
University of Colorado Boulder

Network Management and Automation

Overview of IPv6

Levi Perigo, Ph.D.
University of Colorado Boulder
Department of Computer Science
Network Engineering

Review

- **Discussions**
- **Lab**
  - 11:59:00 p.m.
  - Start Early
- **Assignment**
- **Lectures**
  - Ask/Answer Questions
- **Overall Course**
  - Grades / Outside Class

Why IPv6

- **IPv4 address depletion**
  - Developing countries
  - Mobile IP
  - IoT
  - Rise in price of v4 addresses (commodity)
  - NAT workarounds
- **End-to-end connectivity**
- **Security**

Barriers to IPv6

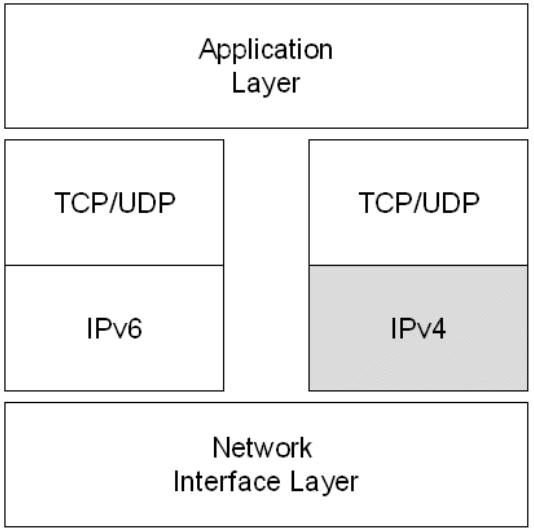
- **Not compatible with IPv4**
- **IPv6 Security**
  - Firewalls
  - Tunneling
- **Trained and experienced professionals to support IPv6**
- **Buy in**
  - ISP vs. Business

IPv4 and IPv6 Comparison

Feature	IPv4	IPv6
IP Address Length	32 bits	128 bits
IP Security (IPSec) Header Support	Optional	On through traffic
Prioritized Delivery Support	Some	Expanded
Packet Fragmentation	Performed by hosts and routers	Performed by hosts only
Minimum MTU	576 bytes	1280 bytes
Checksum in Packet Header	Yes	No
Options in Packet Header	Yes	No
Link-Layer Address Resolution	ARP (broadcast)	Multicast ND messages
Multicast Membership Protocol	Internet Group Management Protocol (IGMP)	Multicast Listener Discovery (MLD)
Router Discovery	Optional	Required
Uses Broadcast Messages	Yes	No
Configuration	Manual, Dynamic Host Control Protocol (DHCP)	Manual, Automatic, DHCP version 6 (DHCPv6)
Domain Naming System (DNS) Queries	Uses A records	Uses AAAA records
DNS Reverse Queries	Uses IN-ADDR.ARPA	Uses IP6.ARPA

Transition Mechanisms

- **Dual stack**
  - Both stacks can operate independently or in parallel
- **Tunneling**
  - ISATAP
  - Teredo
  - 6to4
  - 6over4
  - 6rd (IPv6 Rapid Deployment)
- **Transition**
  - NAT64



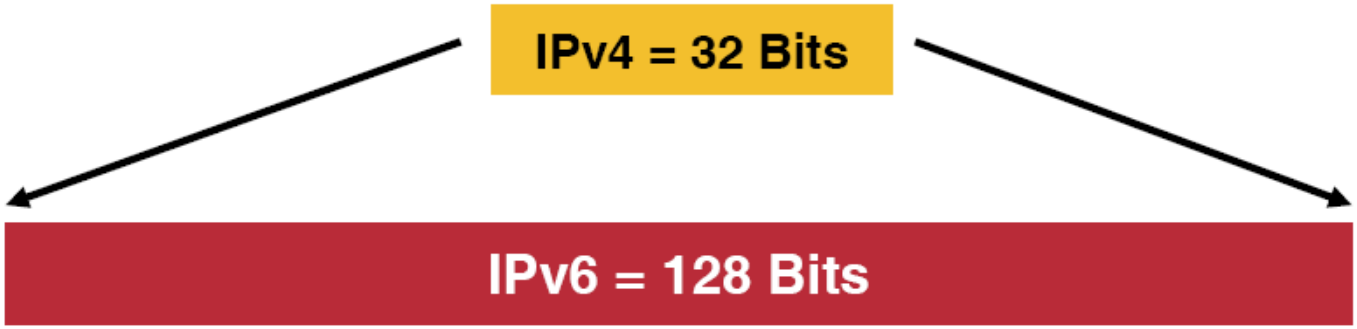
IPv6 Deployment Strategies

- **Prefix /64**
  - Stateless Address Autoconfiguration (SLAAC)
  - Neighbor Discovery (ND)
    - ***Secure Neighbor Discovery (SeND)***
  - DHCPv6

IPv6 Advantages

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

Addressing



- IPv4 - 32 bits, 2^{32}
- IPv6 - 128 bits, 2^{128}

IPv6 Address Syntax

- IPv6 address in binary form
  - 00100000000000010000110110111100000000 00000000000010111100111011 00000010101010100000000011111111111111 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 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**

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 ONLY 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***

IPv6 Prefixes

- **A prefix expresses a route, address space, or address range**

- **IPv6 uses *address/prefix-length* notation**
  - Similar to IPv4 CIDR notation
    - ***192.168.10.0 /24***

- **Examples**
  - 2001:DB8:0:2F3B::/64 for a subnet prefix

  - 2001:DB8:3F::/48 for a route prefix

Types of IPv6 Addresses

- **Unicast**
  - Address of a single network interface
  - Delivery to single, specific interface
- **Multicast**
  - Address of a set of interfaces
  - Delivery to all interfaces in the set, that joined the mcast group
- **Anycast**
  - Address of a group of interfaces
  - Delivery to just one of the member interfaces (typically, nearest host)
- **No more broadcast addresses**
  - Replaced with Neighbor Discovery (ND) and “all-nodes” (FF02::1) link-local multicast group

IPv6 Addresses - Scope

- **The IPv6 “scope” specifies which part of the network the address is valid**

- **Unicast and Anycast addresses in IPv6 have the following scopes (for multicast addresses, the scope is built into the address structure):**
  - **Link-local -** The scope is the local link
    - ***Nodes on the same subnet***
  - **Unique local (Site-local (*deprecated*))** - The scope is the organization
    - ***Private site addressing***
    - ***Only allowed by routers that specifically allow it (i.e. have a route)***
    - ***Rarely used in industry***
  - **Global -** The scope is global
    - ***IPv6 Internet addresses***
    - ***AKA “Public” addresses***

IPv6 Addresses - Unicast

- **General Unicast Address or Global Addresses (GUA)**
  - Similar to “public” IPv4 address
- **Local-use addresses**
  - Link-local addresses
    - ***FE80::/10***
      - (1111111010)
- **Unique Local Addresses (ULA)**
  - FC00::/7
  - Similar to IPv4 “private” addresses
  - Not popular in industry
- **Special Addresses**
  - Teredo Tunneling – 2001::/32
  - Documentation – 2001:DB8::/32

IPv6 Addresses - Multicast

- **Critical part of IPv6 Network Operation**

- **Well-known IPv6 multicast addresses (*FF02 = MCAST on local link scope*)**
  - FF02::1 -> All nodes on local network segment
  - FF02::2 -> All routers on local network segment
  - FF02::5 -> OSPFv3 Routers <-> 224.0.0.5
  - FF02::6 -> OSPFv3 DR <-> 224.0.0.6
  - FF02::9 -> RIPng Routers <-> 224.0.0.9
  - FF02::A -> EIGRP Routers <-> 224.0.0.10
  - FF02::1:2 -> DHCP Servers/ relay Agents <-> 224.0.0.12

- **Solicited-node Multicast Address (SNMA)**
  - FF02::1:FF:xx:xxxx
  - Allow link-layer address resolution via ND
  - Similar to ARP in IPv4

IPv6 Addresses - Anycast

- **Routed to nearest interface configured**
- **Same unicast address assigned to multiple interfaces of different nodes**
- **Used to virtually replicate important network resources (DNS, Web servers, WAPs, etc.) to provide load balancing**

IPv4 and IPv6 Addresses

IPv4 Addresses	**IPv6 Addresses**
Internet address classes	N/A
Multicast addresses (224.0.0.0/4)	IPv6 multicast addresses (FF00::/8)
Broadcast Addresses	Not supported
Unspecified address is 0.0.0.0	Unspecified address is ::
Loopback address is 127.0.0.1	Loopback address is ::1
Public IP addresses are used	Global unicast addresses are used
Private IP addresses are used	Unique-local addresses are used (FC00::/7 prefix)
APIPA addresses are used	Link-local addresses are used (FE80::/10 prefix)
Addresses expressed in dotted decimal notation	Addresses expressed in colon hexadecimal format
Subnet masks or prefix lengths are used	Only prefix lengths are used

IPv6 Challenges

- **IPv6 awareness**
- **Measuring adoption**
- **Security**
- **Security Tools**

Questions?