Lessons from IPv4; Considerations for IPv6

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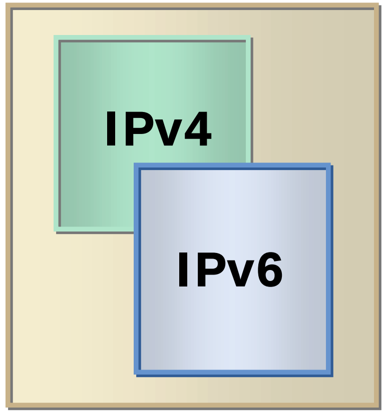
Agenda

- **Addressing & Forwarding**
- Routing Protocols
- Service Richness
- Operational Efficiency



IPv4 Addressing

General lessons from IPv4:

- IPv4 address allocation less than optimal
  - Many organizations received inappropriately sized blocks
    - Class B too big; Class C too small
  - CIDR was created to optimize routing
- Private addressing led to NAT
  - NAT can introduce scalability and management challenges
  - NAT can offer some security benefits
- Internet globalization led to IPv4 address exhaustion
  - More users
  - More Internet-enabled devices

IPv4 Addressing

What went well in IPv4:

- Dynamic routing
- DNS
- Datagram operations
- Separation of internal vs. external routing
- IP ran over all media
- End-to-end reliability via TCP
- MPLS enabled Traffic Engineering, VPNs, & multiservices
- CIDR improved routing optimization

IPv4 Addressing

What could be improved in IPv6:

- **IPv4 address exhaustion**
  - **2^{32} or 4,294,967,296 IPv4 addresses**
- **Much improved in IPv6**
  - **Address space expanded from 32 bits to 128 bits**
  - **340,282,266,920,938,463,463,374,607,431,768,211,465 (3.4 x 10^{38}) IPv6 addresses**
- **Other benefits**
  - **Larger addresses good for auto-configuration.**
  - **Structured hierarchy for addressing**

Address Auto-Configuration

Further improvement for operational ease:

- **DHCP for IPv4 provided stateful auto-configuration**
  - **Also learned from other protocols**
  - **Good: improved mobility and alleviated static address configuration**
  - **Bad: server administration overhead introduced**

- **IPv6 offers both stateful and stateless auto-configuration**
  - **DHCPv6 offers similar stateful auto-configuration to IPv4**
  - **Stateless auto-configuration allows a node to generate its own IPv6 address**

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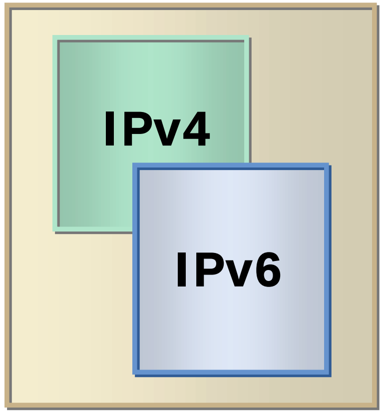

Choosing the IGP

General lesson from IPv4:

- **IPv4 - distance-vector routing protocols create scaling challengs**
  - **Result: OSPF and IS-IS emerge as leaders**

Choosing the IGP

What could be improved in IPv6:

- **IPv6 unicast can be routed by RIPng, OSPFv3, or ISIS**
- **ISIS for IPv6 introduces very little change**
  - **Designed with IPv6 extensibility in mind**
  - **2 new TLVs are added**
- **OSPF for IPv6 requires a few changes**
  - **Addressing semantics removed from LSAs, OSPF packets**
  - **New LSAs introduced to carry IPv6 addresses and prefixes**
  - **OSPF runs on per-link basis instead of per-IP subnet**

BGP

General lesson from IPv4:

- **BGP-MP already supports both IPv4 and IPv6**
- **BGP-MP carries IPv6 NLRI over TCP/IPv4 or TCP/IPv6**
- **BGP scaling is important for IPv4 and IPv6**
  - **Number of BGP peers**
  - **Number of routing entries**
  - **Convergence**

Multicast Routing

General lesson from IPv4:

- IPv4 - performance and scaling for IPv6 multicast clearly important
  - Hardware forwarding becomes critical

Considerations for IPv6:

- PIMv2 defines support for IPv4 and IPv6
  - But, very few IPv6 multicast applications exist yet
- Multicast Listener Discovery (MLD) protocol discovers the presence of multicast listeners
  - Derived from IGMPv2
  - Uses ICMPv6 message type instead of IGMP message types

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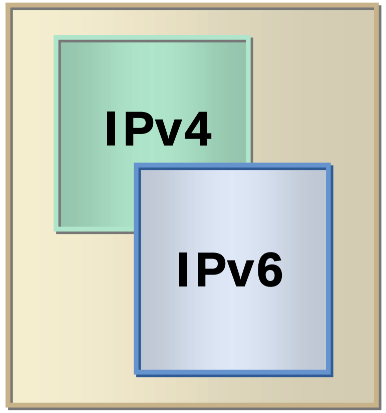

IP Services

General lessons from IPv4:

- **Routing IPv4 alone is not enough**
- **Intelligent packet handling is required to offer IP services**
- **Most IPv4 services were offered via software at the expense of performance**
- **Data, voice & video transport are needed over the Internet**

IP Services

What could be improved in IPv6:

- **Intelligent packet handling must be extended to IPv6**
- **Routers must be able to perform intelligent packet handling in hardware**
  - **Filtering – Selective forwarding and discarding**
  - **Monitoring - Sampling, counting, logging, etc.**
  - **QoS - Policing, shaping, queuing, profiling, etc.**
  - **Forwarding – Directing packets based on any header information**
- **IP services and performance must not be mutually exclusive**

Packet Classification

General lesson from IPv4:

- Classification identifies a packet based on some header information to carry out an action
  - I.e. filtering, forwarding, monitoring, QoS, etc.
  - Key to intelligent IP services
- All classification must be done in hardware to truly minimize performance impact
- Classification must allow a diverse set of actions
  - Not only drop/permit, but control forwarding, etc. (FBF, CoS based forwarding)

Packet Classification

Considerations for IPv6:

- **Packet classification will become more important with IPv6**
  - **Increased number of hosts and systems require faster and more granular classification**
  - **IPv6 has the potential for wider array of applications**
  - **Cellular phones for 3G systems**

QoS

General lessons from IPv4:

- **IPv4 struggled with ToS and DSCP definitions**
  - **Many networks still do not implement ToS/DSCP**
  - **Some routers incur performance impact when these features are enabled**

Considerations for IPv6:

- **IPv6 header includes traffic class and flow label**
  - **Traffic class function = DSCP**
  - **Largely undefined flow label identifies a traffic flow that needing special handling, I.e. voice, video, etc.**
- **Service providers must be able to use traffic class and flow label without incurring performance cost**

VPNs

General lessons from IPv4:

- VPNs are a valuable service
- IPSec, FR, ATM, GRE, etc. all have pros and cons
- VPN models are shifting from customer managed to provider managed

Considerations for IPv6:

- Established VPN technologies used for IPv4 will be carried over to IPv6
- Services offered as part of a VPN, I.e. QoS, will still be required for IPv6
- VPN management must be able to support IPv4 and IPv6 traffic

Security

General lessons from IPv4:

- **IPv4 did not address security**
  - **Multiple security measures were proposed over time**
- **Security is becoming more important as the Internet grows**
  - **DoS a critical concern in Internet.**
  - **Increased number of users and access points**
  - **Hackers becoming more sophisticated and savvy**
- **Some potential solutions emerged**
  - **Filtering, actions**
  - **Routing authentication**
  - **Secure management**
  - **Packet Encryption/authentication**

Security

Considerations for IPv6:

- Security is more important than ever
- IPv6 integrates IPSec
  - Better silicon is now available
  - Costs continue to decrease to enable IPSec as a commercial technology
- On-going DoS work in IPv4 to be extended to IPv6
- Hardware-based packet handling, filtering will optimize key security actions
- SNMPv3 improves router authentication

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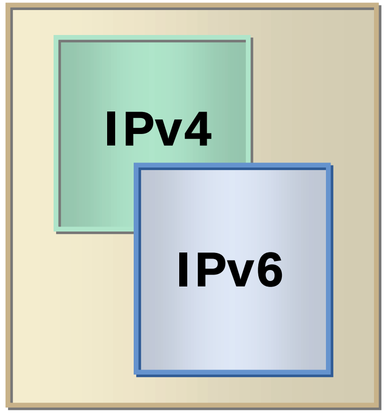

Network Management

General lessons from IPv4:

- SNMP widely used to monitor and collect IPv4 statistics

Considerations for IPv6:

- IPv6 requires SNMP and much more
  - IPv6 MIBs for IPv6, ICMPv6, UDP, TCP, MLD
  - APIs (e.g. XML) for OSS integration
  - Intuitive CLI
  - Multivendor IPv4 & IPv6 management systems
  - IPv6 billing & accounting

Transition

General lessons from IPv4:

- Transitioning in networks is rarely simple
- IPv4 is not the first protocol to ever transition
  - RIP to OSPF/ISIS
  - ATM/FR to IP
  - SNA to IP
  - DECNET Phase 4 to DECNET Phase 5
- Operations must be somehow manageable
  - IPv4 management is already challenging
  - Now add IPv6 networks and one or more transition mechanisms...

Transition

Considerations for IPv6:

- **IPv4 will co-exist with IPv6 for a long time**
  - **We can't transition the Internet overnight**
- **There are many proposed IPv4 and IPv6 transition mechanisms to achieve interoperability and co-existence**
  - **Dual Stack, configured tunnels, automatic tunnels, NAT-PT, SIIT, SOCKS, ISATAP, 6to4, 6over4**
- **Keep transition as simple as possible**
  - **Minimize interaction between multiple transition mechanisms**
  - **Ensure that the implications of transition mechanisms are fully understand**

System Considerations

General lessons from IPv4:

- **IPv4 lessons**
  - **Performance is critical**
  - **Common support of features, services on every interface across all platforms**
  - **Operational efficiency hinges on OSS integration**

Considerations for IPv6:

- **IPv6**
  - **Same approach for hardware-based packet handling**
  - **Separation of routing and control planes**
  - **Linear software releases continue to ensure common support**
  - **XML and APIs reduce latency between new vendor feature/service and OSS integration**

Summary

- **IP has succeeded because products and standards were constrained by Internet**
  - For IPv6 to succeed, products, deployment, and standards must gain from experience
- **IPv6 needed to propel the Internet into new areas**
  - IPv6 will help solve IP address exhaustion problem
- **Knowledge and experience gained from IPv4 are paramount to building successful IPv6 networks**
  - Performance and scalability relies on software and hardware implementation, network design, and manageability

Thank you!

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