What embedded Linux developers should know about IPv6

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History and Motivation

- IPng project – July 1994
- IPv6 - RFC 2460 – December 1998
- “IPv5” - Internet Stream Protocol used version 5 in packet header – v4 uses 4, v6 uses 6
- Recognized IPv4 address exhaustion, but also wanted to solve other network issues

Advantages of IPv6

- 10^{128} addresses (plenty)
- Easier routing
- IPsec required
- Mobility support
- Minimum MTU increase (1280 vs. 576)

Addresses

- 128 bits (4x IPv4 32 bit addresses)
- Represented as 8 groups of 4 hex digits:

  2001:0DB8:AC10:FE01:0000:0000:0000:0001

  Normally written: 2001:DB8:AC10:FE01::1

  (leading zeros, consecutive zeros eliminated)
- 64-bit network prefix, 64-bit host address
- Usually 48-bit routing prefix, 16-bit subnet
- 2001:470:bac3::/48 represents a routed network

Special Addresses

- Loopback ::1 (127.0.0.1 for IPv4)
- Unspecified :: (0.0.0.0 for IPv4 INADDR_ANY)
- Link local FE80:: - host address based on MAC

  MAC: 00:1D:BA:06:37:64 becomes

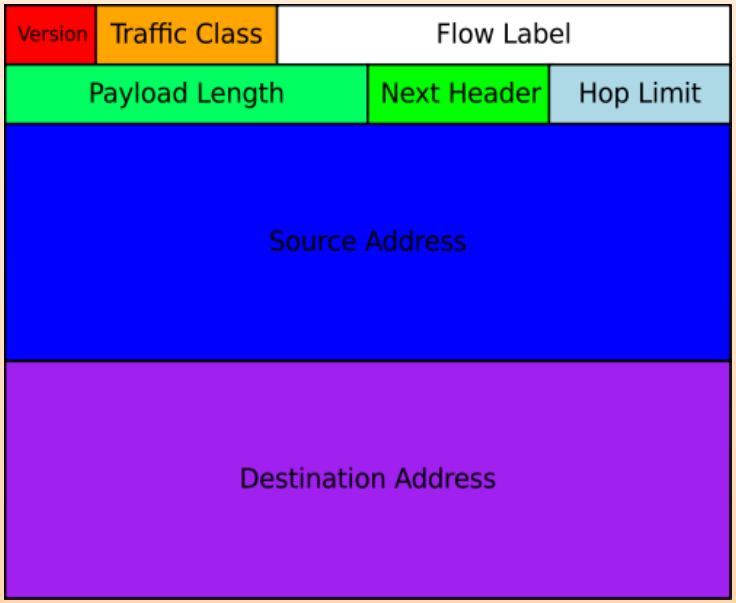
  FE80::021D:BAFF:FE06:3764

  (FFFE inserted in middle and bit 1 in first byte turned on – Modified EUI-64)

  - Privacy concerns

Ipv6 Packet Format

- Much simpler than Ipv4
- Fixed 40-byte length (IPv4 20-60 bytes)
- Moved options into additional headers



(Graphic shamelessly poached from Wikipedia: http://en.wikipedia.org/wiki/IPv6)

Ipv6 Headers

- Next Header is type of any following header
  - 6 for TCP, 17 for UDP, 59 for no next header
  - Other for other options (fragmentation, routing, ...)
- No header checksum (eliminates recalculation), uses lower (CRC on ethernet) and higher (checksum for UDP and TCP headers) layers
- Flags (SYN, ACK, etc. in TCP header)
- Network layer devices only need to see the mandatory header information

Stateless Autoconfiguration (SAC)

- One way to get an initial address
- Host sends router solicitation using link local address (FE80::modified-EUI) to FF02::2
- Routers reply with router advertisement to FF02::1
- Advertisements contain network prefix information and router lifetime
- Multiple routers may reply with different subnets
- Duplicate address detection is used

DHCPv6

- SAC doesn't provide DNS hostnames
- Either have to run IPv4 DNS, statically define, or use DHCPv6
- DHCPv6 can also assign addresses (or those can also be statically configured)
- “Managed” flag in router advertisement notes the presence of DHCPv6 server in subnet
- “Stateless” does DNS, while “stateful” does address assignment

Routing

- Many IPv6 hosts will have multiple addresses one for each router they can talk to (at least)
- IPv6 is supposed to easily enable renumbering networks by just changing network prefix
- Mobile routing is done by having a “home” address, and a “care-of” address, that is routed by the home agent via tunneling
  - When devices roam to a new network (e.g. WiFi to cell data) it informs the home agent of care-of addr
  - Keeps old IPv6 address to maintain connections

DNS

- Uses the same basic DNS structure as IPv4
- Instead of A records, uses AAAA records

```
$ dig aaaa ipv6.google.com

...

;; ANSWER SECTION:

ipv6.google.com.          604800 IN CNAME
   ipv6.l.google.com.

ipv6.l.google.com.        300    IN AAAA
   2001:4860:b006::68
```

- MX and CNAME records use hostnames

Firewall

- Many IPv4 hosts live behind NAT so they can't be connected to from the internet
- That is not true with IPv6, by default all hosts will be reachable from the internet
- Stateful firewalling will be required

Ipv6 Commands

- Some standard commands have a 6 added:
  - ping6:

```
$ ping6 ::1
$ ping6 -I eth0 ff02::1
```

  - traceroute6:

```
$ traceroute6 -i wlan0 fe80...
```

  - iptables6
  - ifconfig and ip used to configure IPv6

Applications

- Some still need changes to handle IPv6:

  http://www.deepspace6.net/docs/ipv6_status_page_apps.html

- Some changes to user interfaces is required:

  https://[2001:db8:85a3:8d3:1319:8a2e:370:7348]:443/

IPv6 and IPv4 coexistence

- Hard to predict when (or if) IPv6 completely replaces IPv4
- Currently the vast majority of the internet is IPv4-only
- IPv6 hosts can talk to IPv4 via tunneling
  - Encapsulate IPv6 packets inside IPv4 packet data
  - Tunnel endpoints pack/unpack IPv6 packets
  - Several tunnel types: 6to4, Teredo, 6in4, ...

World IPv6 Day

- World-wide testing of IPv6 readiness
- Major websites (Google, Yahoo, Facebook, Akamai, ...) will offer content over IPv6
- June 8 - http://isoc.org/wp/worldipv6day/
- Can test your readiness and what needs to be done locally and at ISP, etc.:
  - http://test-ipv6.com/

More Information

- Books – no real recent ones focused on Linux
  - *IPv6 in Practice* – Benedikt Stockebrand
    - Debian sarge (2.6.8 kernel – a bit outdated)
  - *Running IPv6* – Iljitsch van Beijnum
    - RH 9 and RHEL 4

Web Sites

- http://ipv6.com - official IPv6 information site
- http://tldp.org/HOWTO/Linux+IPv6-HOWTO/
  - has some holes, blank topics, but lots of good info
- http://www.deepspace6.net/docs/ipv6_status_page_apps.html
  - status of application support for IPv6
- http://www.linux.com/learn/tutorials/428331-ipv6-crash-course-for-linux
  - Nice quick jump into trying out IPv6 on Linux
- Lots more out there