Module Twelve

CSG1105 Applied Communications

IPv6

- 1990 prediction was that Class B addresses would be exhausted by 1994
- Multiple Class C addresses assigned rather than new Class B
- CIDR aggregation and NAT/PAT used to extend the life of IPv4
- Routing table sizes a problem

IPng (next generation)

- 1992/1993 Multiple proposals for IPng
  - CATNIP - Common Architecture for the Internet
  - SIPP - Simple Internet Protocol Plus
  - TUBA - TCP and UDP with Big Addresses
- None Accepted as they stood
- SIPP proposal modified, resubmitted
- Accepted as basis for IPv6 [rfc1752]

The New Protocol

- IPv6 designed as evolution of IPv4
  - Expanded Routing and Addressing
  - Header format simplification
  - Improved support for options
  - Quality-of-Service Capabilities
  - Authentication and Privacy Capabilities

Addressing

- IPv6 address 128 bits allowing 8x1017 to 2x1033 interfaces
- Three types of address [rfc1884]
  - Unicast An identifier for a single interface
  - Anycast An identifier for a set of interfaces, delivered to “nearest” interface
  - Multicast An identifier for a set of interfaces, delivered to all interfaces

Representation

- Too many digits for dotted decimal like IPv6
- Hex form x:x:x:x:x:x:x:x (x is 16 bits) eg 0800:0:0:0:0:00A0:2408:D421
- "::" represents one or more 16 bit zeros eg 0800::A0:2408:D421, ::1 (loopback)
- Can embed IPv4 addresses eg ::128.1.52.1
- Breaks literal URLs

Address Types

- Variable length Format Prefix [rfc1884]
  - 0000 0000 unspecified, loopback, IPv4
  - 0000 001 Reserved for NSAP allocation
  - 0000 010 Reserved for IPX allocation
  - 010 Provider-based Unicast
  - 100 Geographic-based Unicast
  - 1111 1110 10 Link Local Use
  - 1111 1110 11 Site Local Use
  - 1111 1111 Multicast

Unicast Addresses

- Similar to CIDR IPv4 addresses using bitwise contiguous masks

```
|              n bits              | 80-n bits |     48 bits        |
+----------------------------------+-----------+--------------------+
|        subscriber prefix         | subnet ID |   interface ID     |
+----------------------------------+-----------+--------------------+
  Unicast address using IEEE 802 MAC interface Address

| 3 |  n bits    |  m bits    |   o bits      |    125-n-m-o bits    |
+---+-----------+-----------+--------------+-----------------------+
|010|registry ID|provider ID|subscriber ID|   intra-subscriber    |
+---+-----------+-----------+--------------+-----------------------+
  Provider-Based Unicast Address
```

Autoconfiguration

- Interface may determine own address
- Stateful - using DHCPv6
- Stateless - uses router advertisements plus interface address (eg ethernet) to generate link-local or site-local address

Header Structure

- Simpler header structure than IPv4
- Some IPv4 header fields dropped, others moved to extension headers
- Reduced per case processing by router
- Flow Label is a new field for Quality-of-Service options for real-time data

IPv6 Header

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version| Prio. |                   Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Payload Length        |  Next Header  |   Hop Limit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                         Source Address                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                      Destination Address                      +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Extension Headers

- Hop-by-Hop options
- Routing
- Fragment
- Destination Options
- Authentication [rfc1826]
- Encapsulating Security Payload [rfc1827]
- Full details of the extension headers may be found in [rfc1883]

Security

- Authentication & Encapsulating Security Payload Headers
- Both headers independent of algorithm
- MD5 originally proposed as standard for Authentication Header
- DES CBC originally proposed as standard for Encapsulating Security Header
- Now, multiple options for both

Routing

- Routing IPv6 similar to IPv4 with CIDR
- Uses methods such as OSPF, RIP etc
- Policy Based Routing: anycast address used to construct source-routed path based on provider's prefix
- Mobile Routing

Transition

- Study Group, SIT developing methods to allow gradual phased introduction
- Mechanisms allow infinite coexistence of IPv4 with IPv6
- Individual hosts and routers may be upgraded without requiring renumbering
- IPv4-only, Dual-Stack and IPv6-only

Tunnelling

- IPv6 tunnelling over IPv4 Internet
- Automatic tunnelling using "IPv4-compatible IPv6 addresses"

```
|                80 bits               | 16 |      32 bits        |
+--------------------------------------+--------------------------+
|0000..............................0000|0000|    IPv4 address     |
+--------------------------------------+----+---------------------+
```

- Used where destination is dual-stack IPv4/IPv6

Tunnelling

- Configured tunnelling using "IPv4-mapped IPv6 address"

```
|                80 bits               | 16 |      32 bits        |
+--------------------------------------+--------------------------+
|0000..............................0000|FFFF|    IPv4 address     |
+--------------------------------------+----+---------------------+
```

- Used to represent the address of IPv4 only Node
- Header translation under study

Revised Standards

- Many existing standards to be revised for IPv6'
  - DNS - [rfc1886]
  - ICMP - [rfc1885]
  - Many others considered including methods for transmission of IPv6 over ethernet, token ring, FDDI and PPP. Some now depricated as technology has been obsoleted and new alternatives introduced

Programming Interface

- Berkeley Sockets API extensions to enable use with IPv6
  - New data structure to carry IPv6 addresses
  - New name to address translation library functions
  - New address conversion functions
  - New setsockopt() options
- Philosophy "access to IPv6 features, min. change, compatibility with IPv4"

IPv6 Adoption

- IPv6 became a draft standard in 1997
- Many implementations created based on draft standard
- It became a ratified standard in 2017
- Private IPs, NAT/PAT and CIDR have delayed push for IPv6 as it was cheaper to kludge than to migrate

State of IPv6 Deployment (2018)

- Following stats from https://www.internetsociety.org/resources/2018/state-of-ipv6-deployment-2018/
  - **Over 25% of all Internet-connected networks advertise IPv6 connectivity**.
  - Google reports **49 countries deliver more than 5% of traffic over IPv6**, with new countries joining all the time.
  - Google reports **24 countries whose IPv6 traffic exceeds 15%**.