Introduction to IPv6
Lecture

SUS09

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Contents

Introduction to IPv6

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Objectives

- IPv6 Theory
- IPv6 Practice

IPv6 Theory

Objective Notes:

IPv6 Features

- Increased address space - 128 bit instead of 32 bit
  $3.4*10^{38}$ addresses
- Improved routing capabilities
- Simplified header
- Quality of Service capabilities
- Authentication and privacy capabilities
- Flexible transition from IPv4 to IPv6

To use these features, the kernel has to support IPv6 (the kernel used in SLES does that since long) and have the tools necessary to configure IPv6, such as the ip command. These are available with SLES since long as well.

IPv6 Addresses

- An address consists of 128 zeroes and ones (32 hexadecimal digits)
- For better readability, a colon is inserted every four hexadecimal digits:
  ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff
- Leading zeroes in each block, and one sequence of 16 bit blocks containing only zeroes can be omitted:

  fe80:0000:0000:0000:0211:11ff:fec2:35f4

  can be written as

  fe80::211:11ff:fec2:35f4

Netmasks still exist to designate the network portion of the address and are noted similar to the CIDR notation in IPv4:
2001:0db8:100:1:2:3:4:5/48

resulting in a network address of
2001:0db8:0100:0000:0000:0000:0000:0000

and a netmask of
ffff:ffff:ffff:0000:0000:0000:0000:0000

The maximum length of the network part of the address is 64 bit

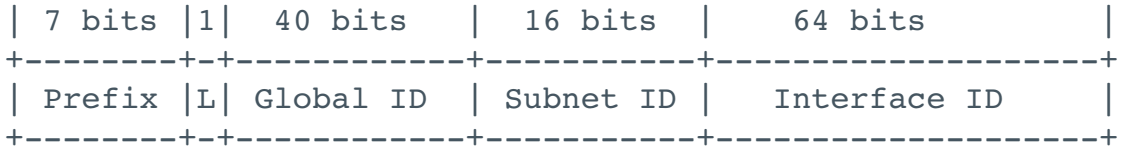
IPv6 Address Types

- Unspecified address (similar to 0.0.0.0 in IPv4):
  0000:0000:0000:0000:0000:0000:0000:0000
  or in short:
  ::
- Loopback interface:
  0000:0000:0000:0000:0000:0000:0000:0001
  or in short:
  ::1

Notes:

IPv6 Address Types: Network

- Link Local Addresses (packets do not pass routers) begin with
  fe8*x* (the only one currently in use)
  fe9*x*
  fea*x*
  feb*x*
  The x could be any hex digit, but usually is 0
- Globally Unique Local IPv6 Unicast Address
  Begins with fd*xx*



You see an fe80:... address on every IPv6 enabled network interface on a Linux machine, as it is used as part of IPv6 link autoconfiguration.

IPv6 Address Types: Network

- Global Address Type “global unicast”
  - Addresses delegated to ISPs currently begin with 2001:
  - Addresses for tunneling IPv6 packets in IPv4 packets begin with 2002:
  - Addresses for documentation and examples begin with 3fff:fff::/32
    2001:0db8::/32

Notes:

IPv6 Address Types: Network

- Multicast addresses
  - Multicast addresses start with ffxy, where x is a hex number and y indicates the scope, such as:
    y=1: node local
    y=2: link local
    y=3: site local

Notes:

IP Address Types: Hosts

- Host addresses can be automatically computed or set manually
  - The MAC address is used and expanded to create the host part of the IP address
    MAC address: 00:11:11:c2:35:d4
    IPv6 address: (network-prefix):0211:11ff:fec2:35d4
  - For specific machines, you might want simpler addresses, such as (network-prefix)::1

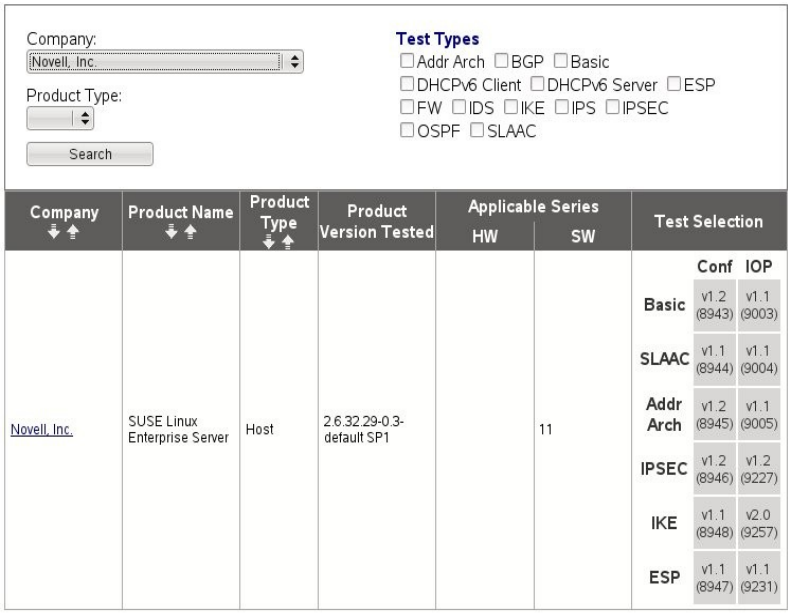
    Unlike the automatic addresses, where the 7th most significant bit is set to 1, it is set to 0 when setting the address manually

Stateless Autoconfiguration
To access the Internet, a host needs an IPv6 address with global scope. The steps to obtain such an address are as follows:
1. Using its link-local address, the host sends a Solicitation Message to the ff02::2 multicast address (all routers on the local link), asking for an IPv6 prefix.
2. The router answers this Solicitation Message with an Advertisement Message containing an address prefix for this network.
3. Using this prefix and its MAC address, the host creates an IPv6 address.
4. Using Duplicate Address Detection (DAD, RFC 4862), the host checks if the address is already in use in the network. If the address is unused, the host assigns the address to the NIC and activates it.
5. The client can now contact other hosts within the local network using their IPv6 addresses and, depending on the network topology, hosts outside the local network as well.
The router distributes the network prefix and information on the default route only. Information that goes beyond this, such as information on DNS or other routes, needs to be added manually to the configuration or distributed using DHCP6.

Privacy problem with automatically computed addresses and a solution (From the IPv6 HOWTO):
Because the "automatically computed" host part is globally unique (except when a vendor of a NIC uses the same MAC address on more than one NIC), client tracking is possible on the host when not using a proxy of any kind.
This is a known problem, and a solution was defined: privacy extension, defined in RFC 3041 / Privacy Extensions for Stateless Address Autoconfiguration in IPv6 (there is also already a newer draft available: draft-ietf-ipv6-privacy-addrs-v2-*). Using a random and a static value a new suffix is generated from time to time. Note: this is only reasonable for outgoing client connections and isn't really useful for well-known servers.

SLES11SP2 and IPv6 Standards

- USGv6 (US Government IPv6 Acquisition Profile) Tested Devices
  - http://www.iol.unh.edu/services/testing/ipv6/usgv6tested.php



Company: Novell, Inc.

Product Type:

Search

Test Types
Addr Arch BGP Basic
DHCPv6 Client DHCPv6 Server ESP
FW IDS IKE IPS IPSEC
OSPF SLAAC

Company	Product Name	Product Type	Product Version Tested	Applicable Series HW	Applicable Series SW	Test Selection	Conf	IOP
Novell, Inc.	SUSE Linux Enterprise Server	Host	2.6.32.29-0.3-default SP1		11	Basic	v1.2 (8943)	v1.1 (9003)
						SLAAC	v1.1 (8944)	v1.1 (9004)
						Addr Arch	v1.2 (8945)	v1.1 (9005)
						IPSEC	v1.2 (8946)	v1.2 (9227)
						IKE	v1.1 (8948)	v2.0 (9257)
						ESP	v1.1 (8947)	v1.1 (9231)

From the SLES11SP2 Release Notes:

IPv6 Improvements

SUSE Linux Enterprise Server has successfully completed the USGv6 test program designated by NIST that provides a proof of compliance to IPv6 specifications outlined in current industry standards for common network products.

Being IPv6 Consortium Member and Contributor Novell/SUSE have worked successfully with University of New Hampshire InterOperability Laboratory (UNH-IOL) to verify compliance to IPv6 specifications. The UNH-IOL offers ISO/IEC 17025 accredited testing designed specifically for the USGv6 test program. The devices that have successfully completed the USGv6 testing at the UNH-IOL by March 2012 are SUSE Linux Enterprise Server 11 SP1. Testing for subsequent releases of SUSE Linux Enterprise Server is in progress, and current and future results will be listed at http://www.iol.unh.edu/services/testing/ipv6/usgv6tested.php?company=105&type=#eqplist.

SUSE Linux Enterprise Server can be installed in an IPv6 environment and run IPv6 applications. When installing via network, do not forget to boot with "ipv6=1" (accept v4 and v6) or "ipv6only=1" (only v6) on the kernel command line. For more information, see the Deployment Guide and also Section 14.6, ?IPv6 Implementation and Compliance?.

US Government IPv6 Acquisition Profile

- USGv6 is meant to:
  - Define their minimal mandatory IPv6 capabilities and identify significant configuration options so as to assist agencies in the development of more specific acquisition and deployment plans
  - Define a simple taxonomy of common network devices
  - Provide the technical basis upon which future USG polices can be defined.
- Testing is done by an accredited Testing Lab for the USGv6 Test Program
  - University of New Hampshire Interoperabilty Lab (UNH-IOL)
  - ICSA

Notes

USGv6 Objectives

- Of the Profile
  - is a reasoned selection of specifications, mostly RFCs, grouped into functional categories and configuration options that can be used to enumerate sets of specific product requirements for individual procurements.
- Allow buyers
  - to use a shorthand notation describing configurations, like e.g. specification for nine fixed Hosts:
    - 9 hosts compliant to: USGv6-V1-Capable+DHCP-client+Sock+DNS-Client+Link=Ethernet
- Vendor issues expression of compliance
  - for a specific product through a Supplier’s Declaration of Conformity (SDOC)

Notes

IPv6 Ready Logo Phase 2

- SLES 11 SP1 has been permitted to use proper Logo ID and logo image
- Public Reference
  - https://www.ipv6ready.org/db/index.php/public/logo/02-C-000636/

Notes

IPv6 Practice

Objective Notes:

IPv6 Tools

- ping6
- traceroute6
- ip6tables

Notes:

IPv4 to IPv6 Transition

- 6to4 tunnel
- 6in4 tunnel

Notes:

6to4 Tunnel

- You need a routeable IPv4 address (not one from a private address space such as 10.0.0.0/8)
- Make sure the sit kernel module is loaded
- Calculate the IPv6 address corresponding to your IPv4 address (1.2.3.4 in the following commands)

```
ipv4="1.2.3.4"; printf \
"2002:%02x%02x:%02x%02x::1" `echo $ipv4 | tr "." " "`
```

- Create a new tunnel device

```
ip tunnel add tun6to4 mode sit ttl 63 remote any
local 1.2.3.4
```

Notes:

6to4 Tunnel

- Bring the interface up and set the MTU
  `ip link set dev tun6to4 mtu 1280 up`
- Add your local IPv6 address to the tunnel interface using a prefix length of 16:
  `ip -6 addr add 2002:0102:0304::1/16 dev tun6to4`
- Add a route to the global IPv6 network using the IPv4 anycast address for all 6to4 routers:
  `ip -6 route add 2000::/3 via ::192.88.99.1 dev tun6to4`

Notes:

6in4 Tunnel

- A UDP-based tunnel is used to connect to a tunnel broker that provides connection to the IPv6 network
- No unique IPv4 address is required, works behind NAT gateways

  (Note that tunneling connections through a firewall can violate existing security policy)
- There are non-profit providers that offer IPv6 tunnels, such as www.sixxs.net
- AICCU - Automatic IPv6 Connectivity Client Utility - is available for various operating systems, for instance for SLES11 at http://download.opensuse.org/repositories/network:/utilities

```
#/etc/aiccu.conf
# AICCU Configuration

# Login information (defaults: none)
username tunneluser
password secret

# Protocol and server to use for setting up the tunnel (defaults: none)
#protocol <tic|tsp|l2tp>
#server <server to use>

# Interface names to use (default: aiccu)
# ipv6_interface is the name of the interface that will be used as a tunnel interface.
# On *BSD the ipv6_interface should be set to gifX (eg gif0) for proto-41 tunnels
# or tunX (eg tun0) for AYIYA tunnels.
ipv6_interface sixxs

# The tunnel_id to use (default: none)
# (only required when there are multiple tunnels in the list)
tunnel_id TXXXXX

# Be verbose? (default: false)
verbose false

...
```

6in4 Tunnel

- When aiccu is successfully started, an interface appears (with the configuration from the notes above it is named sixxs):

```
ip address show dev sixxs
sixxs:
<POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu
1280 qdisc pfifo_fast state UNKNOWN qlen 500
    link/none
    inet6 2002:1:2:3::2/64 scope global
       valid_lft forever preferred_lft forever
    inet6 fe80::1:2:3:2/64 scope link
       valid_lft forever preferred_lft forever
```

Notes:

Router Advertisement Daemon

- radvd provides IPv6 address prefixes and the default route to clients
- IPv6 routing needs to be turned on with

```
echo 1 > /proc/sys/net/ipv6/conf/all/forwarding
```

- A route needs to be set on the gateway host for the internal addresses

```
ip -6 route add 2002:0102:0304:1234::/64 dev eth0
```

- radvd is installed on the 6to4 gateway host
- Configuration file: /etc/radvd (see notes on next page)

```
#/etc/radvd.conf

interface eth0
{
        AdvSendAdvert on;

# These settings cause advertisements to be sent every 3-10
# seconds.  This range is good for 6to4 with a dynamic IPv4
# address, but can be greatly increased when not using 6to4
# prefixes.
        MinRtrAdvInterval 3;
        MaxRtrAdvInterval 10;

# You can use AdvDefaultPreference setting to advertise the
# preference of the router for the purposes of default
# router determination. NOTE: This feature is still being
# specified and is not widely supported!
#
        AdvDefaultPreference low;

# Disable Mobile IPv6 support
#
        AdvHomeAgentFlag off;

# example of a standard prefix
#
        prefix 2002:0102:0304:1234:/64
        {
                AdvOnLink on;
                AdvAutonomous on;
                AdvRouterAddr off;
        };
};
```

Router Advertisement Daemon

- Once the setup is complete, clients can reach any IPv6 host in the Internet
- But, this is true too:

  Any IPv6 host in the Internet can reach your clients!
- Add packet filters on the gateway and/or on each client to protect them as needed.

Notes:

DHCPv6

- radvd distributes prefixes and default route only
- If you want to distribute more network information, such as nameserver, winsserver, routes, you need a DHCP server
- On SLES11 SP1, the ISC DHCP server (3.1.3) is used for DHCP for IPv4, the dhcpv6 server (1.0.22, https://fedorahosted.org/dhcpv6/) is used for IPv6
- radvd and dhcpv6 can be used concurrently in a network

Notes:

The dhcpv6 Server

- Interfaces for the dhcpv6 server are configured in /etc/sysconfig/network/dhcp6s:

```
# specify the interface for dhcp6s
DHCP6SIF=br0
# Command line options here
DHCP6SARGS=
```

- For debugging use `DHCP6SARGS="-v"` and in a terminal enter `tail -f /var/log/messages`

Notes:

The dhcpv6 Server

- The main configuration file is `/etc/dhcp6s.conf`
- Configuration example in the notes section below
  - While testing DHCPv6 in preparation for these slides with SLES11SP1, it turned out that the address of the host had to lie within the range given in the link section. This is not the case in this example from the manual page.

```
#This is a sample of the dhcp6s.conf file
#(from the dhcp6s.conf manual page).

option dns_servers 2003::6:1 ibm.com;
prefer-life-time 10000;
valid-life-time 20000;
renew-time 5000;
rebind-time 8000;
```

```
interface eth1 {
     link AAA {
          allow unicast;
          send unicast;
          allow rapid-commit;
          server-preference 5;
          renew-time 1000;
          rebind-time 2400;
          prefer-life-time 2000;
          valid-life-time 3000;
          range 3ffe:ffff:100::10 to 3ffe:ffff:100::110/64;
          prefix 3ffe:ffef:104::/64;
          pool {
               prefer-life-time 3600;
               valid-life-time 7200;
               range fec0:ffff::10 to fec0:ffff::110/64;
               prefix fec0:fffe::/48;
          };
     };# (cont'd from previous page)
     host host0 {
     duid 00:00:00:00:a0:a0;
     iaidinfo {
          iaid 101010;
          renew-time 1000;
          rebind-time 2000;
          };
          address {
               3ffe:ffff:102::120/64;
               prefer-life-time 2000;
               valid-life-time 3000;
          };
     };
     group {
          prefer-life-time 5000;
          valid-life-time 6000;
          host host1 {
               duid 00:00:00:00:a1:a1;
               iaidinfo {
                    iaid 101011;
                    renew-time 1000;
                    rebind-time 2000;
               };
          };
          host host2 {
               duid 00:00:00:00:a2:a2;
               send information-only;
          };
     };
};
```

ISC DHCP Server

- The ISC DHCP server 4.1.0 and later can distribute IPv4 and IPv6 addresses, but one instance can't distribute both
- If you want to distribute IPv4 and IPv6 addresses at the same time, you need two configuration files and two instances of the ISC DHCP server running
- Should you want to test it, you can use openSUSE 11.4 or later.

```
#/etc/dhcpd6.conf

# Comments are in the file

default-lease-time 2592000;
preferred-lifetime 604800;
option dhcp-renewal-time 3600;
option dhcp-rebinding-time 7200;
allow leasequery;
option dhcp6.name-servers 2a01:1:2:3::1;
option dhcp6.domain-search "digitalairlines.com";
option dhcp6.info-refresh-time 21600;
host myclient {
        host-identifier option
                dhcp6.client-id "00:01:00:01:16:ac:47:29:00:21:cc:70:0b:89";
                fixed-address6 2a01:1:2:3::1234;
                fixed-prefix6 2a01:1:2:3::/64;
        }
         subnet6 2a01:1:2::3::/64 {
                  range6 2a01:1:2:3::10 2a01:1:2:3::11;
                  range6 2a01:1:2:3:: temporary;
                  prefix6 f01:1:2:11:: 2a01:1:2:12:: /64;
         }
```

LAB 1: radvd

Summary: In this exercise, you configure radvd on server1 and provide an IPv6 address to server2.

Special Instructions

- Add the 2001:0db8::10 IP address to eth0 of server1 (temporary with the `ip` command, or permanently with YaST or by editing the `/etc/sysconfig/network/ifcfg-eth0` file)
- Edit the `/etc/radvd.conf` file to distribute the 2001:0db8::/64 prefix
- Turn on IPv6 routing (it has to be done even if there is only one NIC, because radvd won't start without it)
- Start radvd; on server2 `ip add show` should display the new IPv6 address.

Duration: 20 min.

Notes:

LAB 2: DHCPv6

Summary: In this exercise, you configure dhvp6s on server1 and provide an IPv6 address from an address range and other information to server2.

Special Instructions

- On server1, edit the `/etc/dhcp6s.conf` file so that the dhcp6s server distributes IPv6 addresses between 2001:db8::1 and 2001:db8::100/64
- Add the eth0 interface to `/etc/sysconfig/network/dhcp6s` (you can also add the -v option if you like)
- Start the dhcp6s server
- In a terminal window on server2, start dhcp6c. In a second terminal window check to see if an IPv6 address from the range defined on the DHCPv6 server appeared. Terminate the dhcp6c process with Ctrl+c.

Duration: 20 min.

```
#/etc/dhcpv6s
interface eth0 {
    server-preference 255;
    renew-time 60;
    rebind-time 90;
    prefer-life-time 130;
    valid-life-time 200;
    allow rapid-commit;
    option dns_servers 2001:db8::10;

    link AAA {
        pool{
            range 2001:db8::1 to 2001:db8::100/64;
            prefix 2001:db8::/64;
        };
    };
};
```

LAB 3: DHCPv6 - Fixed Address

Summary: In this exercise, you configure dhvp6s on server1 to provide a specific IPv6 address to server2.

Special Instructions

- On server1, check the `/var/lib/dhcpv6/server6.leases` file and note the DUID and the IAID for the lease from the last lab
- On server1, edit the `/etc/dhcp6s` file so it matches the configuration given on the next page, using the DUID and IAID just noted.
- Restart the dhcp6s server
- On server2, in a terminal window, enter
  `dhcp6c -v --netconfig -c /var/lib/dhcpv6/dhcp6c.eth0.conf -f eth0`
  In a second terminal window check to see if the IPv6 address appeared and if `/etc/resolv.conf` was modified.

Duration: 20 min.