use on the link

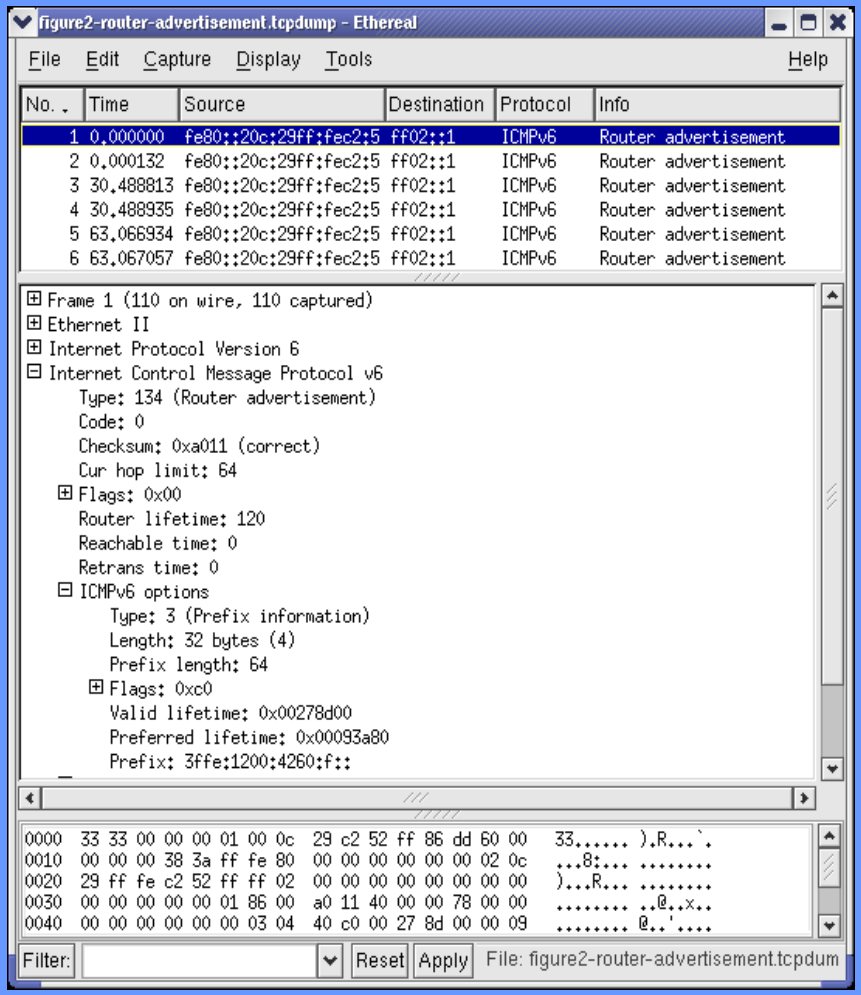
IPv6 Router Solicitation

- Host sends a multicast Router solicitation when an interface is enabled
  - To discover IPv6 routers present on the link
  - To request an immediate Router advertisement
  - Sent to All-Router Multicast Address
  - Source link layer address of sender may be sent as an option



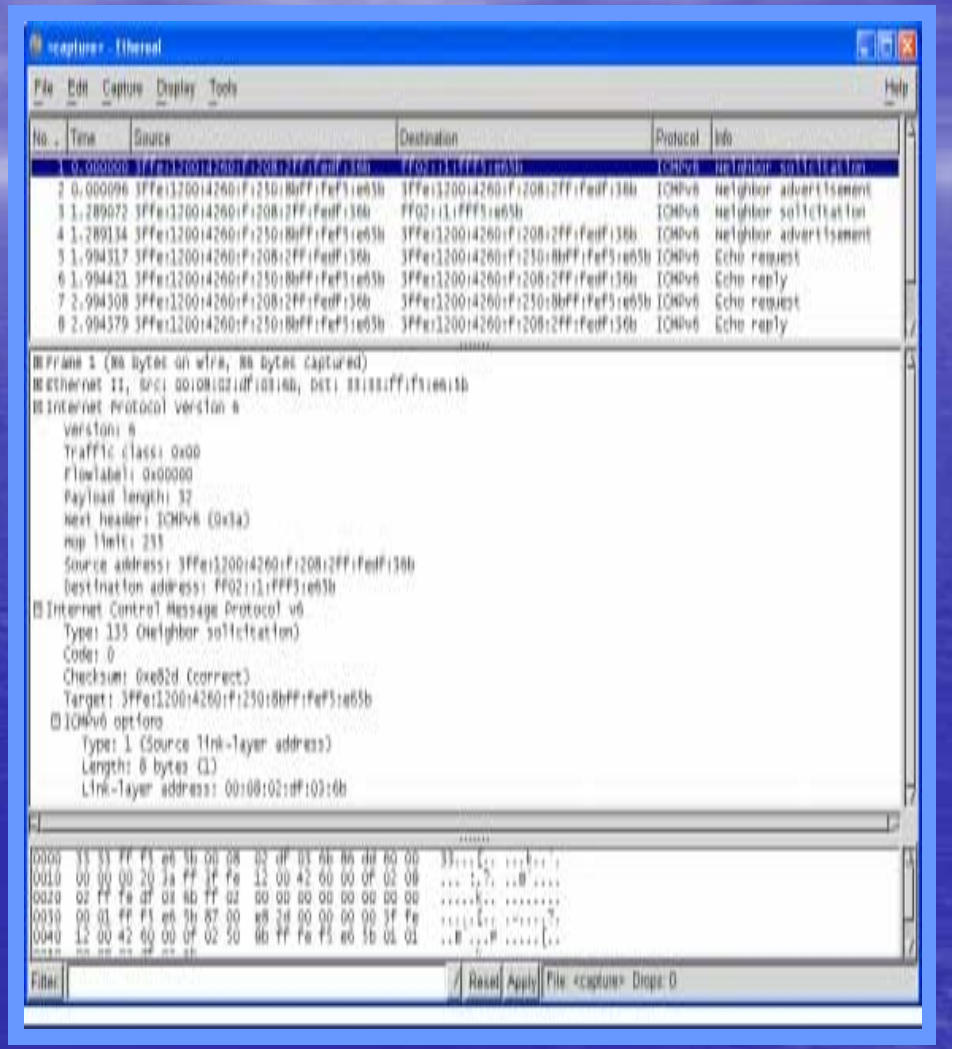
IPv6 Router Advertisement

- Router multicasts periodically (or on demand) its availability
- Router advertisements carry
  - Lifetime as a default router
  - Managed flag to inform hosts how to perform Address Autoconfiguration
  - List of prefixes used for a link
  - Link-layer address
  - Advertise an MTU for hosts to use on the link



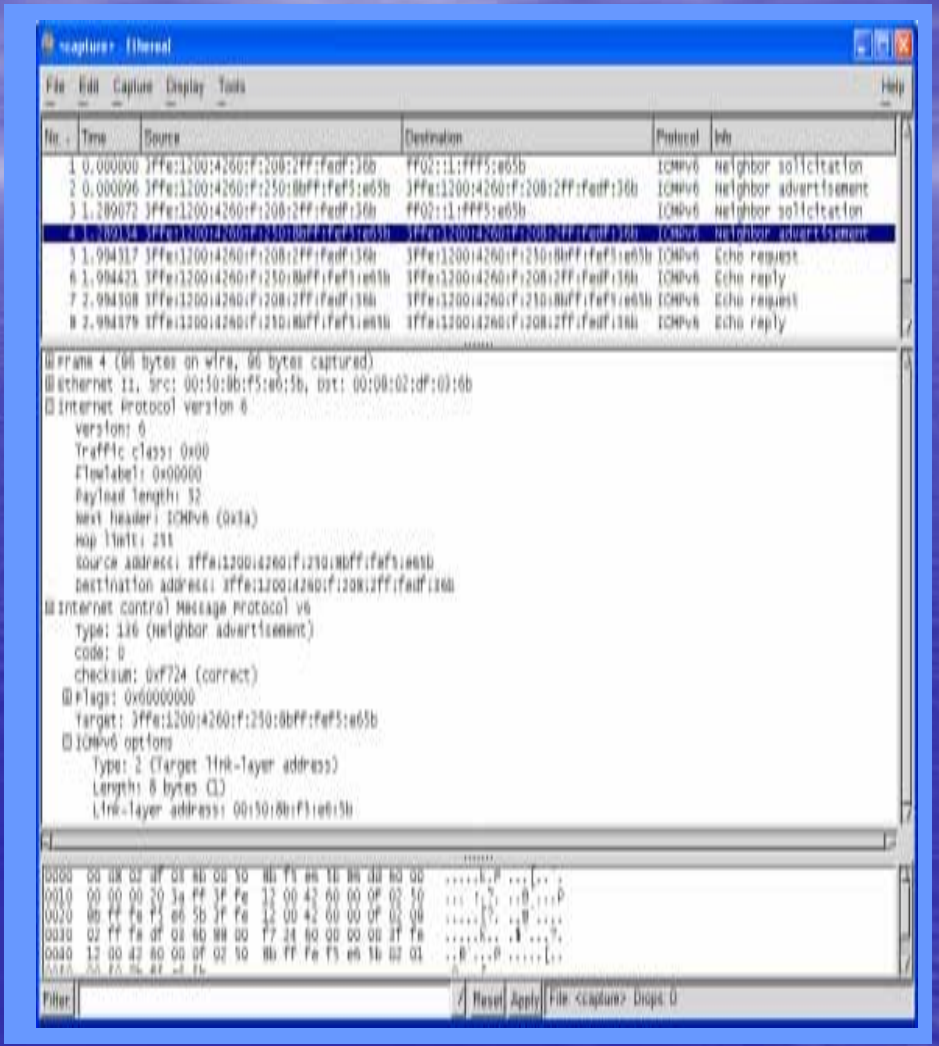
IPv6 Neighbor Solicitation

- Sent to request the Link Layer address of a target host
- Unicast-ed to target host during Neighbor Unreachability Detection (NUD)
- Multicast-ed to target host during address resolution
- Used for Duplicate Address Detection (DAD)



IPv6 Neighbor Advertisement

- Sent as a response to a Neighbor Solicitation
- Sent as needed in order to update other host neighbor cache



Router Redirect

- Sent by a router to inform a host of a better first hop on the path to the destination
- Used to inform if the destination is a neighbor

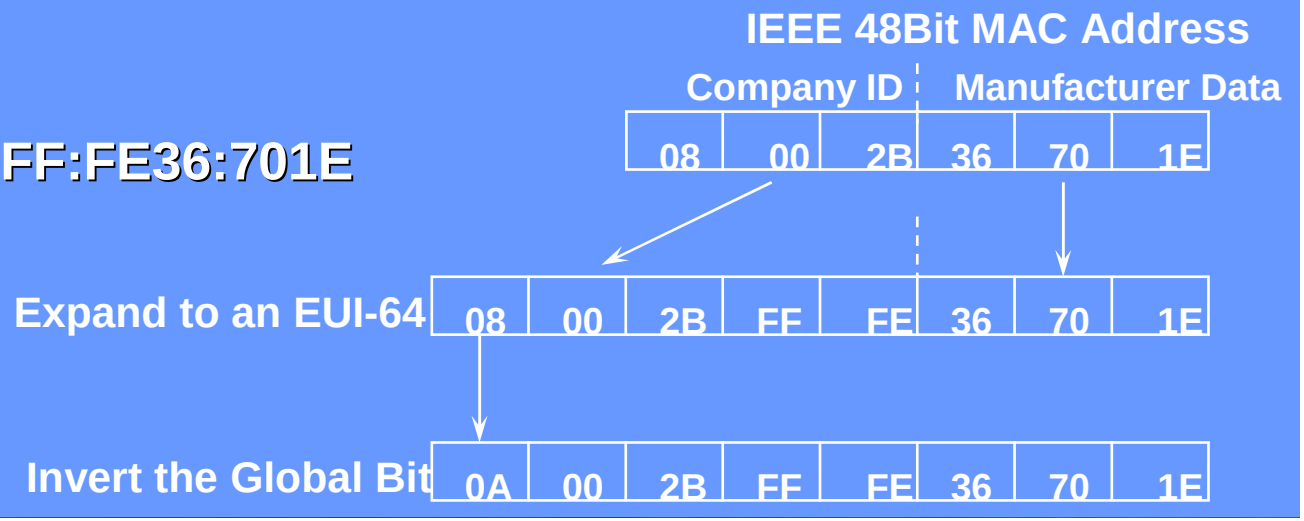
Address Autoconfiguration Process

1. Create a Link Local Address
   - No router or server required
2. Determine whether Addresses should be obtained via Stateless or Stateful mechanism or both
   - Stateless mechanism
     - Router advertisements provide prefix
   - Stateful mechanism
     - Server provides address (for example via DHCPv6)

IPv6 Link Local Address Creation

- Link-Local address is formed by appending token to the architecturally defined Link-Local prefix FE80::/10
  - See IPv6-over-x specs for details on how to form the Interface Identifier
- Interface ID based on EUI-64
  - Constructed from a Global Token E.g. IEEE 48-bit MAC Address With the “global” bit inverted

FE80::0A00:2BFF:FE36:701E



IPv6 Stateless Address Autoconfiguration

- Routers advertise prefixes that identify the subnet(s) associated with a link
- Hosts generate an "interface token" that uniquely identifies an interface on a subnet.
- An address is formed by combining the two.

IPv6 Stateful Address Autoconfiguration

- Clients obtain address and / or configuration from a DHCP server
- DHCP server maintains the database and has a tight control over address assignments.
- Host sends DHCP Solicit
  - DHCPv6 Multicast Address
- Agent replies with DHCP Advertisement

Policy Stateless or Stateful?

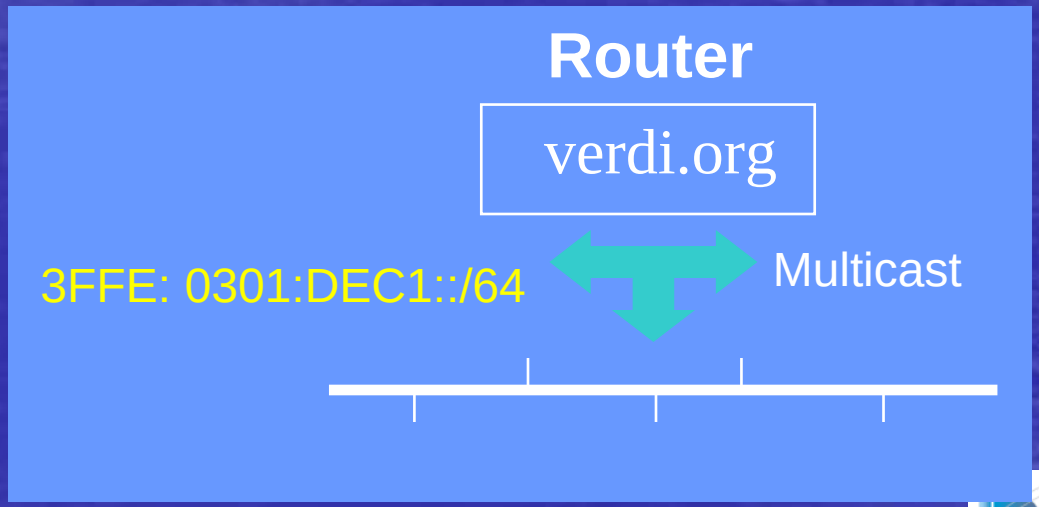
- Site administrator specifies which type of autoconfiguration to use
  - through setting / clearing a switch on the ICMPv6 Router Advertisement (M bit)
- Stateless and Stateful can Coexist
  - For example:
    - Addresses could come from Stateless
    - Additional Configuration Information could be provided by DHCPv6

IPv6 Stateless Operations Explored

- Prefix Advertisement
- Prefix Discovery
- Tentative Address Formation
- Duplicate Address Detection
- Address Resolution

Prefix Advertisement

- Router configured with the appropriate prefix(es)
  - & with associated lifetime for each prefix
- Router sends Router Advertisement
  - periodic and on-demand

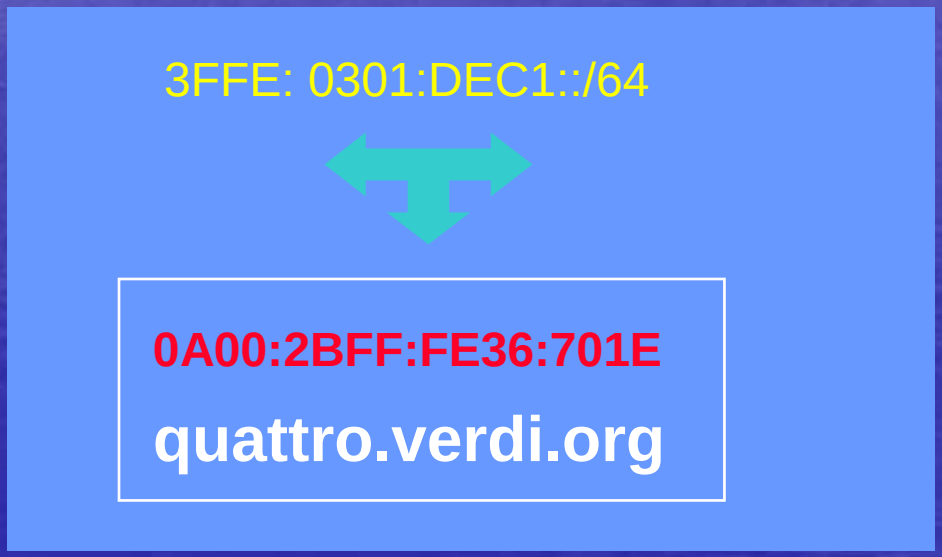


Prefix Discovery

- Host sends Router Solicitation
  - To All-Routers Multicast Address
- Routers send Router Advertisement
  - Flags L bit (on-link), A bit (Autonomous)
  - Prefix(es) Information
  - Associated lifetimes
    - Preferred Lifetime
    - Valid Lifetime

Forming Tentative Address

- Host uses the prefix to form a tentative address
- For safety Duplicate address Detection algorithm should be performed



IPv6 Address: 3FFE:0301:DEC1::0A00:2BFF:FE36:701E

Duplicate Address Detection (DAD)

- Used during Address Acquisition
- Stateless
  - DAD is performed only on Link-Local address
  - thus is not in critical path in large-scale-renumbering
- Stateful
  - all address should be tested for uniqueness.
- DAD can be disabled
  - But adds little or no overhead

DAD Operation

- Used to verify uniqueness of the tentative address
  - Host join All-Nodes-multicast (FF02::1) and Solicited-Node-multicast of the tentative address.
  - Transmit Neighbor solicitation with tentative address as a target address
  - If Neighbor Advertisement received
    - Address in use cannot be assigned to the interface
  - No response assume address is unique and available

Duplicate Address Detection Solicited Node Neighbor Solicitation

Ethernet Header Dst Mac Address 33-33-FF-36-70-1E
IPv6 Header Src Address :: Dst Address FF02::1:FF36:701E Hop Limit 255
ICMPv6 Header Target Address FE80::0A00:2BFF:FE36:701E

Mac Address 08-00-FE-36-70-1E
Link Local (tentative)
FE80::0A00:2BFF:FE36:701E
All Nodes Multicast FF02::1

duo.verdi.org

Multicast Solicited Node Neighbor Solicitation

Mac Address 08-00-FE-36-70-1E
Mac Address Multicast 33-33-FF-36-70-1E
Link Local FE80::0A00:2BFF:FE36:701E
Solicited Node Multicast Address FF02::1:FF36:701E

quattro.verdi.org

Duplicate Address Detection
Multicast Neighbor Advertisement

Ethernet Header Dst Mac Address 33-33-00-00-00-01
IPv6 Header Src Address FE80::0A00:2BFF:FE36:701E Dst Address FF02::1 Hop Limit 255
ICMPv6 Header Target Address FE80::0A00:2BFF:FE36:701E

Mac Address 08-00-FE-36-70-1E
Link Local (tentative)
FE80::0A00:2BFF:FE36:701E
All Nodes Multicast FF02::1

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Multicast Neighbor Advertisement

Mac Address 08-00-FE-36-70-1E
Mac Address Multicast 33-33-FF-36-70-1E
Link Local FE80::0A00:2BFF:FE36:701E
Solicited Node Multicast Address FF02::1:FF36:701E

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Address Resolution
Neighbor Solicitation

Ethernet Header
Dst Mac Address 33-33-FF-36-70-1E

IPv6 Header
Src Address FE80::200:F8FF:FE21:E530
Dst Address FF02::1:FF36:701E
Hop Limit 255

ICMPv6 Header
Target Address FE80::0A00:2BFF:FE36:701E
Option Src Link Layer 00-00-FE-21-E5-30

Mac Address 00-00-FE-21-E5-30
Link Local
FE80::200:F8FF:FE21:E530

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Multicast Neighbor Solicitation

Mac Address 08-00-FE-36-70-1E
Mac Address Multicast 33-33-FF-36-70-1E
Link Local FE80::0A00:2BFF:FE36:701E
Solicited Node Multicast Address FF02::1:FF36:701E

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Address Resolution
Neighbor Advertisement

Ethernet Header
Dst Mac Address 00-00-FE-21-E5-30

IPv6 Header
Src Address FE80::A00:2BFF:FE36:701E
Dst Address FF80::200:F8FF:FE21:E530
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Option Target Link Layer 00-00-FE-36-70-1E

Mac Address 00-00-FE-21-E5-30
Link Local
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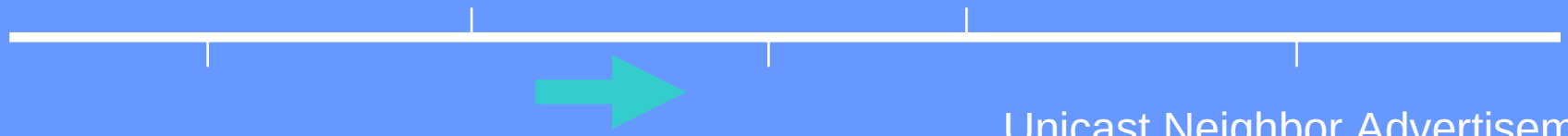

Unicast Neighbor Advertisement

Mac Address 08-00-FE-36-70-1E
Mac Address Multicast 33-33-FF-36-70-1E
Link Local FE80::A00:2BFF:FE36:701E
Solicited Node Multicast Address FF02::1:FF36:701E

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Automatic Renumbering

- Renumbering IPv6 hosts is easy
  - Add a new prefix to the router
  - Reduce the lifetime of the old prefix
  - As nodes deprecate the old prefix, they begin using the new prefix for new connections
  - No network downtime
- Renumbering IPv6 routers
  - New protocol: Router Renumbering
- Use both to renumber entire site

Additional Considerations for Auto Configuration

- Privacy Extensions for Auto Configuration?
- Dynamic Updates to DNS?
- Link-Local Address Name Resolution?

IPv6 Benefit - Life Is Easier for Operations

- Better manageability
- IPv6 address scope
  - GLOBAL or LOCAL
- Configuration Policy Control
  - Stateless
  - Stateful (DHCPv6)
  - Routers dictating configuration policy and MTU size for the link

IPv6 Value Proposition
Engineered to Perform and Protect

IPv4

- Uses a 32-bit address
- Running out of internet addresses
- Security was an add-on
- System management is complex and slow
- Incredibly successful
- 20 + years old

IPv6

- Uses 128-bit addressing
- Enough address space to give every human on the planet a unique IP address
- Mandatory and effective IP security
- Less Infrastructure Maintenance and complexity required
- More efficient Mobile IP = seamless service availability
- Architecture of the future = Next Generation internet protocol

IPv6 Impact on the Communications Industry

- Complexity is reduced
- Optimal conditions for continued evolution of the Internet
  - To provide seamless Internet connectivity anytime, anywhere, always-on
  - To provide as many pervasive services as possible to as many users as possible
- New End-to-End Applications can now evolve again

Internet End-to-End
+ Pervasive Services
+ New Applications
+ Reduced Cost
= Profit

North American IPv6 Task Force

“Remember TIMING is an important factor in any success story”

IPv6 Everything is possible

Questions?